Fecundity and Development Rate of the Bird Cherry-oat Aphid, *Rhopalosiphum padi* (L) (Hom.: Aphididae) on Six Wheat Cultivars

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Abstract

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Rhopalosiphum padi is a polyphagous species with a nearly worldwide distribution. Biological parameters of this aphid on six commonly grown wheat cultivars in the Fars province including Chamran, Darab2, Shiraz, Ghods, Marvdasht and Niknezhad were investigated at the two-leaf stage of wheat. The experiments were carried out at 24 ± 5°C, 65 ± 5% R.H. and a photoperiod of 14:10 h (L:D) in a greenhouse. The number of nymphs per female of *R. padi* was 62.05, 55.84, 49.89, 47.63, 42.76 and 40.65 (nymphs/female) on Niknezhad, Shiraz, Ghods, Marvdasht, Chamran, and Darab2, respectively. Also, the highest and the lowest r_m values of this aphid were obtained on Niknezhad (0.381 per day) and Darab2 (0.328 per day), respectively. In addition, other population growth indices were estimated. In general, a high level of antibiosis in Darab2 compared with the other tested cultivars may decrease the population density of *R. padi* on wheat and also cause a suppression of cereal viruses (e.g. BYDV) and reduce the pesticide application to wheat fields of Iran.

Keywords: *Rhopalosiphum padi*; wheat cultivars; biological parameters

The bird cherry-oat aphid, *Rhopalosiphum padi* (L) (Hom., Aphididae), has recently become one of the most important pests of cereals in some European countries including England, Scandinavian countries and some areas of Turkey (Leather *et al*. 1989; Blackman & Eastop 2000; Legrand & Barbosa 2000) but the abundance of *R. padi* in cereal crops varies greatly between years, at least in Northern Europe. This aphid, however, causes severe damage in cereal-producing countries (Mallott & Davy 1978; Papp & Mesterházy 1993). Wheat is the most important cereal in Iran and based on the Iranian Ministry of Agriculture reports, it is annually planted on more than 7 200 000 ha in this country. This crop is normally planted near in November and subsequently harvested in June every year in many provinces of Iran. The bird cherry-oat aphid is one of the most important pests of wheat in Iran and it is almost spread throughout the country. *Rhopalosiphum padi* damages cereals by sucking the sap and depriving the plant of nutrients at their two leaf stage, which causes 40–60% yield loss. This aphid also acts as the main vector of *Barley yellow dwarf virus* and it is able to cause a yield loss of up to 85% in this way (reviewed in Papp &

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Mesterházy 1993). The bird cherry-oat aphid is an aphid that completes its life cycle on various hosts including the bird cherry (*Prunus padus* L.) as a primary host and cereal crops, particularly maize, barley, oats and wheat as the secondary hosts. In autumn, winter eggs are deposited on bird cherry. In spring, nearly two generations of fundatrigeniae are also generated on the plant. The parthenogenetic populations of this aphid are developed on the secondary hosts during late spring and summer (Blackman & Eastop 2000; Powell & Hardie 2001).

The host plant quality is a key determinant of the fecundity of herbivorous insects that affects the fecundity of herbivorous insects at both the individual and the population scale (Awmack & Leather 2002)**.** The low quality of plants can perform as a defence mechanism against herbivorous pests and cause a decline in their fecundity and an increase in developmental time (Legrand & Barbosa 2000). Various studies have been conducted to detect at least a relatively resistant cultivar for the development of control techniques of aphids and to decrease insecticide applications (Roberts & Foster 1983; Papp & Mesterházy 1993; Ozder 2002; Razmjou *et al.* 2006, 2009). For accurate decision-making in IPM, it is also necessary to determine the pest population growth parameters on different hosts and cultivars. Thus, the life table technique represents one measure normally used to evaluate the fitness and the level of plant resistance to aphids and other pests (Foster *et al.* 1988; Robinson *et al.* 1991; Hesler *et al.* 1999; Tsai & Wang 2001; Satar & Yokomi 2002; Frel *et al.* 2003; Razmjou *et al.* 2006; Silva *et al.* 2006).

The main objective of this research was to assess development and fecundity rates of the bird cherry-oat aphid as well as its population growth parameters on six commonly grown wheat cultivars in the Fars province of Iran.

MATERIALS AND METHODS

This study was accomplished during 2006 at the Zarghan Station, Fars Agriculture and Natural Resources Research Institute, Iran.

Plants. Six wheat cultivars commonly found in the Fars province and other regions of Iran were selected for this study: Chamran, Darab2, Shiraz, Ghods, Marvdasht, and Niknezhad, which were used to determine the aphid development and reproduction parameters. The seeds of wheat cultivars used in our experiments were obtained from the Agricultural and Natural Resources Research Institute of Fars province, Iran and were sown in 12-cm plastic pots filled with suitable field soil. The plant growing and the experiments carried out at 24 ± 5°C (19–29°C), 65 ± 5% RH and a photoperiod of (approximately) 14:10 h (L:D) with ambient light in a greenhouse. Overall, we used 120 potted plants in the experiment.

