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N-nutrition of tomato plants affects life-table parameters of the greenhouse whitefly

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Whiteflies (*Trialeurodes vaporariorum*) were reared on tomato plants grown at different nitrogen levels. Life history parameters such as whitefly longevity and fecundity increased with higher N-levels in the nutrient solution, whereas the developmental time decreased. Sex ratio, respiration rate, and egg to adult survival were not consistently affected by the various N-treatments. Life table analysis showed that high N-concentrations in the leaves resulted in a shorter generation time and doubling time of the populations and in a higher net reproductive rate (R_0) and intrinsic rate of natural increase (r_m). Hence, overall population growth was faster on high-N plants than on low-N plants.

Keywords: survival, fecundity, sex ratio, intrinsic rate of natural increase, doubling time, whitefly, *Trialeurodes vaporariorum*

INTRODUCTION

Tomatoes are one of the economically most important vegetable cash crops. They are grown worldwide, outdoor, or in greenhouses to protect them from unfavorable weather conditions (low temperature, winds, hail etc.) or from pests, primarily from the transmission of virus diseases (BERLINGER & LEBIUSH-MORDECHI 1996). As a result of the high initial investment in greenhouse production, growers tend to increase their income by maximizing yield per unit area, which brings them to over-fertilize their crop, as a kind of insurance. A series of previous observations and experiments in other crops clearly showed that pest population increased when the host plants were over-fertilized, especially when nitrogen was in excess (e.g. MATTSON 1980; WILSON et al. 1988; WERMELINGER et al. 1991; BERLINGER 1992). Over-fertilization not only leads to a direct waste of money and to environmental contamination, but also to a severe increase in pest and disease problems. Increasing population growth will enhance the development of resistance to pesticides. This will in turn result in a significant and completely unwanted increase in pesticide application.

The purpose of this study was to examine how various levels of N-fertilization in tomatoes affect the population dynamics of the greenhouse whitefly, *Trialeurodes vaporariorum* (WESTW.) and to get more insight into the mechanisms of these effects.

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MATERIALS AND METHODS

Host plants: Tomato seedlings (var. Super Marmande) were transplanted into plastic pots (10 cm) containing clean calibrated quartz sand (0.8–1.2 mm). Pots of the same N-treatment were placed on trays in which a water level of 3 cm was maintained. Three different nitrogen-levels (2N, 1N, and 0.1N) were applied, using a modified Hoagland solution, which contained 2, 1, and 0.1 times the N-quantity of the standard (1N) Hoagland solution (Tab. 1A). Plants were fertilized twice a week by adding per plant 50 ml of solution to the irrigation water, starting one week after transplanting. The plants were raised at 25-26°C, long day light regime, and a light intensity of 400 µM/m^{2}s.

N-content of the leaves: Leaf samples, taken on the days when adult survival and age specific fecundity were checked, were dried at 105°C for one hour to quickly degrade the enzymes, and subsequently at 60°C for two days. Each sample consisted of at least three leaflets taken from leaves of comparable age. The total N-content of the leaves was measured by means of a Carlo Erba® autoanalyzer on a chromatographic basis with thermal conductivity detection.

Table 1. Nitrogen treatments (2N, 1N, 0.1N) used in the whitefly experiments: A) composition of the modified Hoagland solutions, B) corresponding N-concentrations of tomato leaves (means ± sd).

	Treatment		
	2N	1N	0.1N
A) Nutrient solution (mM/l)			
KNO_3	5	5	1.5
$NH_4 NO_3$	7.5	-	-
$Ca(NO_3)_2$	5	5	-
$CaCl_2$	-	-	5
$MgSO_4$	2	2	2
KH_2PO_4	1	1	1
K_2SO_4	-	-	1.75
Fe: Sequestren 138*)	0.1	0.1	0.1
H_3BO_3	0.025	0.025	0.025
$MnSO_4$	0.002	0.002	0.002
$ZnSO_4$	0.002	0.002	0.002
$CuSO_4$	0.0005	0.0005	0.0005
Na_2MoO_4	0.0005	0.0005	0.0005
KCl	0.05	0.05	0.05
B) Leaf N-concentration (%)	3.1[a] ± 0.60	1.9[b] ± 0.31	1.7[b] ± 0.51

*) Chelate

[a] Numbers with same letters do not differ significantly ($p<0.05$)

Whitefly rearing: Three separate whitefly population stocks were reared individually in three cages, each whitefly population on differently N-fertilized tomato plants. The upper side of each cage was covered by glass, and its walls were covered by a stretched nylon mesh. A doorway was made by means of a mesh sleeve for manipulating the plants and whiteflies. The rearing was situated in a greenhouse, at 25–30°C, 60% RH and long day photoperiod (L/D 16:8).

