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Scientific paper

Life History Traits and Population Growth of Greenhouse Whitefly (*Trialeurodes vaporariorum Westwood*) on Different Tomato Genotypes

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SUMMARY

The effects of five tomato genotypes (cv. Narvik and hybrids NS-6, Tamaris, Alliance and Marko) on the survival, reproduction, development and population growth of the greenhouse whitefly *Trialeurodes vaporariorum* were examined. A laboratory population of *T. vaporariorum* had been reared on tobacco plants for three years before the study. Females that laid eggs on the genotype Marko lived significantly longer and their offspring needed significantly shorter periods to develop than females on the genotype Narvik. The highest gross and net fecundity rates were found in females on the genotype Marko (36.74 eggs/female and 27.93 eggs/female, respectively) and they differed significantly from the corresponding rates of females living on the genotype NS-6 (18.55 eggs/female and 15.33 eggs/female), who had the lowest fecundity rates. The highest gross and net fertility rates were also found in females on the genotype Marko (31.24 adults/female and 23.73 adults/female), and they were significantly higher than those of females living on NS-6 (14.85 adults/female and 12.53 adults/female). Besides, net fertility rate of the females living on the genotype Narvik (13.80 adults/female) was also significantly lower than the rate of females on Marko. The instantaneous rates of increase showed no significant difference over a 10-day interval following the start of oviposition, while the increase rate was significantly higher on the genotype Marko after 12, 14 and 16 days, compared to the genotype NS-6. Eighteen, 20 and 22 days after the beginning of oviposition, the instantaneous rate of increase on the genotype Marko was significantly higher than it was on NS-6 and Narvik. Our data provide a basis for further research aiming to improve programs of integrated management of greenhouse whitefly.

Keywords: Females; Eggs; Tomato genotypes; *Trialeurodes vaporariorum*

INTRODUCTION

The greenhouse whitefly *Trialeurodes vaporariorum* Westwood (Hemiptera: Aleyrodidae) is a cosmopolitan and highly polyphagous pest species of greenhouse crops especially infesting tomato. It is widespread in Serbia and one of the most damaging pests of vegetables and organmentals in glass and plastic greenhouses (Perić et al., 2009). Adults and larvae of this species suck saps of phloem cells, causing chlorosis and overall weakening of their host plant, while their honeydew secretion creates favourable conditions for the development of sooty mould that reduces plant photosynthesis. Indirect damage is caused by the role of *T. vaporariorum* as a vector of plant viruses (Wisler et al., 1998; Brødsgaard and Albajes, 1999; Martin et al., 2000). Greenhouse whiteflies are also vectors of the broad mite *Polyphagotarsonemus latus* Banks, a serious pest of several greenhouse crops worldwide, which has also been detected in Serbia over the past several years (Palevsky et al., 2001; Petanović et al., 2010).

The use of insecticides is still the principal approach to *T. vaporariorum* control. However, exposed to selection pressure by repetitive spray treatments, *T. vaporariorum* populations develop resistance to first generation insecticides (organophosphates, carbamates, pyrethroids), as well as to neonicotinoids and other newer insecticides (Gorman et al., 2001, 2007, 2010; Karatolos et al., 2010; Whalon et al., 2013). A viable long-term strategy for control of this pest species should therefore be based on an integration of different chemical, biological, cultural and other activities. In that context, the interaction between host plants and *T. vaporariorum* can be an important element in the improvement of integrated pest management programs. Host plants (species, cultivars or hybrids) are known to affect the development, reproduction and population growth of *T. vaporariorum* (Erb et al., 1994; Fancelli and Vendramim, 2002; Kakimoto et al., 2007; Manzano and van Lenteren, 2009; Baldin and Beneduzzi, 2010) and their susceptibility to insecticides (Liang et al., 2007; Castle et al., 2009; Xie et al., 2011). In this bioassay, we evaluated the survival, reproduction, development and population growth of *T. vaporariorum* on five tomato genotypes popular on the Serbian market as a foundation for research that should improve programs of integrated management of this pest.

MATERIAL AND METHODS

Five commercial tomato genotypes (cv. Narvik and hybrids NS-6, Tamaris, Alliance and Marko) were used in this bioassay. Plants were grown on Floradur® Multiplication Substrate (Floragard Vertriets GmbH für Gartenbau, Germany) in plastic 1 L pots.

