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Effects of Constant Temperatures on Population Growth of Three Aphid Species, *Toxoptera citricidus* (KIRKALDY), *Aphis citricola* VAN DER GOOT and *Aphis gossypii* GLOVER (Homoptera : Aphididae) on Citrus[1]

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Three species of aphid attacking on citrus were studied about effects of constant temperatures on population growth in growth cabinets. Pre-reproductive period, longevity, fecundity, age-specific survival rate and age-specific fecundity were calculated. From these data, the intrinsic rate of natural increase, net reproductive rate and mean generation time were estimated. Temperature at which the intrinsic rate of natural increase became maximum was near 27°C for *Toxoptera citricidus* and *Aphis citricola*, but for *Aphis gossypii*, this was near 22°C. From the curve of the intrinsic rate of natural increase, these species were compared with other aphid species and their adaptability to temperature was discussed.

INTRODUCTION

Several species of aphid attack citrus in Japan (FURUHASHI and NISHINO (1968)). In some species the attack is only temporary or lasts from spring to early summer and the feeding damage is not serious. *Toxoptera citricidus*, *Aphis citricola* and *Aphis gossypii* however attack citrus during the entire summer season and their populations become high. Because of the feeding damage, new shoots become curled and do not fully expand. These species transmit the citrus tristeza virus (SASAKI, 1974; NORMAN and GRANT, 1956; RACCAH et al., 1979). Also, in these aphid species overwintering eggs are deposited on citrus (KOMAZAKI et al., 1979), resulting in early spring increase whereas the less harmful species overwinter on the other host plants. To better understand the population dynamics of *T. citricidus*, *A. citricola* and *A. gossypii*, studies were conducted to determine the effects of temperature on these species.

MATERIALS AND METHODS

Alienicolae were collected from a citrus orchard at Okitsu Branch, Fruit Tree Research Station and reared on potted *Citrus unshiu* in net cages. Before experimental use, the aphids were reared more than three generations on the same plant species that was used in experiments. Plants used in the experiments were *C. unshiu* and *C. aurantium* (only for *T. citricidus*) in pots. The experimental aphids were reared on

[1] Contributions from the Fruit Tree Research Station, B-76.

the young (1 to 2 cm long) shoots of potted citrus trees in growth cabinets. The basal part of new shoots was covered with a sticky material (Tanglfoot)® to prevent the aphids from escaping. Temperature was controlled and R.H. was maintained at 60 to 80%. Photoperiod was under natural condition in April to July except for the test with *A. gossypii* conducted at 27.5°C. In this case, the photoperiod was prolonged to 16 hr with fluorescent lamps. At each temperature, 50 to 60 aphids were used. Adults of apterous exules were transferred from rearing colonies to new shoots and allowed to larviposit for 24 hr. The next day, all but one newly-born first instar larva were removed from each shoot. Observations were made daily, and the time of maturity, start of larviposition and the number of deposited larvae per day were recorded. The larvae were removed after counting. From these data, age-specific fecundity (m_x) and age-specific survival rate (l_x) were calculated. The intrinsic rate of natural increase (r) was estimated by equation (1) (BIRCH, 1948).

$$\Sigma\, l_x \cdot m_x \cdot \exp(-r \cdot x) = 1 \qquad (1)$$

When r was known, R_0 (net reproductive rate per generation) and T (mean generation time) were computed.[2]

RESULTS

The results for *T. citricidus* on *C. unshiu* are summarized in Table 1 and Fig. 1. As temperature was increased the pre-reproductive period, longevity and mean gen-

Table 1. Effects of constant temperatures on population parameters of *Toxoptera citricidus* reared on *Citrus unshiu*

Temperature (°C)	Survival rate at beginning of larviposition	Pre-reproductive period (days)	Longevity (days)	Fecundity (/female)	Net reproductive rate	Mean generation time (days)
14.9	0.982	15.96	48.00	53.90	53.16	21.65
20.1	0.977	8.10	28.43	58.46	56.18	11.20
24.9	0.931	6.33	22.29	68.24	62.65	8.90
27.6	0.837	6.19	14.57	55.31	45.28	8.53
29.7	0.0	—[a]	8.18	0.0	0.0	—[a]

[a] Data was not attained because all aphids died before larviposition.

