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Susceptibility of Seven Selected Tomato Cultivars to *Tuta absoluta* (Lepidoptera: Gelechiidae): Implications for Its Management

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Abstract

Tuta absoluta (Meyrick) (Lepidoptera: Gelechiidae) is a serious pest originating from South America that affects tomato production in many countries, particularly in Iran (since 2010). In this study, by using age-stage, two-sex life-table parameters, the resistance of seven tomato cultivars, namely, 'Primo Early', 'Rio Grande', 'Cal JN3', 'Petomech', 'Early Urbana Y', 'Super 2270', and 'Super Strain B' to *T. absoluta*, was evaluated under laboratory conditions (25 ± 1°C, 60 ± 5% RH, and a photoperiod of 16:8 (L:D) h). Larval and pupal periods were longest on Early Urbana Y, 13.86 and 6.52 d, respectively, and shortest on Cal JN3, 10.92 and 5.5 d, respectively. The longest and shortest development times of immature stages lasted 26.42 and 20.83 d on Early Urbana Y and Cal JN3, respectively. Male and female adult longevity was longest on Early Urbana Y, 30.42 and 38.52 d, respectively, and shortest on Cal JN3, 11.67 and 18.8 d, respectively. The net reproductive rate (R_0) ranged between 80.94 (Cal JN3) and 45.87 (Primo Early) offspring. The lowest and the highest values of the intrinsic rate of increase (r) and finite rate of increase (λ) were on Early Urbana Y and Cal JN3, 0.1052 and 0.1522 and 1.1109 and 1.1644 d^{-1}, respectively. The mean generation time (T) on different cultivars varied from 30.47 to 37.28 d. Our results indicated that Cal JN3 was the most susceptible to infestation and Primo Early and Early Urbana Y were the most resistant to *T. absoluta* among the tomato cultivars tested.

Key words: *Tuta absoluta*, tomato moth, tomato cultivars, two-sex life-table

Tuta absoluta (Meyrick) (Lepidoptera: Gelechiidae) is one of the most serious tomato pests worldwide. This pest is native to South America, although through its ability to actively disperse and the regional transfer of the infested organs of host plants, particularly tomatoes and potatoes, it has spread to Afro-Eurasian and Middle Eastern countries, including the UK, The Netherlands, Russia, Lithuania, Libya, Morocco, Algeria, Tunisia, Syria, Lebanon, Jordan, Iraq, and Iran, and also some Asian countries, such as Japan (Desneux et al 2010, 2011, Urbaneja et al. 2011, Baniameri and Cheraghian 2012). *Tuta absoluta* attacks tobacco, eggplant, potato plants, and many solanaceous weeds, but the tomato is its main host plant (Desneux et al. 2010, 2011). This pest damages the flowers, leaves, stems, and fruits during the fruiting stage and the larvae feed on mesophyll tissues, in which the damage symptoms on leaves and fruits are apparent as mining (Harizanova et al. 2009). *Tuta absoluta* is a difficult pest to control, and various different methods have been used to control it as part of an integrated pest management (IPM) program to try to improve tomato yields in the face of *T. absoluta* infestation; these have included using a biological control, selective pesticides, and resistant cultivars (Urbaneja et al. 2012). Using pesticides not only causes environmental pollution, resulting in a decrease in *T. absoluta*'s natural enemies, but also encourages the emergence of secondary pests, all consequentially resulting in additional costs to farmers. Thus, finding an effective way of controlling these pests has recently concentrated on finding high-yielding and/or resistant plant cultivars so as to avoid the use of pesticides, first by examining the varieties and then by selecting the most suitable according to location (Cuthbertson et al. 2013). Selecting appropriate cultivars for the IPM program depends on various factors, including productivity potential, regional adaptability, pest and disease resistance, market demand and the end use of the product. Host plant resistance has been reported to be the most effective means of management (Price 1986). Because pest populations are affected by many factors such as the quality of the food source among host plants, there is a positive correlation between host plant suitability and the intrinsic rate of increase of such populations; therefore, determination of insect population growth is one of the most important parameters for decision-making in an IPM program.

In this study, therefore, an age-stage, two-sex life-table was used to estimate *T. absoluta* population parameters on seven traditionally cultivated cultivars of tomato to determine the susceptibility and resistance of these cultivars to this pest.

Materials and Methods

Host Plants

Seeds of seven tomato cultivars ('Primo Early', 'Rio Grande', 'Cal JN3', 'Petomech', 'Early Urbana Y', 'Super Strain B', and 'Super 2270') were obtained from the Seed and Plant Improvement Institute, Karaj, Iran. These cultivars are standard open-pollinated cultivars that are widely used in Iran and in many countries worldwide and that exhibit high quality and yield. The seeds were cultivated in seedling trays containing peat moss in greenhouse conditions at 27 ± 5 °C and under a photoperiod of 16:8 (L: D) h until the growth of the first leaves. Then, cut leaves of the tomato cultivars were fed to *T. absoluta* larvae kept within petri dishes. No pesticides or additional fertilizers were applied.