A laboratory population of *T. vaporariorum* was set up in 2009 from insects collected from eggplants grown in a plastic greenhouse at Padinska Skela (N:44^{0}57.005; E:020^{0}25.700) and reared on tobacco plants (cv. Samsun) under long-day conditions. The bioassay was set up in three replicates in a climate-controlled room (27±2^{0}C, RH 50±10%, 16/8 h of light/dark photoperiod). Fifty females were selected from the colony and placed on a four-week-old tobacco plant to lay eggs. Two days later, the females were removed and the plant moved to a separate cage. Offspring development was monitored into the stage of new adults. After copulation (i.e. at the end of preoviposition), one-day-old females were removed from the colony, five females were placed into each muslin beg and the bags slipped over the oldest leaves. Two 4-weeks-old plants were used for each tested genotype and put into insect cages (BugDorm-44545F Insect Cage, Taiwan). Females were transferred to fresh leaves at 48 h intervals until the end of oviposition and both the number of females alive and eggs laid were counted. ***Female survival rates*** were calculated as $(Sa/5 + Sb/5) \times 0.5$, where *Sa* is the number of live females at the beginning, and *Sb* the number of live females at the end of each 48-hour interval. ***Gross fecundity*** (the number of eggs laid per female alive at the midpoint of 48-h interval), ***net fecundity*** (gross fecundity weighted by female survival rates), ***gross fertility*** (the number of adults per female alive at the midpoint of 48-h interval), and ***net fertility*** (gross fertility weighted by female survival rates) were defined and calculated according to Carey (1993). Lifetime ***gross fecundity/fertility rates*** and ***net fecundity/fertility rates*** were calculated as the sum of calculated fecundity/fertility rates.

Females on the first leaf that had no eggs laid were kept on its surface until death, and checked at 48 h intervals. Leaves with laid eggs were cut off after the hatched larvae reached the fourth instar stage and placed onto 1% agar in Petri dishes with four 8 mm ventilation openings on covers in order to determine the number of unhatched eggs and calculate ***egg viability*** (the percent of hatched eggs). Further larval

development was monitored daily to determine the number of insects reaching the adult stage and calculate the ***offspring development time*** (egg-to-adult), assuming that egg-laying took place at the midpoint of 48-h interval. ***Female longevity*** was defined as the mean number of days that females lived after emergence, assuming that females died at the midpoint of 48 h interval.

Data on the survival, longevity, fecundity, fertility, development time and egg viability were analyzed by a one-way ANOVA with the means separated by Fisher's LSD test (α=0.05). Fecundity and fertility data were transformed by $\sqrt{(x+0.5)}$ and egg viability data by arcsin $\sqrt{(x/100)}$ prior to analysis.

The instantaneous rate of increase (r_i) was calculated by the following equation:

$$r_i = [\ln (Nt / N_0)]/\Delta t$$

where N_0 is the initial number of individuals (i.e. five adult females per replicate), Nt is the number of individuals at the end of t^{th} day (i.e. the number of surviving adult females, eggs laid and nymphs hatched), and Δt is the number of days elapsed between the start of bioassay and the end of t^{th} day. Whiteflies were counted at the end of the 8th, 10th, 12th, 14th, 16th, 18th, 20th and 22th day after the start of oviposition. Positive r_i values indicate a growing population, negative r_i values indicate a population in decline while $r_i = 0$ is a stable population (Stark and Banks, 2003). The calculated r_i values were analysed by the one-way ANOVA and the means separated by Fisher's LSD test (α=0.05).

RESULTS AND DISCUSSION

Tomato genotypes significantly affected the survival, development and reproduction of *T. vaporariorum*. Females lived longest on the genotype Marko (2.0-8.5 days longer than other females on the average), but a significant difference was detected only between those females and the shortest-living females on the genotype Narvik. A significant difference between these two genotypes was also found regarding the offspring development time, which was 1.2 days shorter on the genotype Marko. Egg viability was high on all genotypes (95-98%), but significantly lower on NS-6 than on all other genotypes (Table 1).