Adult longevity, age specific fecundity: Newly emerged adults raised on a specific N-treatment plant, were confined pairwise by a clip-on cage onto a leaflet of a plant of the corresponding N-treatment. Every 2–3 days the leaflets bearing the caged whiteflies were detached. If the females, or both adults, were still alive, they were confined again onto another leaflet of a new plant of the same N-treatment. The eggs were counted using a binocular (10x) two days after oviposition when the eggs' color had turned purple-dark making counting easier. The experiments were performed in a phytotrone at 25°C. Two sets of experiments were performed; one started with 25 pairs (n=25) of whiteflies per N-treatment, and the second experiment with 40 whitefly pairs in each N-treatment. Since the results of the two experiments did not differ they were pooled for the final data analysis.

Egg to adult survival, developmental time and sex ratio: Differently fertilized tomato plants, at the 3–4 fully expanded leaf stage, were put into the whitefly rearing cage of the corresponding N-treatment to allow oviposition. The plants were removed after 12 hours from the cage and transferred to a phytotrone at 25°C, after the whiteflies had been shaken off. Two days later, the purple colored eggs were counted on the attached leaves. As the larvae reached the red-eye-stage the plants were transferred singly into plastic cages covered with glass, and possessing an opening with a mesh sleeve. The newly emerged adults were collected daily by means of an aspirator. This indicated the duration of egg to adult development. The total number of whiteflies that emerged from each N-treatment was then divided by the initial number of eggs of the same N-treatment, yielding egg to adult survival rate. The number of females and male progenies was counted and sex ratio (SR), i.e. % females was calculated.

Whitefly respiration rate: The absolute respiration rate of single whitefly females, reared on two differently N-fertilized host plants (2N and 0.1N), was determined by adjusting the method described for spider mites (WERMELINGER 1989). Because of the size of the individual whitefly, capillaries of 1.15 mm inner diameter were used. To prevent the flies from moving around they were confined between two cotton "plugs" which were inserted into the capillary.

Capillary preparation: First a cotton plug was inserted and a whitefly female was introduced. Subsequently, the second "plug" was inserted, and some NaOH as well as liquid paraffin were sucked in. Finally, the capillary was sealed at the other end with Vaseline®. Female respiration rate was assessed by measuring the O_2 consumption (mg O_2/h per mg female dry weight). The experiment was performed at 25°C, in 6 and 5 replicates for the 2N- and 0.1N-treatments, respectively.

Life-table parameters: To assess the impact of the various N-treatments on the population growth of the whiteflies, life-table parameters were calculated from populations reared on differently fertilized host plants. The net reproductive rate (R_0), generation time (T), intrinsic rate of natural increase (r_m), and doubling time (t), were computed (KREBS 1972; SOUTHWOOD 1978).