Insect Rearing

The *T. absoluta* individuals were collected from infested tomatoes in the Varamin region (southeast of Tehran, Iran) in 2015. Subsequently, the moths were reared on the seven selected tomato cultivars for two generations in separate wooden cages under greenhouse conditions (27 ± 5 °C and a photoperiod of 16:8 (L: D) h). All the *T. absoluta* individuals were maintained without exposure to any pesticides.

Life-Table Study

Before the initiation of the experiments, two generations of *T. absoluta* were reared on each tomato cultivar. In the experiments, adult moths that emerged from the larvae reared on different tomato cultivars were used. In total, 35 trifoliate whole leaves with petioles were removed from each tomato cultivar. Next, 20 pairs of both sexes of the moth that had been reared on the tested cultivars were maintained inside oviposition containers (clear plastic containers with a plastic lid and 10% honey-coated paper for feeding adult moths, with fresh leaves of one of the cultivars) and allowed to lay eggs. After 24 h, both sexes of the moth were removed and the eggs reared on each cultivar were used for demographical studies. All experimental moths were maintained in a growth chamber at 25 ± 2 °C, 60 ± 5% RH, and a photoperiod of 16:8 (L:D) h.

For recording the incubation period, 100 eggs of *T. absoluta* on each cultivar were checked daily. After egg hatching, the larvae were individually transferred into the Plexiglas containers (9 by 7 by 4 cm) using a fine camel hairbrush. The petioles were wrapped in wet cotton to maintain the freshness of the leaves, and the leaves were changed every 3 d. Every 24 h until the death of each individual, the development and survival rates were recorded. When an individual developed to adult stage, it was paired with an individual of the opposite sex from the cohort, with the dead males being substituted until the death of the female. In the oviposition containers, a piece of small cotton, which was soaked in 10% honey solution, was placed inside to provide a carbohydrate food source for moths. For females, the daily fecundity of each individual moth was also recorded. Until the death of the last moth of the cohort, the preoviposition and oviposition periods, daily fecundity (number of eggs laid per reproductive day), total fecundity (number of eggs laid per female), and adult longevity were recorded. In accordance with the age-stage, two-sex life-table theory, the life history raw data of all individuals (males, females, and those dying before the adult stage) were analyzed (Chi and Liu 1985, Chi 1988, Khanamani et al. 2013, Fathipour and Maleknia 2016). Data were analyzed and population parameters (r, λ, R_0, and T) calculated by using the TWOSEX-MS Chart program (Chi 2016). The standard errors of the population parameters were estimated by using the bootstrap procedure (Goodman 1982, Nikooei et al. 2015).

By using the bootstrap technique, the standard errors of the fecundity, reproduction period, developmental times, population parameters, and the differences among the cultivars were estimated. To obtain stable estimates, 10,000 bootstraps were used. For both the bootstrap and paired bootstrap test, a user-friendly computer program, TWOSEX-MSChart, was used to estimate the parameters (Chi 2016).

Results

Development Times for the Various Life Stages

The means of the developmental times for each life stage and the total preadult period, preoviposition period and fecundity of *T. absoluta* reared on the seven different tomato cultivars are presented in Table 1. The incubation, larval, and pupal periods showed significant differences among the cultivars of tomato tested. The longest incubation period was observed on Early Urbana Y (6.08 d) and the shortest on Cal JN3 (4.41 d). The larval and pupal periods on Early Urbana Y were longer than those on the other cultivars (13.86 and 6.52 d, respectively), and these periods were the shortest on Cal JN3 (10.92 and 5.5 d, respectively). In addition, the total developmental time was the longest on Early Urbana Y (26.42 d) and shortest on Cal JN3 (20.83 d).

Oviposition Period, Longevity and Fecundity

The mean adult preoviposition period (APOP), defined as the duration from adult emergence to first oviposition, and the total preoviposition period (TPOP), defined as the duration from egg to first oviposition, of *T. absoluta* reared on different tomato cultivars were significantly different (Table 1). The females reared on Cal JN3 had the shortest APOP and TPOP, 1.04 and 23.02 d, respectively. The longest APOP and TPOP were observed on Early Urbana Y, 2.42 and 29.55 d, respectively. The longest oviposition period was recorded on Primo Early (25.72 d) and the shortest period was on Super Strain B (12.91 d). Among the tomato cultivars, adult longevity of *T. absoluta* differed significantly, and the longest, 35.56 d, was on Early Urbana Y, whereas the shortest, 15.67 d, was on Cal JN3 (Table 2). The male and female longevity (mean number of days from eclosion to death) of *T. absoluta* and total lifespan (mean number of days from birth to death) were significantly different among cultivars (Table 2). For adult longevity, the longest-lived female was 38.52 d and for males, it was 30.42 d, both observed on Early Urbana Y. The shortest female and male longevity were 21.98 and 19.33 d, respectively, and were observed on Cal JN3. The total lifespan of females was the longest on Early Urbana Y (65.64 d) and the shortest was on Cal JN3 (40.78 d), and the longest total longevity of males was shown on Early Urbana Y, 55.63 d. The total lifespan of males was shortest on Cal JN3. The total fecundity of *T. absoluta* was affected by the tomato cultivar used by the larvae and was the highest on Cal JN3, and the lowest on Primo Early, 161.85 and 108.22 eggs, respectively (Table 1).