Figure 1 presents the gross and net fecundity rates of *T. vaporariorum* females. The highest rates were recorded for females on the genotype Marko (36.74 eggs/female and 27.93 eggs/female, respectively) and they were 9-98% and 11-82% higher than the rates on the other genotypes. Females on the genotype NS-6 had the lowest fecundity rates (18.55 eggs/female and 15.33 eggs/female) and a statistically significant difference was detected between females on that genotype and on Marko. The highest gross and net fertility rates (Figure 2) of females were also found on the genotype Marko (31.24 adults/female and 23.73 adults/female), and they were 12-104% and 16-89% higher than the fertility rates of the other females. The lowest female fertility rates, found on the genotype NS-6 (14.85 adults/female and 12.53 adults/female), differed significantly from those on the genotype Marko. Besides, female net fertility on the genotype Narvik (13.80 adults/female) was also significantly different from the net fertility of females on Marko.

Table 1. Survival and development traits (means ± SE) of *T. vaporariorum* on tomato

Genotype	FL	EH	DT
Narvik	18.57 ± 1.14 b	97.70 ± 0.68 a	21.85 ± 0.15 b
NS-6	20.33 ± 2.38 ab	95.27 ± 0.49 b	21.41 ± 0.09 ab
Tamaris	24.10 ± 2.75 ab	97.60 ± 0.70 a	22.07 ± 0.60 ab
Alliance	25.17 ± 1.51 ab	97.77 ± 0.58 a	21.80 ± 0.15 ab
Marko	27.20 ± 2.72 a	97.80 ± 0.35 a	20.64 ± 0.08 a

Means followed by different letters within a column differ significantly (ANOVA followed by Fisher LSD test, α = 0.05)

FL = Female longevity (days)
EH = egg viability (% of hatched eggs);
DT = offspring development time (days)

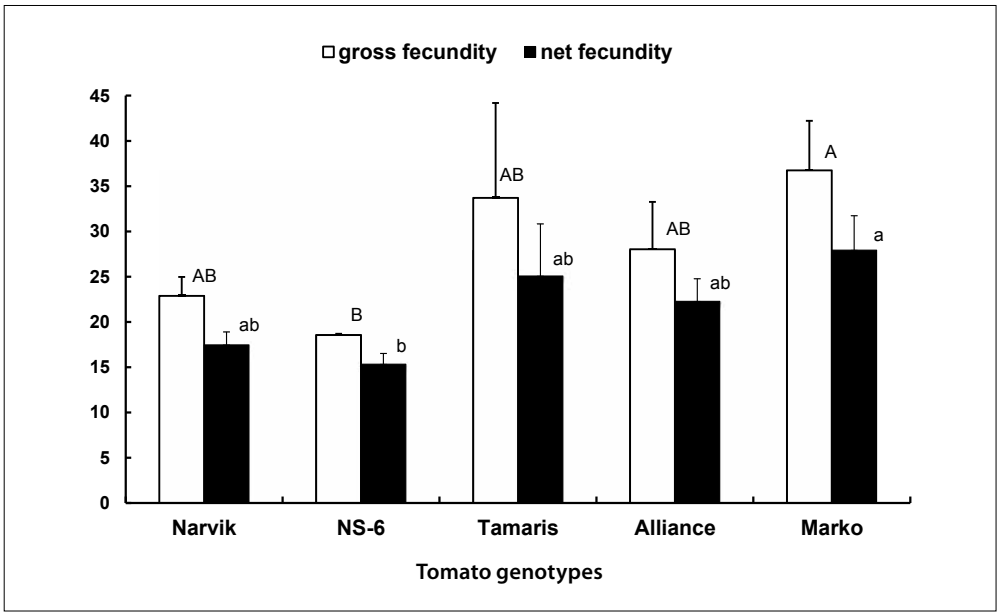

Figure 1. Gross and net fecundity rates (eggs/female) of *T. vaporariorum* on tomato

Means followed by different letters (Capital letters - Gross fecundity; Small letters - Net fecundity) differ significantly (ANOVA followed by Fisher LSD test, $\alpha = 0.05$)

