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ORIGINAL ARTICLE

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Effect of temperature on development, mortality, fecundity, and reproduction of *Aphis rumicis* L. (Homoptera: Aphididae) on broadleaf dock (*Rumex obtusifolius*) and Swiss chard (*Beta vulgaris vulgaris* var. *cida*)

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Abstract Temperature effects on developmental period, survival rate, and reproductive capacity of *Aphis rumicis* L. were studied on Broadleaf dock and Swiss chard at four constant temperatures (17.5°C, 20°C, 22.5°C, and 25°C). The developmental time of immature stages ranged from 10.9 days at 17.5°C to 6.5 days at 25°C on Broadleaf dock, and 11.8 days at 17.5°C to 6.5 days at 25°C on Swiss chard. The total percentage of survivorship of immature stages varied from 54.2% and 67.6% 17.5°C–25°C on Broadleaf dock, and 49.7% and 62.4% at 17.5°C–25°C on Swiss chard. The largest r_m value occurred with 0.2845 at 25°C on Broadleaf dock and with 0.2785 at 25°C on Swiss chard. The results obtained on this study indicated that Swiss chard was a less favorable host of the *A. rumicis* than Broadleaf dock. The optimal temperature for *A. rumicis* growth, developmental time, and reproduction was 22.5°C–25°C.

Keywords *Aphis rumicis* · Developmental time · Reproduction · Host plants · Life table · Turkey

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Introduction

Swiss chard, *Beta vulgaris* subsp *vulgaris* var. *cida*, is the oldest member of the beet family and is grown for its tasty leaves and stalks; the roots are inedible. The plant is a nutritious green whose wide leaf stalks or petioles are often eaten like asparagus. Swiss chard is productive in a wide range of soil in Turkey.

Aphids are an important pest that can severely damage a Swiss chard crop. Aphid feeding can cause distorting and curling of Swiss chard leaves and will deplete the plant's phloem sap. Extreme aphid feeding can deplete enough phloem sap to reduce the plant's vigor or even kill the plant. Another concern is the viruses that the rumex aphids can transmit such as the Celery mosaic virus. The presence of aphids in Swiss chard or the aphid damage to the leaves will make the plant unmarketable.

Various aphids suck juices from the upper stems and leaves of Swiss chard. The rumex aphid, *Aphis rumicis*, is one of the most common species of aphids found on Swiss chard, and is generally a serious pest of Swiss chard in Turkey particularly and Mediterranean region, generally. They are found feeding on the lower surface of mature leaves and they will quickly colonize younger leaves as the population increases.

Broadleaf dock plant, *Rumex obtusifolius* L., in or near Swiss chard fields can serve as alternative hosts and may support the rumex aphid populations. According to biological control, increasing plant diversity can improve the effectiveness of parasitoids and predators in agroecosystems (Russell 1989). Therefore, the conservation of wild plants in agricultural fields can help to maintain small population of host insects over extended periods, ensuring the survival of viable natural enemy populations (Powell 1986). Nevertheless, due to the lack of detailed data describing the performance of aphids on different weeds, manipulation of weedy host plants in cultivated areas may result in crop damage caused by aphid outbreaks (Perng 2002). Thus, the objective of this study was to determine the variation on biological parameters of the rumex aphid on Swiss chard and Broadleaf dock in the laboratory, and provide information to aphid control and weed management programs.

Materials and methods

Aphid and plant source

The rumex aphids were reared on Swiss chard, and Broadleaf dock laboratory clones were established from apterous specimens. The rumex aphids had been collected from each of the two species plants in Adana, Turkey. The aphid clones were maintained separately on the leaves of their respective host plants in a climatic room held at 25 ± 1°C, a relative humidity 65 ± 5%, and a light regime (16 h light; 8 h dark). The offspring had been reared under the conditions before the aphid individuals were used in the experiments.

Swiss chard and Broadleaf dock seedling used in the experiment were grown in the laboratory in pots (12 cm diameter by 10 cm height). Swiss chard and Broadleaf dock were grown in a cage at 25 ± 1°C, a relative humidity 65 ± 5%, and light regime (16 h light; 8 h dark) in the laboratory. When the plants emerged, they were thinned to one plant per Styrofoam cups (8 cm diameter). The plants were grown in a growth chamber in 16:8 (L:D) photoperiod; at 25 ± 1°C, a relative humidity 65 ± 5% in the laboratory.