Age-Specific Fecundity, Life Expectancy, and Survival Rate

The curves of age-stage survival rate (s_{xj}) show the probability that an egg of *T. absoluta* will survive to age x and stage j (Fig. 1).

Table 1. Mean (± SE) preadult duration, adult longevity, preoviposition and oviposition periods (days), and fecundity (eggs) of *T.absoluta* on different tomato cultivars

Tomato Cultivar	Egg (d)	Larva (d)	Pupa (d)	Preadult (d)	APOP (d)*	TPOP (d)**	Oviposition period (d)	Adult longevity (d)	Total longevity (d)	Total fecundity (egg)
Cal JN3	4.41 ± 0.07c	10.92 ± 0.09d	5.50 ± 0.08d	20.83 ± 0.19a	1.04 ± 0.03d	23.02 ± 0.19e	14.26 ± 0.26e	15.67 ± 0.42d	34.01 ± 0.92b	161.85 ± 3.77a
Early Urbana Y	5.99 ± 0.08a	13.86 ± 0.11a	6.52 ± 0.09a	26.42 ± 0.23c	2.42 ± 0.09a	29.55 ± 0.34a	22.85 ± 0.39b	35.56 ± 0.61a	46.18 ± 2.4ab	125.55 ± 4.02c
Petomech	4.62 ± 0.05b	11.57 ± 0.06c	5.86 ± 0.08c	22.01 ± 0.18ab	1.78 ± 0.07b	24.98 ± 0.09c	16.07 ± 0.21c	23.82 ± 0.54b	40.9 ± 1.37b	133.24 ± 3.13c
Primo Early	6.08 ± 0.07a	12.42 ± 0.1b	6.27 ± 0.06b	25.08 ± 0.13bc	1.89 ± 0.13b	27 ± 0.22b	25.72 ± 0.39a	34.37 ± 0.54ab	48.58 ± 2.06a	108.2 ± 4.46d
Rio Grande	4.63 ± 0.05b	11.56 ± 0.06c	6.07 ± 0.1bc	22.26 ± 0.18ab	1.41 ± 0.08c	24.71 ± 0.11d	15 ± 0.17d	22.9 ± 0.48bc	39.45 ± 1.41b	151.29 ± 1.98a
Super 2270	4.56 ± 0.05bc	11.45 ± 0.07c	6.04 ± 0.1 c	22.03 ± 0.19ab	1.32 ± 0.07c	24.68 ± 0.11d	15.03 ± 0.19d	21.7 ± 0.48bc	38.78 ± 1.27b	158.93 ± 3.05a
Super Strain B	4.63 ± 0.05ab	11.47 ± 0.06c	5.91 ± 0.09c	22.01 ± 0.19a	1.35 ± 0.07c	24.7 ± 0.09d	12.91 ± 0.18f	18.85 ± 0.32c	37.56 ± 1b	129.05 ± 2.23c

*APOP, adult preovipositional period.
**TPOP, total preovipositional period. The means followed by different letters in each column, which signify significant differences among cultivars using the paired bootstrap test (B = 10,000) at 5% significance level.

Table 2. Duration of different life stages in males and females (mean ± SE) of *T. absoluta* on different tomato cultivars

Cultivars	Development time				Adult longevities				Total life span			
	n	Male	*n*	Female	*n*	Male	*n*	Female	*n*	Male	*n*	Female
Cal JN3	36	19.33 ± 0.15c	46	21.98 ± 0.19e	36	11.67 ± 0.19e	46	18.80 ± 0.2e	36	31.00 ± 0.15e	46	40.78 ± 0.12g
Early Urbana Y	19	25.21 ± 0.14a	33	27.12 ± 0.3a	19	30.42 ± 0.5a	33	38.52 ± 0.33a	19	55.63 ± 0.45a	33	65.64 ± 0.28a
Petomech	31	20.45 ± 0.15b	41	23.2 ± 0.07d	31	18.84 ± 0.25b	41	27.59 ± 0.23b	31	39.29 ± 0.21b	41	50.78 ± 0.2c
Primo Early	27	25.04 ± 0.2a	36	25.11 ± 0.16b	27	29.86 ± 0.31a	36	37.72 ± 0.3a	27	54.93 ± 0.3a	36	62.83 ± 0.31b
Rio Grande	29	20.79 ± 0.19b	41	23.29 ± 0.12c	29	18.52 ± 0.41b	41	26.00 ± 0.17c	29	39.31 ± 0.31b	41	49.29 ± 0.16d
Super 2270	34	20.47 ± 0.12b	40	23.35 ± 0.11c	34	17.44 ± 0.22c	40	25.32 ± 0.17d	34	37.91 ± 0.18c	40	48.67 ± 0.16e
Super Strain B	36	20.42 ± 0.13b	43	23.35 ± 0.11c	36	16.14 ± 0.28d	43	21.12 ± 0.16e	36	36.56 ± 0.27d	43	44.47 ± 0.16f

The means followed by different letters in each column which signify significant differences among cultivars using the paired bootstrap test (B = 10,000) at 5% significance level.