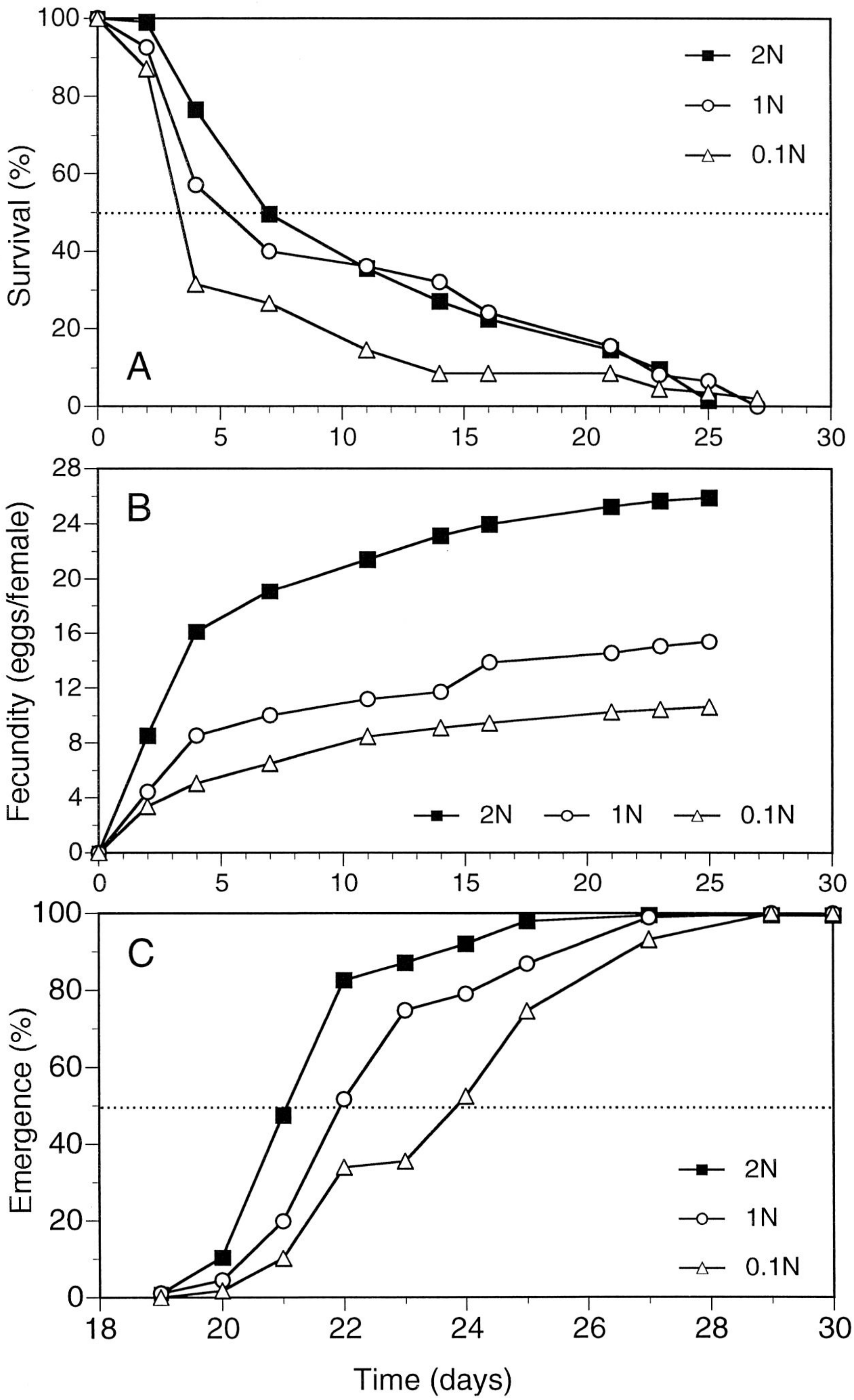

Fig. 1. Dynamics of life history parameters of the whitefly *Trialeurodes vaporariorum* on differently N-fertilized tomato plants. A) female longevity, B) cumulative egg production, and C) developmental time from egg to adult.

RESULTS AND DISCUSSION

A positive relationship was found between the N-levels in the nutrient solution and the average N-levels of the plant leaves (Table 1B). The highest N-content of the leaves was associated with the highest N-treatment (2N). The plants in the two lower N-treatments (1N and 0.1N) showed a general trend of decreasing N-levels, though the differences between these treatments were not significant.

Fig. 1A depicts the longevity of the whitefly females. The maximum lifetime was approximately 3–4 weeks. Longevity was only slightly affected by the N-levels of the plants' nutrient solution. On plants with higher N-supply (2N, 1N) whitefly longevity was similar and clearly exceeded that on N-deficient (0.1N) plants. In the latter treatment 50% mortality was reached 4 days earlier than on the 2N-plants.

The age specific oviposition rate, i.e. the number of eggs per female per day, varied with the N-treatment (Fig. 1B). The average reproduction on 2N-treated plants was 26.0 eggs/female. On 1N-treated plants 15.6 eggs/female were oviposited. On 0.1N-treated plants only 10.6 eggs/female were laid. This means that whitefly fecundity was about 2.5 times higher on high-N plants than on low-N plants and was strongly dependent on the N-treatment.

The duration to develop from egg to adult, determined by the emergence of 50% of the adult progenies, decreased with increasing N-levels from about 24 days in the 0.1N-treatment to about 21 days in the 2N-treatment (Fig. 1C).

Egg to adult survival rate tended to be higher on 2N-treated plants than in the two other treatments (Fig. 2), but the results were not significant. Likewise SR tended to be lower in the 1N-treated plants (39.3 %; Fig. 2), whereas that on 2N- and 0.1N-treated plants was above 50%. The overall sex ratio in all treatments was 49.0%, fairly close to the 50% expected rate of sex ratio. Therefore, it is unclear