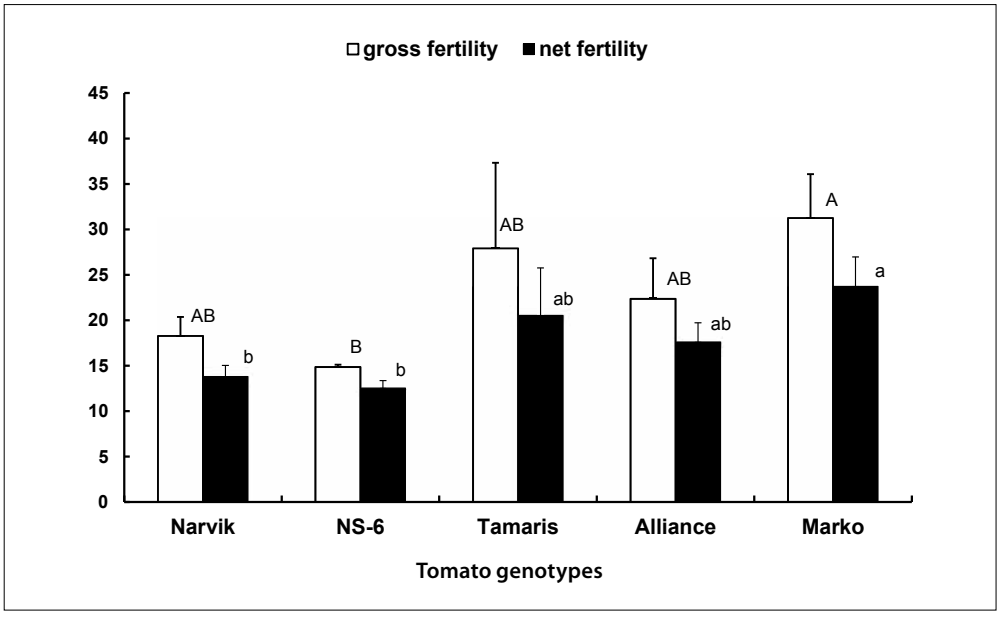

Figure 2. Gross and net fertility rates (adults/female) of *T. vaporariorum* on tomato

Means followed by different letters (Capital letters - Gross fertility; Small letters - Net fertility) differ significantly (ANOVA followed by Fisher LSD test, $\alpha = 0.05$)

Table 2. Instantaneous rates of increase (means ± SE; day-1) of *T. vaporariorum* on tomato

Genotype	Oviposition (days)							
	8	10	12	14	16	18	20	22
Narvik	0.280 (0.014) a	0.245 (0.011) a	0.214 (0.006) ab	0.186 (0.006) ab	0.166 (0.006) ab	0.148 (0.004) b	0.132 (0.004) b	0.119 (0.004) b
NS-6	0.289 (0.026) a	0.244 (0.017) a	0.201 (0.007) b	0.179 (0.001) b	0.161 (0.003) b	0.143 (0.002) b	0.127 (0.003) b	0.115 (0.003) b
Tamaris	0.297 (0.034) a	0.262 (0.018) a	0.224 (0.010) ab	0.208 (0.018) ab	0.186 (0.016) ab	0.167 (0.015) ab	0.149 (0.013) ab	0.134 (0.012) ab
Alliance	0.286 (0.037) a	0.247 (0.023) a	0.221 (0.013) ab	0.198 (0.007) ab	0.177 (0.008) ab	0.160 (0.007) ab	0.144 (0.007) ab	0.130 (0.006) ab
Marko	0.310 (0.033) a	0.276 (0.022) a	0.244 (0.014) a	0.217 (0.013) a	0.193 (0.005) a	0.176 (0.008) a	0.159 (0.007) a	0.144 (0.007) a

Means followed by different letters within a column differ significantly (ANOVA followed by Fisher LSD test, $\alpha = 0.05$)

Table 2 shows instantaneous rates of increase starting with an 8-day ovipositional interval (massive hatching of larvae from eggs laid on the first day was recorded at the end of the 8th day) until the end of oviposition. In that interval, the highest r_i values were found on the genotype Marko (0.144-0.310 day^{-1}) and the lowest on NS-6 (0.115-0.289 day^{-1}). From the 12th day of oviposition until the end of oviposition, those values showed significant differences. The instantaneous rate of increase on the genotype Marko was significantly higher than it was on Narvik (0.119-0.214 day^{-1}) 18, 20 and 22 days after the beginning of oviposition.