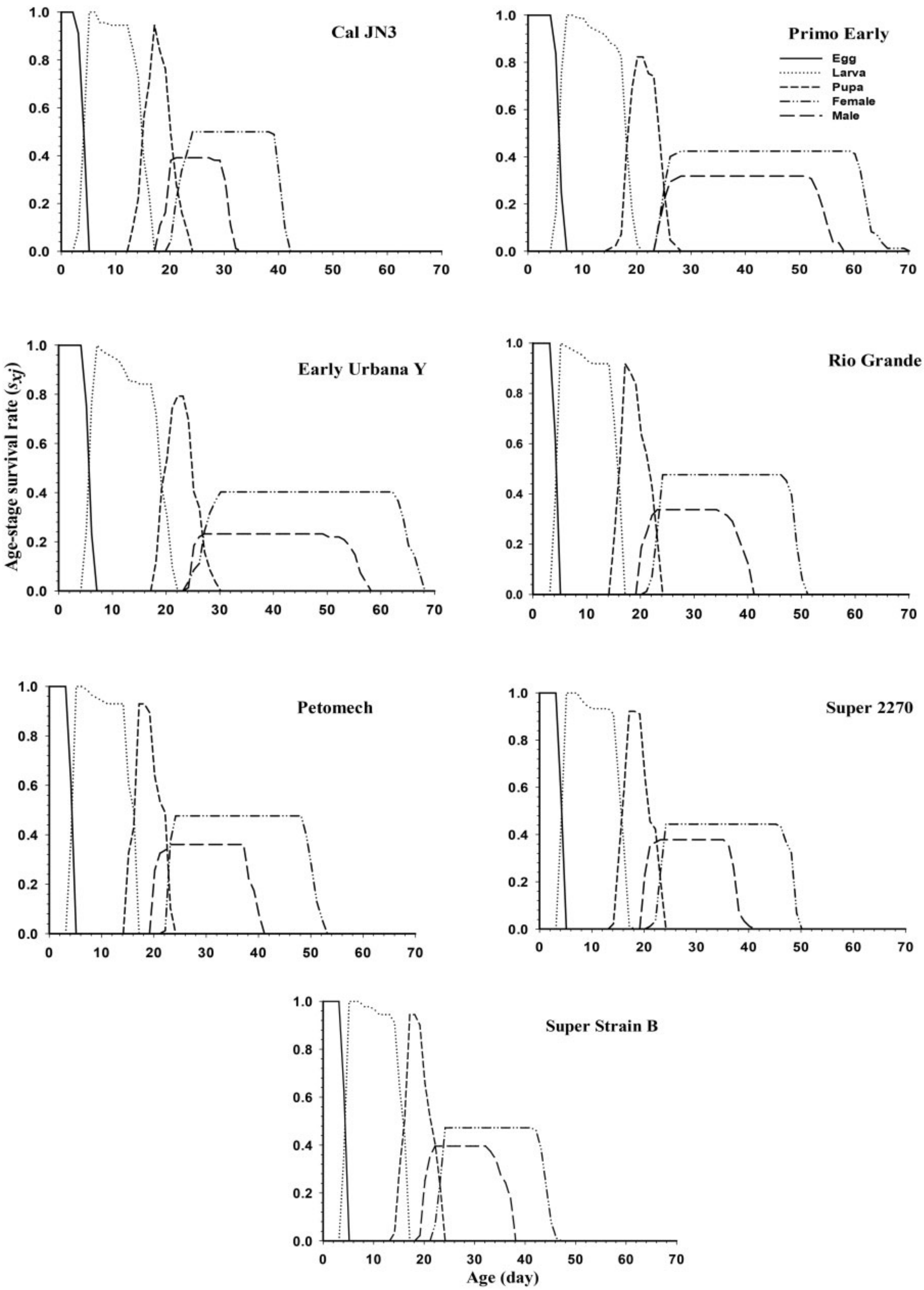

Fig. 1. Age-stage survival rate (s_{xj}) of *T. absoluta* on different tomato cultivars.

In addition, these curves show the stage differentiation, the survivorship, and the variable developmental rate. During the developmental period, the overlap of stages can also be observed in Fig.1. The age-stage-specific life expectancy (e_{xj}) of *T. absoluta* on different tomato cultivars is plotted in Fig. 2. The life expectancy (e_{xj}) decreased with increasing age under the laboratory conditions because no other mortality factors existed, except for aging. The age-stage reproductive value (ν_{xj}) is defined as the contribution of an individual of the