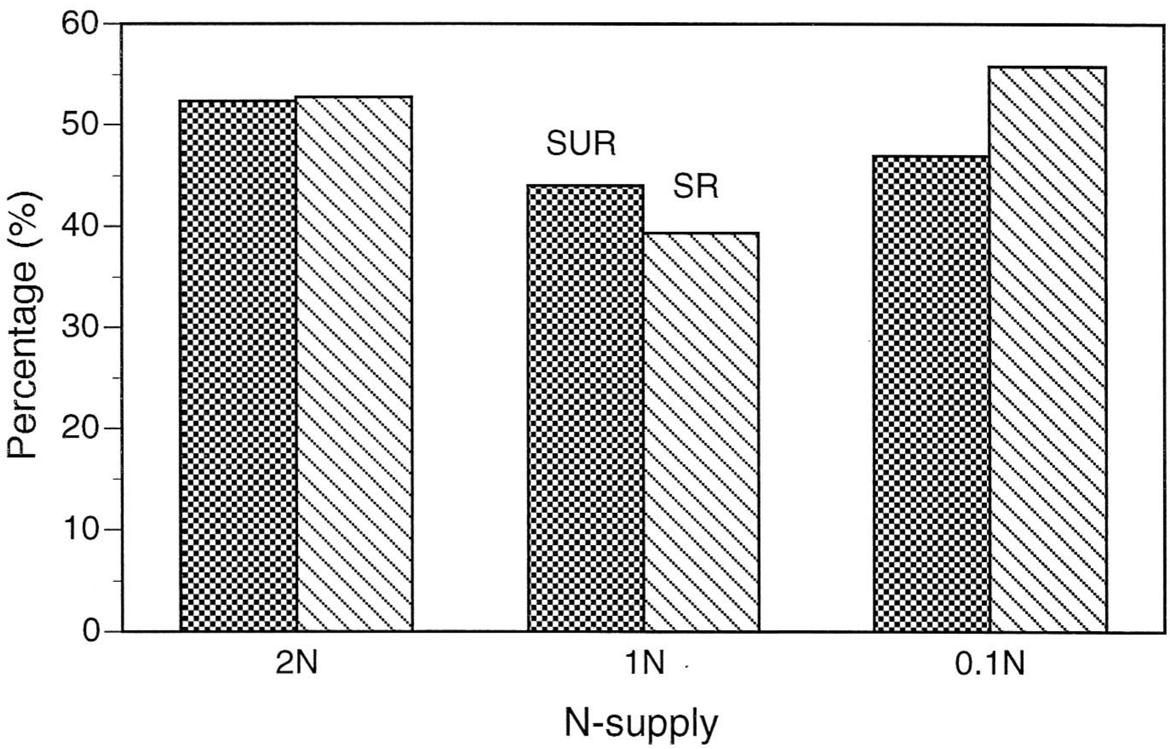

Fig. 2. Egg to adult survival (SUR) and sex ratio (SR) of the whitefly *Trialeurodes vaporariorum* on differently N-fertilized tomato plants.

Table 2. Life table parameters of whitefly (*Trialeurodes vaporariorum*) populations reared on tomato plants with different N-supply.

	Treatment		
	2N	1N	0.1N
Developmental time (days)	21.1	22.0	23.9
Net reproductive rate R_0	8.08	3.01	2.92
Generation time T	28.89	29.49	30.76
Intrinsic rate of natural increase r_m [1)]	0.072	0.036	0.036
Time for doubling population size t (days) [1)]	9.6	19.0	19.4
Intrinsic rate of natural increase r_m [2)]	0.071	0.044	0.032
Time for doubling population size t (days) [2)]	9.8	15.6	21.5

[1)] when calculated with the observed SR for each N-treatment
[2)] when calculated with a theoretical SR=0.5

whether this pattern is meaningful or whether N-levels of differently fertilized plants do not affect the sex ratio of whiteflies.

Males were smaller than females, their average dry weight being about 10 mg whereas the dry weight of females was almost twice as much (approx. 18 mg). Female dry weight tended to be lower when reared on the 2N-treated plants (17.0±5.25 mg) compared to the 0.1N-treatment (18.5±4.07 mg).

Female respiration rate was slightly but not significantly ($p<0.05$) higher (0.17±0.04 mg O_2/h/mg female dry weight) when reared on 2N-treated plants than when reared on 0.1N-treated plants (0.15±0.06 mg O_2/h/mg). The tendency of an increased respiration rate, i.e. higher basal metabolism rate, at elevated N-supply points to a change in whitefly physiology and hence in the biological performance.

Increasing N-levels provided to tomato plants caused an increase of the overall growth rate of the whitefly populations (Table 2). This is mainly due to an increase of the net reproductive rate (R_0) and a shorter generation time (T). This resulted in a higher intrinsic rate of increase (r_m) at high N-levels. As a consequence, the doubling time (t) of a population was reduced by more than 50 %.

In this experiments nitrogen positively affected development, survival and reproduction. This has been confirmed by several earlier studies mainly on sucking arthropods such as whiteflies (e.g. BLUA & TOSCANO 1994; JAUSET et al. 1998) and spider mites (e.g. WERMELINGER et al. 1991). Therefore, the advantages of vigorous plant growth due to plentiful nitrogen fertilization run the risk of being overridden by increased insect feeding.

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