Table 2. Effects of constant temperatures on population parameters of *Toxoptera citricidus* reard on *Citrus aurantium*

Temperature (°C)	Survival rate at beginning of larviposition	Pre-reproductive period (days)	Longevity (days)	Fecundity (/female)	Net reproductive rate	Mean generation time (days)
11.3	0.851	34.65	71.79	29.51	25.12	43.34
15.2	0.857	19.22	49.87	51.94	44.43	27.08
19.9	0.776	12.87	25.76	47.82	38.84	18.67
21.5	0.907	8.77	23.56	55.64	51.12	12.28
25.1	0.853	7.66	17.48	40.40	36.79	11.31
27.1	0.896	6.49	13.87	40.53	36.66	9.16
29.9	0.600	7.37	8.61	3.01	3.87	8.35

[2] These parameters were caluculated by the Computing Centre for Research in Agriculture, Forestry and Fishery.

eration time were shortened. Fecundity, net reproductive rate and r became maximum at 24.9°C. On *C. aurantium* (Table 2 and Fig. 1), same as on *C. unshiu*, the pre-reproductive period and longevity were shortened as temperature increased, but fecundity and net reproductive rate became maximum at 21.5°C, and r was greatest at 27.1°C. Comparing the results on these plant species, pre-reproductive periods were shorter, longevities were longer and fecundities were greater on *C. unshiu* than on *C. aurantium*.

In *A. citricola* (Table 3 and Fig. 2), pre-reproductive period was shortened as temperature was increased except above 29.5°C. Longevity was shortened as temperature increased except at 30.1°C. Fecundity and net reproductive rate became maximum at 19.5°C. Mean generation time was shortened as temperature was increased except at 29.5°C and r was maximum at 27.2°C.

In *A. gossypii* (Table 4 and Fig. 2), pre-reproductive period, longevity and mean generation time were shortened as temperature was increased. Fecundity, net reproductive rate and r became maximum at 19.8°C.

A. citricola and *A. gossypii* were also reared on *C. aurantium*, but the results were more variable and did not provide clear data. Summarizing the three species on *C. unshiu*, survival rates were high at the lower temperatures and decreased at temperature near 30°C in *T. citricidus* and near 27°C in two *Aphis* species. Pre-reproductive periods (the periods from birth to beginning of larviposition) became minimum near 27°C in *T. citricidus* and *A. citricola*, and near 30°C in *A. gossypii*. This period was shorter in *A. gossypii* than in the other species at temperatures under 20°C. Longevities became maximum near 20°C in the two species of *Aphis*, and near 25°C in *T. citricidus*. Net reproductive rates were larger in *T. citricidus* than the other species except near 20°C in *A. citricola*. Above 25°C, mean generation time was comparatively

Table 3. Effects of constant temperatures on population parameters of *Aphis citricola* reared on *Citrus unshiu*

Temperature (°C)	Survival rate at beginning of larviposition	Pre-reproductive period (days)	Longevity (days)	Fecundity (/female)	Net reproductive rate	Mean generation time (days)
14.7	0.951	14.95	61.71	54.24	50.76	22.08
19.5	0.944	9.59	33.06	64.43	61.14	14.84
25.1	0.818	5.56	15.16	36.58	30.70	8.21
27.2	0.930	5.50	12.85	26.06	24.35	7.39
29.5	0.649	6.29	10.84	6.48	5.66	7.73
30.1	0.370	6.82	11.16	1.25	0.98	7.30

Table 4. Effects of constant temperatures on population parameters of *Aphis gossypii* reared on *Citrus unshiu*

Temperature (°C)	Survival rate at beginning of larviposition	Pre-reproductive period (days)	Longevity (days)	Fecundity (/female)	Net reproductive rate	Mean generation time (days)
15.2	0.900	14.17	50.47	52.94	47.86	22.51
19.8	0.913	7.57	33.23	63.57	58.68	12.05
24.5	0.898	6.93	18.45	25.78	23.41	10.49
27.5	0.571	6.88	9.60	13.44	8.56	9.79
29.7	0.600	6.17	8.94	4.60	3.31	7.40

shorter in *A. citricola* than in the other species.