Development and survival of immature nymphs

Randomly selected apterous females from the stock culture were transferred separately onto an excised Swiss chard and Broadleaf dock leaf disc, placed upside down on wet filter paper in each Petri dishes. The nymph born within 24 h from the Petri dish was transferred individually to each of the fresh-cut leaf discs in a Petri dish (6 cm diameter × 1.5 m deep) with a small camel's-hair brush, and placed in a climatic cupboard under constant temperatures of 17.5°C, 20°C, 22.5°C, and 25°C, with 65 ± 5% R.H., in 16:8 (L:D) photoperiod. All replications in which the nymphs died within 24 h after transfer were omitted. The filter papers in the Petri dishes were wetted daily, and the aphids were transferred to new Swiss chard and Broadleaf dock leaf discs every 2–3 days. The nymph and adult on each Petri dish were checked daily under a stereoscopic microscope, and their survival recorded at the constant temperatures. The presence of the discarded exuviae were used to determine when molting had occurred.

Adult longevity and reproduction

When the immature nymphs become adults, they were observed daily for reproduction and survival, and all new-born nymphs were removed from each Petri dishes after counting and these observations continued until the mature aphid died at all constant temperature regimes. Developmental times for each nymphal instar, duration of adult pre-reproductive, reproductive, and post-reproductive periods, lifetime fecundity, and average daily reproduction were calculated for each aphid. Fifty aphids were tested for each temperature degree condition. All test Swiss chard and Broadleaf dock leaves were provided every 1 or 2 days throughout the study period.

Data analyses and statistics

Effect of different temperatures on biology of the rumex aphid were assessed by constructing a life table, using age-specific survival rates (l_x) and fecundity (m_x) for each age interval (x) per day. The intrinsic rate of increase r_m was calculated by iteratively solving the equation $\Sigma\ e^{-rx}\ l_x\ m_x = 1$, where the age-specific survival rate (l_x) is the proportion of individuals in the original cohort alive at age x, and the age-specific fecundity (m_x) is the mean number of female progeny produced per female alive in the age-interval x. The net reproductive rate, $R_0 = \Sigma\ l_x\ m_x$, were also calculated (Birch 1948). In addition, life table parameters of *A. rumicis* were calculated from the data collected by a computer program TWOSEX (Chi 1997).

Data on nymphal development times, adult life span, fecundity, and daily reproduction at four constant temperatures were analyzed SPSS and treatment differences were determined by Duncan's Multiple Range Tests. Differences at probability level ($P < 0.05$) were considered significant.

Results

Development and survival of immature nymphs

The developmental time for the immature stages at four constant temperatures are presented on Broadleaf dock and Swiss chard in Table 1. The developmental time of *A. rumicis* decreased significantly, as constant temperature increased on Broadleaf dock and on Swiss chard (Table 1; $P < 0.05$). The rumex aphid developed higher on Broadleaf dock (5.71 days) than on Swiss chard (6.48 days).

Survivorship rate for immature stages differed significantly with four constant temperatures on the two hosts (Table 2; $P < 0.05$). The highest mortality occurred on the two hosts at 17.5°C and 25°C. The optimal temperature range for survivorship of the immature nymph was 20°C–22.5°C. Mortality rates at all constant temperatures were higher on Swiss chard than on Broadleaf dock (Table 2).

Table 1 Developmental periods (days ± SE) of immature stages of *Aphis rumicis* on Broadleaf dock and Swiss chard at four constant temperatures

	Broadleaf dock				Swiss chard			
	117.5°C (n = 27)	20°C (n = 34)	22.5°C (n = 31)	25°C (n = 28)	17.5°C (n = 25)	20°C (n = 30)	22.5°C (n = 31)	25°C (n = 27)
First instar	2.37 ± 0.09 d	1.94 ± 0.04 c	1.70 ± 0.08 b	1.39 ± 0.09 a	2.96 ± 0.12 c	2.33 ± 0.09 b	2.16 ± 0.06 b	1.51 ± 0.09 a
Second instar	2.33 ± 0.09 c	1.67 ± 0.08 b	1.80 ± 0.07 b	1.07 ± 0.04 a	2.52 ± 0.10 b	1.70 ± 0.09 a	1.70 ± 0.08 a	1.48 ± 0.09 a
Third instar	2.55 ± 0.09 c	1.67 ± 0.08 b	1.83 ± 0.06 b	1.03 ± 0.03 a	2.52 ± 0.10 c	1.93 ± 0.08 b	1.70 ± 0.08 b	1.37 ± 0.09 a
Fourth instar	3.66 ± 11 c	2.67 ± 0.10 b	2.58 ± 0.09 b	2.17 ± 0.07 a	3.80 ± 0.10 c	2.73 ± 0.08 b	2.61 ± 0.08 b	2.11 ± 0.06 a
Total of immature	10.88 ± 0.22 c	7.94 ± 0.19 b	7.93 ± 0.17 b	5.71 ± 0.16 a	11.80 ± 0.32 c	8.70 ± 0.21 b	8.19 ± 0.15 b	6.48 ± 0.22 a