The life history traits and/or population growth of *T. vaporariorum* have been studied on tomato (*Solanum lycopersicum*) in order to investigate the resistance of various tomato cultivars, breeding lines and hybrids to this pest (Romanow et al., 1991; Bas et al., 1992; Erb et al., 1994; Lucatti et al., 2010). In spite of the economic importance of *T. vaporariorum*, we found no published data on the life history of this pest on the most widely grown tomato genotypes in Serbian greenhouses. Our results show that the genotype Marko is the most favorable host for greenhouse whiteflies, while NS-6 is the least favorable genotype. Whitefly females on the genotype Marko had the highest fecundity and fertility rates, 1.8-2.1 times higher than those of females on the genotype NS-6. The instantaneous rate of increase, which is a population-level endpoint and integrates survivorship and reproduction, was 20-25% higher on the genotype Marko than on NS-6 in the second half of oviposition.

Reduction in reproductive parameters of *T. vaporariorum* on different tomato genotypes had also been detected in other studies. Erb et al. (1994) found a reduced number of laid eggs and F2 adults on two interspecific hybrids between *S. lycopersicum* and wild tomato species. In a five-day no-choice bioassay, Lucatti et al. (2010) found the oviposition rate of *T. vaporariorum* to range from 0.2 eggs/day on a wild line *S. habrochaites* to 4.4 eggs/day on a *S. lycopersicum* breeding line resistant to root knot nematodes. The adult survival rates ranged from 0.0 females/day to 0.8 females/day.

An analysis of data in our present study and their comparison with data in similar studies suggest a need to continue investigation of the effects of host plants and adaptation of *T. vaporariorum* to different genotypes. Research should proceed to examine the susceptibility to insecticides of populations reared on different genotypes, especially as the host plant is known to have a major influence on susceptibility of *T. vaporariorum* and silverleaf whitefly *Bemisia tabaci* Gennadius to insecticides (Liang et al., 2007; Castle et al., 2009; Xie et al., 2010).

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Životni parametri i rast populacije bele leptiraste vaši (*Trialeurodes vaporariorum* Westwood) na različitim genotipovima paradajza

REZIME

Ispitivan je uticaj pet genotipova paradajza (sorta Narvik, hibridi NS-6, Tamaris, Alliance i Marko) na preživljavanje, reprodukciju, razviće i rast populacije bele leptiraste vaši *Trialeurodes vaporariorum* Westwood. Laboratorijska populacija *T. vaporariorum* gajena je na duvanu tri godine pre postavljanja ogleda. Ženke koje su polagale jaja na genotipu Marko živele su značajno duže, a razviće njihovog potomstva trajalo je značajno kraće, u poređenju sa ženkama na genotipu Narvik. Najviše stope bruto fekunditeta i neto fekunditeta zabeležene su kod ženki na genotipu Marko (36,74 jaja/ženki i 27,93 jaja/ženki) i one su se značajno razlikovale od odgovarajućih vrednosti kod ženki na genotipu NS-6 (18,55 jaja/ženki i 15,33 jaja/ženki), gde su zabeležene najniže stope fekunditeta. Najveće vrednosti bruto i neto fertiliteta takođe su imale ženke na genotipu Marko (31,24 jedinki/ženki i 23,73 jedinki/ženki), i ove vrednosti su bile značajno veće u poređenju sa ženkama na genotipu NS-6 (14,85 jedinki/ženki i 12,53 jedinki/ženki). Pored toga, i stopa neto fertiliteta ženki na genotipu Narvik (13,80 jedinki/ženki) bila je značajno niža u poređenju sa stopom neto-fertiliteta ženki na genotipu Marko. Vrednosti trenutne stope rasta nisu se značajno razlikovale za interval 10 dana od početka ovipozicije, dok je za intervale od 12, 14, i 16 dana trenutna stopa rasta na genotipu Marko bila značajno viša u odnosu na genotip NS-6. U intervalima 18, 20 i 22 dana od početka ovipozicije, trenutna stopa rasta na genotipu Marko bila je značajno viša u odnosu na genotipove NS-6 i Narvik. Dobijeni rezultati predstavljaju polaznu osnovu za dalja istraživanja u okviru unapređivanja programa integralnog upravljanja štetnom vrstom *T. vaporariorum*.

Ključne reči: Ženke; jaja; genotipovi paradajza; bela leptirasta vaš