Threshold temperature and thermal constant were calculated for pre-reproductive stages of the three species (Table 5). Because of the curvilinear relationship between developmental rate and temperature (SIDDIQUI et al., 1973; MESSENGER, 1964) these values were estimated to the extent that the relation was linear. On *C.*

Table 5. Threshold temperatures and temperature summations of pre-reproductive period of three species of aphid

Aphid	Plant	Threshold temperature (°C)	Thermal constant (day. °C)
Toxoptera citricidus	*Citrus unshiu*	8.0	104.6
	C. aurantium	8.4	125.0
Aphis citricola	*C. unshiu*	7.9	101.0
Aphis gossypii	*C. unshiu*	−0.4	181.8

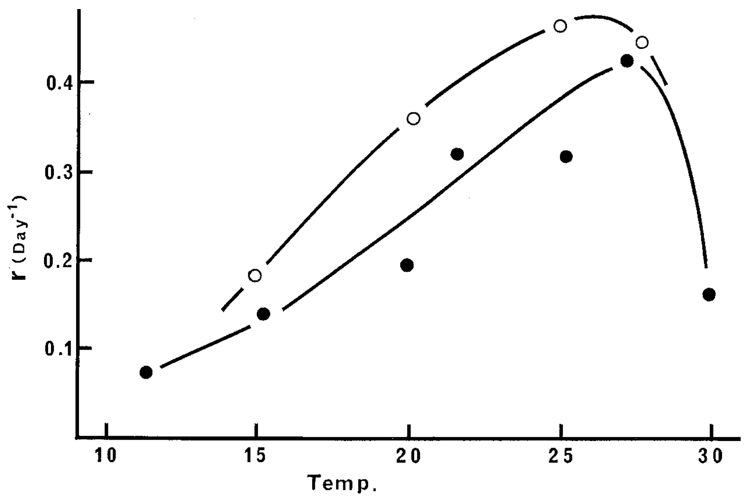

Fig. 1. Relation r and temperature in *T. citricidus* on different host plants. ○ : on *C. unshiu*, ● : on *C. aurantium*.

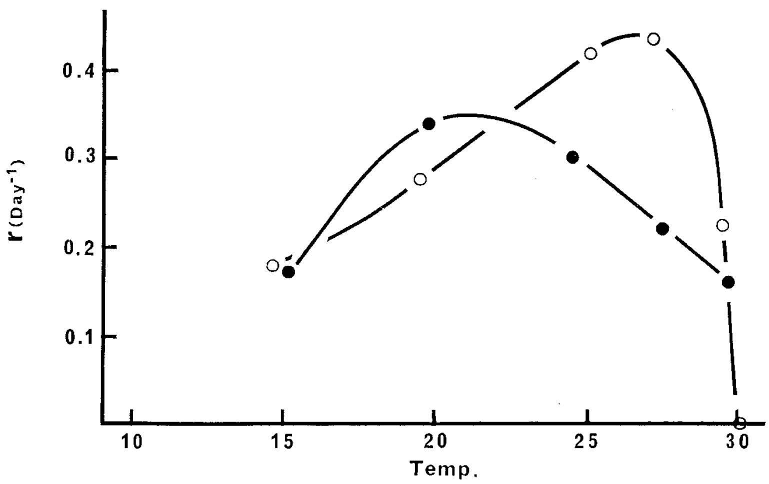

Fig. 2. Relation r and temperature in *A. citricola* and *A. gossypil* on *C. unshiu* ○ : *A. citricola* ● : *A. gossypii.*