Means within a row sharing the same letter are not significantly different (α = 0.05, Duncan multiple range test)

Adult longevity and reproduction

Temperature affected adult longevity and fecundity significantly on Broadleaf dock and Swiss chard (Table 3). The mean longevity of adult females declined exponentially from 22.72 days to 13.86 days on Broadleaf dock, and from 24.72 days to 17.48 days on Swiss chard as temperature increased from 17.5°C through 27.5°C, respectively (Table 3). At all constant temperatures, the mean longevity of the female was higher on Swiss chard than on Broadleaf dock.

Fecundity was affected significantly on the two hosts at 17.5°C though 27.5°C (Table 3). The average nymph production of female (offspring per female) reached a maximum of 74.22 nymphs per female (17.5°C) and lowest of 50.82 nymphs per female (25°C) on Broadleaf dock, whereas a maximum of 78.36 nymphs per female (17.5°C) and lowest of 47.40 nymphs per female (25°C) on Swiss chard (Table 3).

The intrinsic rate of increase (r_m), net reproductive rate (R_0), and generation time (T_0) were calculated for the aphid on Broadleaf dock and Swiss chard at different temperatures (Table 4). The largest r_m occurred with 0.2845 on Broadleaf dock at 25°C. At all (except 20°C) constant temperatures r_m was higher for the aphid reared on Broadleaf dock than on Swiss chard (Table 4). Net reproductive rate (female offspring per adult female), R_0 at all constant temperatures was longer on Broadleaf dock than on Swiss chard (Table 4). Increasing temperatures resulted in shorter generation times (T_0) of the rumex aphid on Broadleaf dock with 19.21 days at 17.5°C and 11.77 days at 25°C, while on Swiss chard 19.72 days at 17.5°C and 11.64 days at 25°C (Table 4).

Discussion

Temperature is a key biotic factor that regulates the insect population dynamics, rates of development, reproduction, mortality, survival, and seasonal occurrence of aphids (Campbell et al. 1974; Dixon 1977, 1987; Logan et al. 1976; Schowalter 2000). Although insects are not always subject to constant temperatures in nature, a controlled laboratory study can provide a valuable insight into the population dynamics of a particular species (Summers et al. 1984). Our data clearly showed the effects of temperature on the development time, mortality, survival, longevity, and fecundity of *A. rumicis*.

The development time at all constant temperatures examined here was relatively longer for the fourth instar of *A. rumicis*, compared to those for the other three instars on the two hosts (Table 1). This observation was also reported by Tsai and Wang (1999) for the brown citrus aphid, *Toxoptera citricida* (Kirkaldy); the spirea aphid, *Aphis spiraecola* Patch (Wang and Tsai 2000), *Macrosiphum rosae* (L) (Ölmez et al. 2003), and *Aphis punicae* (Passerini) (Bayhan et al., 2005). Similar phenomena have been reported for other species of Homoptera. For example, high mortality also was reported for the fifth instar of the potato leafhopper, *Empoasca fabae* (Harris) Simonet and Pienkowski (1980), the blackfaced leafhopper, *Graminella nigrifrons* (Forbes) (Sedlacek et al. 1986), the bean aphid, *Aphis fabae* (Scop.) (Tsitsipis and Mittler 1976).

The total development time of immature stages on Broadleaf dock for the rumex aphid is much shorter

Table 2 Survival (percentage) of immature stages of *Aphis rumicis* on Broadleaf dock and Swiss chard at four constant temperatures

	Broadleaf dock				Swiss chard			
	17.5°C	20°C	22.5°C	25°C	17.5°C	20°C	22.5°C	25°C
First instar	87.6 b	87.7 b	83.6 a	92.2 c	71.7 a	87.7 c	86.2 b	92.2 d
Second instar	81.6 a	85.6 b	91.6 c	92.3 c	85.7 c	86.2 d	76.3 b	73.4 a
Third instar	95.6 c	96.3 c	92.3 b	82.3 a	91.7 b	89.7 a	100.0 c	90.0 a
Fourth instar	88.4 a	97.7 d	94.3 c	90.2 b	100.0 a	96.4 b	100.0 a	100.0 a
Total immatures	54.2 a	67.6 d	62.7 c	55.7 b	49.7 a	59.2 c	62.4 d	54.3 b

Means within a row sharing the same letter are not significantly different (α = 0.05, Duncan multiple range test)