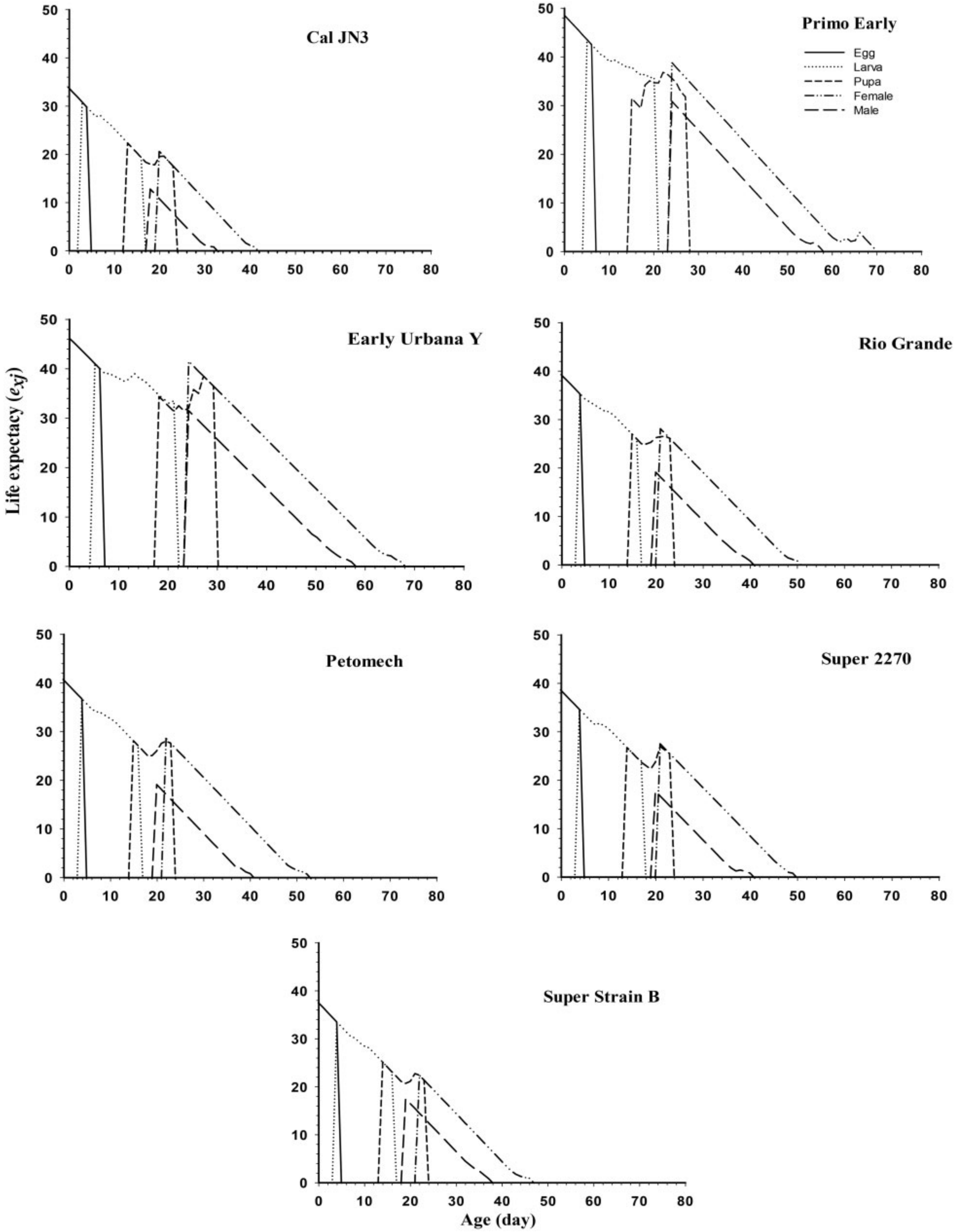

Fig. 2. Age-stage life expectancy (e_{xj}) of *T. absoluta* on different tomato cultivars.

age x and stage j to the future population. The curves of v_{xj} are shown in Fig. 3. On different tomato cultivars, the v_{xj} value increased when adults emerged, increasing again when females began to produce offspring. The age-specific survivorship (l_x) that shows the probability that a newborn individual will survive to age x, the age-specific fecundity of the total population (m_x), and the age-stage