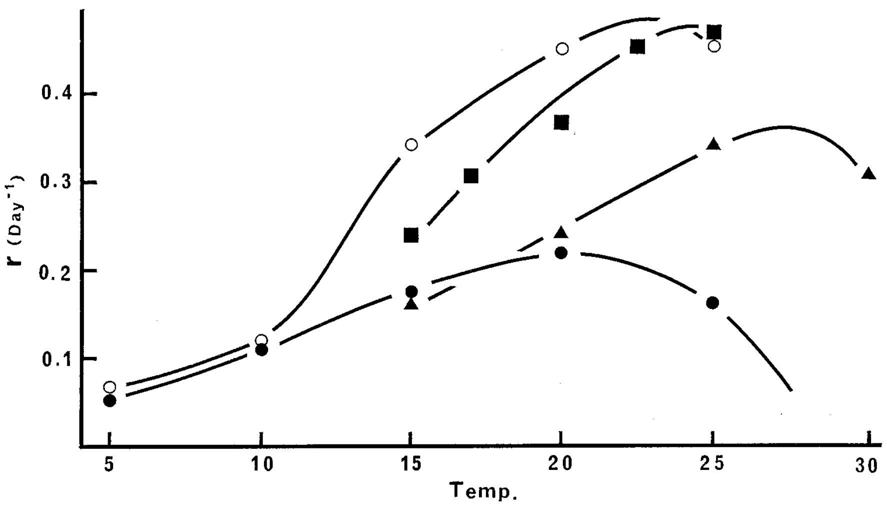

Fig. 3. Relation r and temperature illustrated after BARLOW (1962), GRAHAM (1959) and SIDDIQUI (1973). ● : *M. euphorbiae*, ○ : *M. persicae*, ▲ : *A. maculata*, ■ : *A, pisum.*

unshiu, the threshold temperature was lowest in *A. gossypii*, and almost the same in *T. citricidus* and *A. citricola*. The thermal constant was maximum in *A. gossypii* and almost the same in *T. citricidus* and *A. citricola*. *T. citricidus* had a lower threshold temperature and smaller thermal constant on *C. unshiu* than *C. aurantium*.

The relations between r and temperature are shown in Fig.1 and Fig.2. In *T. citricidus*, r was larger on *C. unshiu* than on *C. aurantium* between 15°C and 27°C. On *C. unshiu*, *T. citricidus* had a higher r than the other species at all temperatures. In *T. citricidus* and *A. citricola*, the curve peaked at 26°C to 27°C but in *A. gossypii* it peaked at 21°C to 22°C. In *T. citricidus* and *A. citricola*, the shape of the curves differed from that in *A. gossypii*, and r decreased drastically when temperature exceeded the point at which r became maximum, whereas in *A. gossypii* the r decreased more gradually.

DISCUSSION

It has been demonstrated many times that populations of crop aphids grow exponentially under favorable conditions in the field (EMDEN, 1963; WAY, 1966; DIXON and LAIRD JR., 1962; OTAKE, 1966). And it is thought that temperature is an important factor affecting population increase (MESSENGER, 1964; SIDDIQUI et al., 1973). If the stable age structure is realized in the field population, the r can be directly used in analyzing the population dynamics (BIRCH, 1948). HUGHES (1963) stated that in the cabbage aphid *Brevicoryne brassicae* (L.) the stable-instar distributions occurred frequently during the development of aphid populations. If this stable-instar distributions are generally realized in the field populations of aphids, the r could be a meaningful parameter that illustrated the relationship between temperature and population increase. From this point of view, these species were compared with other aphid species which have been studied under constant temperature conditions. Fig. 3 was illustrated after BARLOW, (1962), GRAHAM (1959) and SIDDIQUI et al. (1973). The curves for *T. citricidus* (Fig. 1) and *A. citricola* (Fig. 2) resemble that for *Therioaphis maculata* (BUCKTON) and *Acyrthosiphon pisum* (HARRIS) in the shape and the peak point. *A. gossypii* (Fig.2) resembles *Myzus persicae* (SULZER) in the peak point and *Macrosiphum* *euphorbiae* (THOMAS) in the shape of curve. When these seven species were ordered according to the temperature where r becomes maximum, *T. maculata*, *T. citricidus* and *A. citricola* could increase most rapidly near 27°C, *A. pisum* near 25°C, and *M. persicae* and *A. gossypii* near 22 to 23°C, and *M. euphorbiae* near 20°C. This could reflect their adaptability to temperature. It seems that *T. citricidus* and *A. citricola* belong to the group which is adapted to higher temperatures, and *A. gossypii* belongs to a lower temperature-adapted group.

Also the influence of the host plants (TAMAKI & OLSON, 1979) might be considered. In the species studied in this experiment, *A. gossypii* and *A. citricola* have a wide and *T. citricidus* has a relatively narrow host range (EASTOP, 1966; INAISUMI, 1981; SORIN, 1975). When the relations between temperature and r on different host plants are known, the adaptability of aphid to host plants will be estimated from the figure of curves. For example, in *T. citricidus* the curves of r on temperature always exceeded on *C. unshiu* from on *C. aurantium*, and the peak point temperature were almost the same. Because the two species of host plants are in the same genus, the difference was not so great. But it could be said that for *T. citricidus*, *C. unshiu* would be the more suitable host than *C. aurantium*.

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