Table 3 Mean ± SE fecundity and longevity of female *Aphis rumicis* on Broadleaf dock and Swiss chard at four constant temperatures

	Broadleaf dock				Swiss chard			
	17.5°C	20°C	22.5°C	25°C	17.5°C	20°C	22.5°C	25°C
Longevity of female (days)	22.72 ± 1.33 b	14.56 ± 0.49 a	16.06 ± 0.69 a	13.86 ± 0.78 a	24.72 ± 1.00 c	18.46 ± 0.55 ab	19.45 ± 0.30 b	17.48 ± 0.50 a a
No. progeny/female	74.22 ± 0.25 b	63.76 ± 1.95 b	73.81 ± 2.88 b	50.82 ± 3.13 a	78.36 ± 3.10 c	65.73 ± 2.39 b	62.64 ± 2.02 b	47.40 ± 2.53 a a

Means within a row sharing the same letter are not significantly different (α = 0.05, Duncan multiple range test)

Table 4 Life table parameters of *Aphis rumicis*on Broadleaf dock at four constant temperatures

Temperature (°C)	Broadleaf dock			Swiss chard		
	Generation time (T_0)	Reproduction rate (R_0)	Intrinsic rate of increase (r_m)	Generation time (T_0)	Reproduction rate (R_0)	Intrinsic rate of increase (r_m)
17.5	19.21	40.08	0.1921	19.72	39.18	0.1860
20	14.25	43.36	0.2645	13.61	39.42	0.2700
22.5	13.92	45.68	0.2746	13.50	38.84	0.2711
25	11.77	28.46	0.2845	11.64	25.60	0.2785

than on Swiss chard at all constant temperatures (Table 1). Adult longevity and nymphal reproduction were correlated with temperature and the hosts (Table 3). Adult longevity of the rumex aphid was greater on Swiss chard than on Broadleaf dock at all constant temperatures. The results about longevity of adult of the rumex aphid on the two hosts were greater for *Rhopalosiphum padi* (L.) on the wheat variety "Flamura" at 9.72 days (Özder and Bayhan 1998), for *A. punicae* (Passerini) on Pomegranate at 12.04 days (Bayhan et al. 2005), and for *Rhopalosiphum rufiabdominalis* (Sasaki) on *Oryza rufipogon* at 13.1 (Tsai and Liu 1998) but smaller for *T. citricida* (Kirkaldy) on the *Citrus paradisi* at 19.4 days (Tsai and Wang 1999).

The reproduction of the rumex aphid (50.8 nymphs on Broadleaf dock, and 47.4 nymphs on Swiss chard) at 25°C was higher than number of nymphs at 44.8 reported for *T. citricida* (Tsai and Wang 1999). Tang and Yokomi (1996) also observed that the reproduction of *A. spiraecola* on *Viburnum odoratissimim* (Awabuki) (Caprifoliaceae) at 24°C was 39.7 nymphs. Wang and Tsai (2000) reported that reproduction for *A. spiraecola* at 25°C was 42.7 nymphs.

The intrinsic rate of increase (r_m) alone adequately summarizes the physiological qualities of an animal in relation to capacity to increase (Andrewartha and Birch 1954). The r_m values for different aphid species varied significantly with temperature fluctuation as the r_m value we obtained on Broadleaf dock and Swiss chard. The calculated r_m was obtained lowest on Swiss chard at all constant temperatures (except 20°C on Broadleaf dock) (Table 4). The high r_m value indicates that the rumex aphid has a greater reproductive potential on Broadleaf dock than on Swiss chard (Table 4).

On Swiss chard long developmental time of immature stages, low survival of immature nymphs, low reproductive rate, and low intrinsic rate of increase (r_m) have obtained in this study (Table 5). Therefore, it seems that Swiss chard was a less favorable host of the rumex aphid than Broadleaf dock.

Table 5 Important criteria of rumex aphid life at 25°C differing between the host plants studied

Host plant	Swiss chard	Broadleaf dock
Developmental period (days)	6.48	5.71
Survival of immatures (%)	54.3	55.7
No. of progeny per female	47.40	50.82
r_m	0.2785	0.2845

Data obtained on the host plants at all constant temperatures show that the optimal temperature for *A. rumicis* growth, developmental time, and reproduction was 22.5°C–25°C.

These results may explain why the rumex aphid populations were significantly higher during March and April in the mentioned region, Turkey. Such general findings are quite important when attempts are made to evaluate geographic distribution or development, reproduction rate, and longevity in the Swiss chard fields' situations. Also, results obtained in this study might provide useful information to aphid control and weed management programs.

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