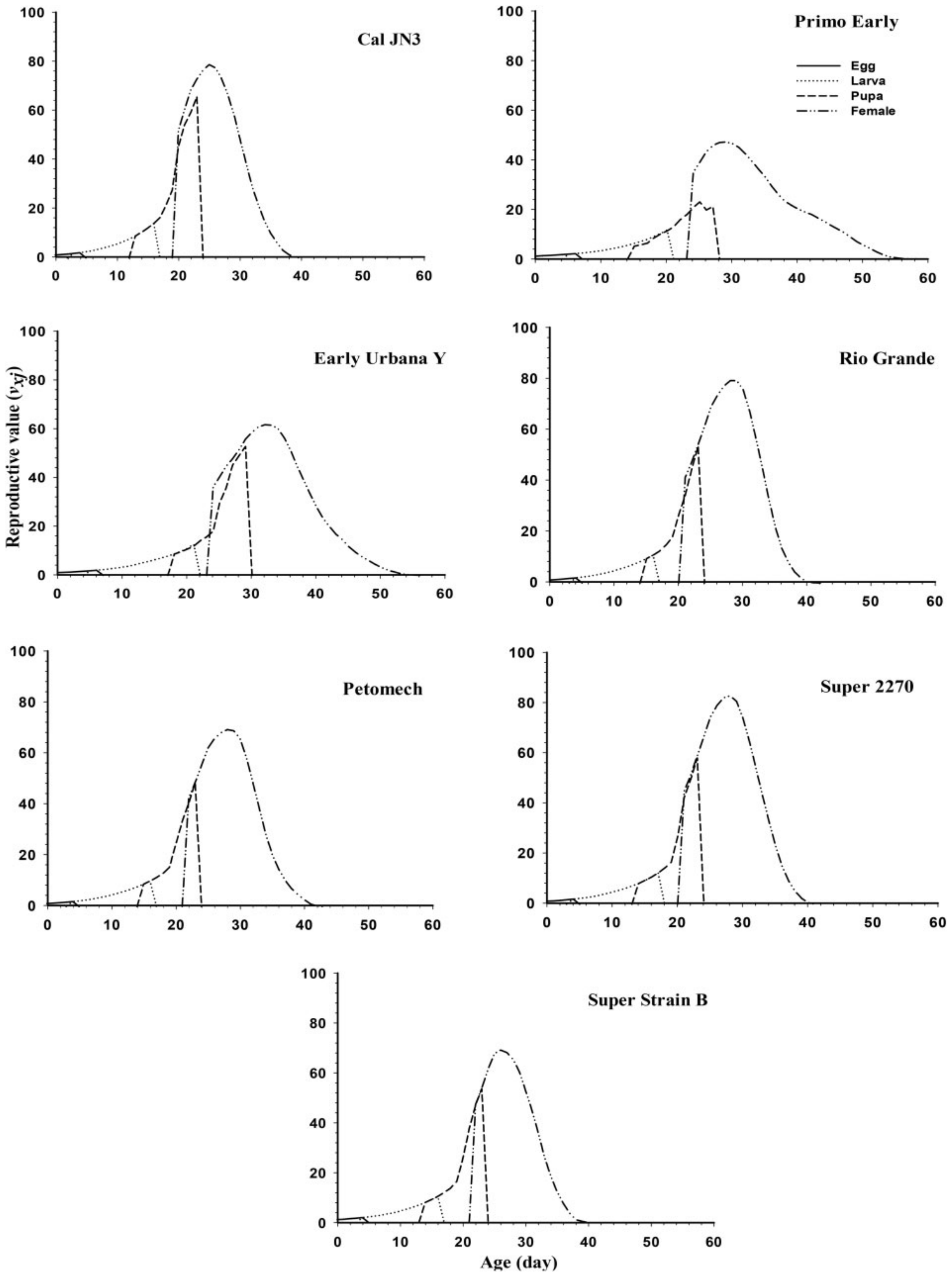

Fig. 3. Age-stage-specific reproductive values (v_{xj}) of *T. absoluta* on different tomato cultivars.

specific fecundity (f_{xj}) of *T. absoluta* reared on seven tomato cultivars are shown in Fig. 4. Because only females produce eggs, there is only a single curve, f_{xj}. The curve of l_x is a simplified version of the curves of s_{xj}. It shows that *T. absoluta* could successfully survive and reproduce on different tomato cultivars under defined laboratory conditions (Fig. 2).

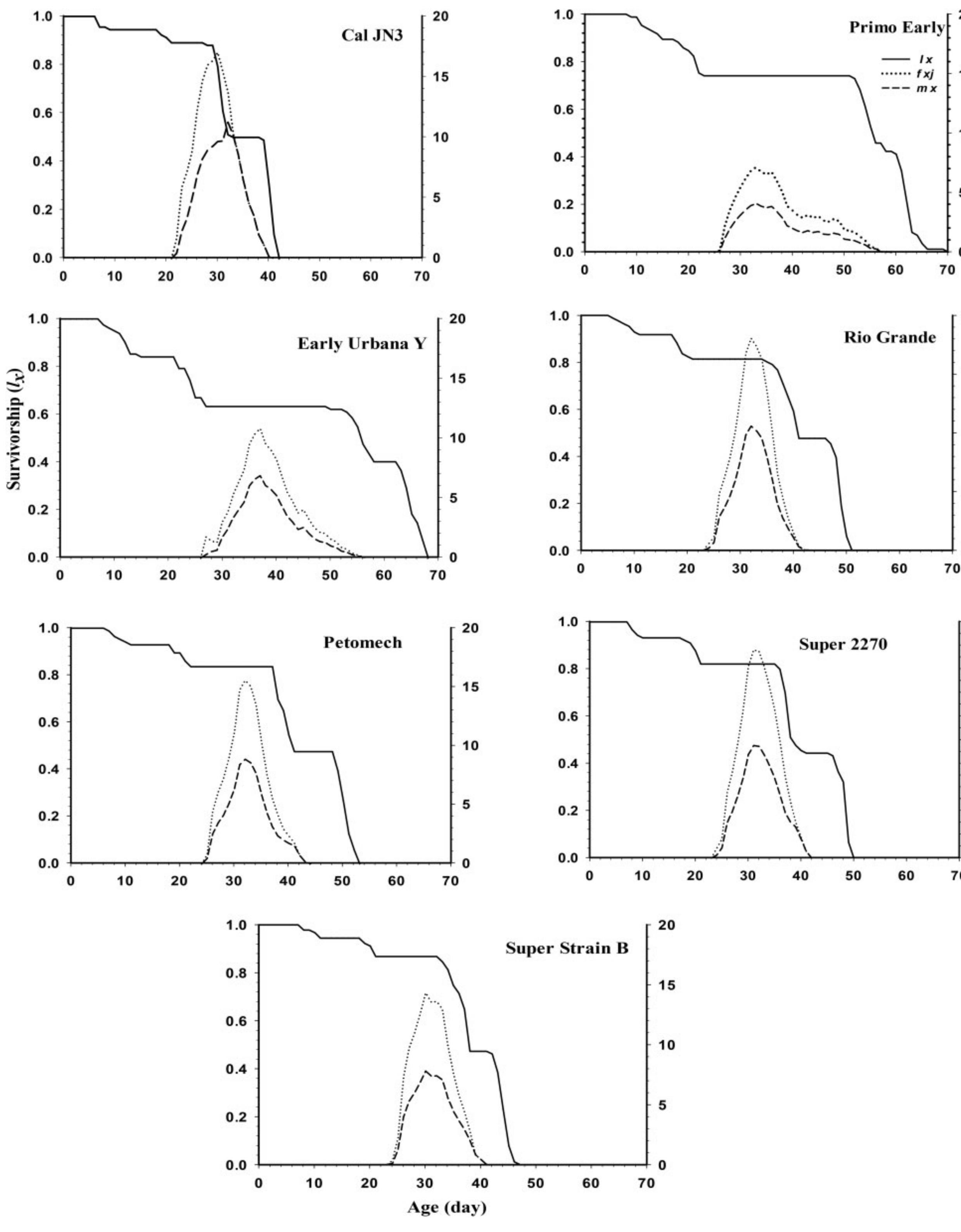

Fig. 4. Age-specific survivorship (l_x), age-stage-specific fecundity (f_{xj}) and age-specific fecundity (m_x) of *T. absoluta* on different tomato cultivars.

Life-Table (Population) Parameters

Tuta absoluta population parameters are presented in Table 3. Depending on the tomato cultivars, the net reproductive rate (R_0) was significantly different. The highest value of the net reproductive rate was 80.94 offspring per individual, observed on Cal JN3, and the lowest, on Priomoearly, was 45.87 offspring per individual. Among tomato cultivars, the finite rate of increase (λ) and the intrinsic rate of increase (r) showed significant differences; the lowest values of these parameters were on Early Urbana Y, 0.1052 and 1.1109 d^{-1}, respectively, and the highest were on Cal JN3, 0.1522

Table 3. Population parameters (mean ± SE) of *T. absoluta* on different tomato cultivars

Cultivars	n	GRR (offspring/individual)	R_0 (offspring/individual)	r (d^{-1})	λ(d^{-1})	T (d)
Cal JN3	92	111.72 ± 7.24a	80.94 ± 8.713a	0.1522 ± 0.004a	1.1644 ± 0.004a	28.85 ± 0.168f
Early Urbana Y	82	79.74 ± 8.826bc	50.57 ± 6.985bc	0.1052 ± 0.004c	1.1109 ± 0.004c	37.28 ± 0.301a
Petomech	86	77.53 ± 7.761bc	63.53 ± 7.213abc	0.1309 ± 0.003b	1.1399 ± 0.004b	31.34 ± 0.099c
Primo Early	85	62.09 ± 7.164c	45.87 ± 6.035c	0.1076 ± 0.003c	1.1136 ± 0.004b	35.55 ± 0.203b
Rio Grande	86	89.5 ± 8.935ab	72.13 ± 8.139a	0.1353 ± 0.003b	1.1449 ± 0.004b	31.61 ± 0.095cd
Super 2270	90	88.32 ± 9.236b	70.58 ± 8.544ab	0.1358 ± 0.004b	1.1455 ± 0.004b	31.33 ± 0.116d
Super Strain B	91	72.8 ± 7.28bc	61.04 ± 6.880abc	0.1348 ± 0.003b	1.1443 ± 0.004b	30.47 ± 0.11e

The means followed by different letters in each column that signify significant differences among cultivars using the paired bootstrap test (B = 10,000) at 5% significance level.

and 1.1644 d^{-1}, respectively. In addition, among the different tomato cultivars tested, the mean generation time (T) varied from 37.28 d on Early Urbana Y to 28.85 d on Cal JN3.

Discussion

The use of cultivars resistant to pests is a fundamental approach in IPM programs that helps reduce crop loss without incurring environmental pollution and additional costs (Lorenzen et al. 2001). To implement this, detailed knowledge of pest biology on different cultivars of the host plant is necessary. This study undertook a thorough comparison of the demographic characteristics of *T. absoluta* on different tomato cultivars by using the age-stage, two-sex life-table to determine the susceptibility and resistance of tomato cultivars to this noxious pest. Our results showed the different influences of seven commonly grown tomato cultivars on the development, survival, fecundity, and life-table parameters of *T. absoluta*. These results are similar to those of other studies on *T. absoluta* (Pereyra and Sánchez 2006, Erdogan and Babaroglu 2014, Gharekhani and Salek-Ebrahimi 2014), all of which revealed the profound influence of different tomato cultivars on the performance of *T. absoluta*. Our findings revealed that *T. absoluta* spent a large proportion of its lifespan in the oviposition phase and because the primary function of the organism is to reproduce promptly and proficiently, short pre- and postoviposition periods are beneficial to *T. absoluta*. The egg incubation period of *T. absoluta* was significantly affected by different tomato cultivars. Our findings concur with Pereyra and Sánchez's (2006) results on host plants other than the tomato. The Cal JN3 tomato cultivar, relative to the other cultivars, showed a shorter duration of the immature stages of *T. absoluta*, which showed that this cultivar meets the nutritional requirements of the larvae better than the other cultivars. Conversely, the developmental time of *T. absoluta* on Early Urbana Y was longer than that on the other cultivars. On different plant cultivars, variations in the development times of pests can be related to either differences in nutrients or in primary and secondary compounds among different cultivars, or to physiological differences, depending on the host plants (Adango et al. 2006, Fathipour and Naseri 2011). Adult longevity of *T. absoluta* was significantly different among the tomato cultivars, with the longest and shortest longevity obtained on Early Urbana Y and Cal JN3, respectively. Regarding the total longevity and fecundity of *T. absoluta*, our results showed that Cal JN3 was the most susceptible cultivar and Early Urbana Y was the most resistant of those tested. Low susceptibility of Early Urbana Y to *T. absoluta* could be attributed to the physical or biochemical characteristics of the different tomato host plants. Previous studies have revealed that a tomato genotype containing high concentrations of zingiberene, acylsugars, and 2-tridecanone expressed high resistance to *T. absoluta* (Resende et al. 2006, Maluf et al. 2010). Moreover, as measured by overall plant damage, genotypes heterozygous for higher concentrations of both zingiberene and acylsugars exhibited higher levels of resistance to the insect compared with genotypes heterozygous for either zingiberene or acylsugar alone, thereby suggesting a synergistic effect of the allelochemicals on resistance. These factors may affect fecundity potential; Pereyra and Sánchez (2006) showed that total fecundity of *T. absoluta* varied from 97.73 to 132.78 eggs per female on various different solanaceous plants, whereas Erdogan and Babaroglu (2014) reported this value as 141.16 eggs per female on tomato plants. However, this value was recorded as 25.5 and 50.6 eggs per female on different potato cultivars by Caparros et al. (2013). Possible differences among these findings may reflect factors such as the quantity and quality of nutrients in host plants, phagostimulant factors, and defensive metabolites that directly affect potential and achieved herbivore fecundity, the origin of the *T. absoluta* population, experimental conditions, and rearing techniques. Speight et al. (2008) found that on leaves of host plants, high densities of trichomes or levels of toxins could affect population size and reproductive potential of pests, and that these factors cause high mortality. In addition, polyphenol oxidase causes a reduction in digestibility, nutritive quality, and palatability of plant tissues to insects.

In this study, the net reproductive rate (R_0) was the lowest on Primo Early and the highest on Cal JN3. Pereyra and Sánchez (2006) indicated that the R_0 value of *T. absoluta* varied on different host plants, and differed between tomatoes (48.92 offspring) and potatoes (14.43 offspring). To assess host–plant resistance levels to insects and insect suitedness to host plants, the life-table parameters, and especially the intrinsic rate of natural increase (r), are the most important usable parameters. In fact, the intrinsic rate of increase is a basic parameter from which an ecologist may be able to measure the establishment of an insect population. Moreover, along with insect density, fecundity and survival rates will vary with any given combination of physical factors. Therefore, r is a useful index for evaluating the performance of an insect on different host plants. Our finding showed that the r value of *T. absoluta* varied from 0.1052 on Early Urbana Y to 0.1522 d^{-1} on Cal JN3. The higher r values of *T. absoluta* on Cal JN3 could be related to the considerably higher survival rate, higher net reproductive rate and shorter developmental time on this cultivar, making it the most suitable cultivar for population growth of *T. absoluta*. Conversely, Early Urbana Y had the lowest r value so Early Urbana Y was an unsuitable host for *T. absoluta*. Therefore, this cultivar has high resistance to *T. absoluta*, as suggested by the lower survival rate and longer developmental time of immature stages, reflected in the lower value of r.

Furthermore, jasmonic acid is found in many plant species and is involved in regulating various plant functions such as plant senescence and resistance (Creelman and Mullet 1997). Following caterpillar damage, jasmonic acid is produced by the plant and results in increased production of compounds involved in antiherbivory activity (Constabel et al. 1995, Thaler et al. 1996). Our results on tomatoes may suggest that in the Early Urbana Y cultivar that has low susceptibility to *T. absoluta*, jasmonic acid may cause induction of proteinase inhibitors and polyphenol oxidase, thereby decreasing the preference, performance, and abundance of many tomato pests such as *T. absoluta*; however, further research in this area is needed.

Hence, Early Urbana Y can be used in an IPM strategy to control *T. absoluta*. Using this cultivar reduces the requirement for additional management techniques, such as biological controls, pheromone traps, and insecticides. However, further field and laboratory experiments are needed to explore plant–herbivore interactions, and basic biochemical studies are needed to undertake the extraction and identification of phytochemicals that reduce the build-up of *T. absoluta* populations on tomato plants. Some research has been conducted on the resistance of tomato cultivars to other pests, diseases, and nematodes. Safuraie-Parizi et al. (2014) evaluated the resistance of 10 tomato cultivars to *Helicoverpa armigera* (Hübner) and they found no significant difference between Early Urbana Y and Cal JN3 regarding total fecundity, but the intrinsic rate of increase on these two cultivars differed significantly. Although reported studies of pests, diseases, and nematode resistance of tomato cultivars have all been performed under laboratory conditions, the findings vary considerably on account of differences in experimental design, variations in laboratory conditions, and genetic variation.

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