Insects. At first, the aphids used in the laboratory were collected from wheat fields in the Fars province, Iran (coordinates: 29°46’N latitude, 1600 m altitude a.s.l.). Colonies were established on seedlings of Zarin wheat cultivar in wood-framed cages for preventing from infestation by other insects in the greenhouse according to the procedure mentioned above. The aphid population was reared for one month before using any aphids in the experiment.

Experiments. All experiments were conducted in a greenhouse under the aforementioned conditions. To evaluate the developmental time and survivorship of immature stages and fecundity and longevity of adults, adult apterous aphids were randomly chosen from the rearing colonies and placed on the leaf surface into each clip cage (6 cm in diameter by 1.5 cm in height) to avoid escape or parasitism using a suitable paintbrush. They were permitted to produce nymphs for 24 h and then the adult aphids and all but one nymph were eliminated from the leaf clip cage. These remaining nymphs were monitored daily to assess the performance of the aphid on cultivars. After maturity and the beginning of reproduction, adult mortality and fecundity were recorded daily and the offspring were removed from each leaf cage until the death of each adult aphid. In this experiment, we estimated the fecundity of 20 adult aphids per each cultivar.

Life table. The survivorship of apterous aphids and each nymph were recorded at 24-h intervals. The percentages of survival of each aphid and offspring on all examined cultivars as well as the longevity of each aphid were calculated. The r_m for apterous aphids on different cultivars were estimated using the following equation (Birch 1948):

$$\Sigma e^{-rx} l_x m_x = 1$$

where:

r – intrinsic rate of natural increase

l_x – age-specific survival

m_x – age-specific number of female offspring

x – age in days

Also, the life expectancy (e_x), as the mean number of days of life remaining at age x, was calculated. In addition, the net reproductive rates ($R_0 = \sum_{\beta}^{\alpha} l_x m_x$), mean generation time ($T = \ln R_0/r$), doubling time (DT), and finite rate of increase ($\lambda = e^r$) were estimated (Birch 1948; Carey 1993).

Data analysis. Parameters of development and fecundity were analyzed by SAS software; means were compared by the least significant difference (LSD) test after the significant F-test at $\alpha = 0.05$ (SAS Institute 2000). Also, life table parameters including the intrinsic rate of natural increase (r_m), net reproductive rate (R_0), doubling time (DT), finite rate of increase (λ) and the mean generation time (T) were estimated by the jackknife method (Meyer *et al.*1986; Carey 1993; Maia *et al.* 2000) using the SAS System version 8.2 (SAS Institute 2000). Significance of differences between the mean values of life table parameters was determined using Student's t-test (Maia *et al.* 2000).

RESULTS

Developmental time and survivorship of nymphs

The developmental time of nymphal stages of *R. padi* indicated significant differences among the six examined wheat varieties ($F = 11.20$, df = 5, $P < 0.01$). The nymphs reared on Niknezhad had a shorter developmental time (4.4 days) than those on any other varieties whereas the offspring living on Darab2 demonstrated a longer value of development (5.5 days) (Table 1). The percentage of nymphal mortality was the highest for Darab2 and Chamran (15%), while this value was equally the lowest for the remaining four cultivars (5%) (Table 1, Figure 1). The life expectancy of 1-day-old nymphs on the first day was the highest on Niknezhad (26.9) and the lowest on Darab2 (16), and this value was intermediate for the other varieties (Figure 2).

Adult longevity and reproductive ability

The aphid longevity showed significant differences among the varieties ($F = 4.71$; df = 5; $P < 0.01$) as well as the mean total number of offspring produced by each aphid was significantly different among the tested cultivars ($F = 39.42$; df = 5; $P < 0.01$) but significant effects were not observed for the means of offspring produced per female per day ($F = 1.85$; df = 5; $P = 0.24$) (Figure 1). The average longevities on Niknezhad, Ghods, Chamran, Shiraz, Marvdasht, and Darab2 were 27.3, 23.4, 17.5, 24.2, 19.9 and 16.1, respectively (Table 1). So, the longest mean for the aphid adult longevity was found on Niknezhad and the shortest on Darab2 (Table 1). The mean total number of offspring per female was the highest on Niknezhad and the lowest on Darab2 (Table 1). As a result, from the aspect of development and fecundity, *R. padi* populations had the best performance on Niknezhad and the worst on Darab2 (Table 1).

Table 1. Nymphal mortality, developmental time, adult longevity, and fecundity of *R. padi* reared on six wheat cultivars

Cultivar	Developmental data (mean ± SD)[a, b]				
	nymphal mortality (%)	developmental time (day)	adult longevity (days)	total No. of offspring/ female	No. of offspring/ reproduction day
Niknezhad	5	4.37 ± 0.11^{d}	27.3 ± 2.08^{a}	62.05 ± 1.44^{a}	2.99 ± 0.13^{a}
Ghods	5	5.05 ± 0.09^{bc}	23.4 ± 2.14^{abc}	49.89 ± 1.31^{c}	2.74 ± 0.11^{a}
Chamran	15	5.35 ± 0.15^{ab}	17.5 ± 1.98^{bc}	42.76 ± 1.12^{d}	2.50 ± 0.11^{a}
Shiraz	5	4.79 ± 0.12^{c}	24.2 ± 2.03^{ab}	55.84 ± 1.05^{b}	2.91 ± 0.12^{a}
Marvdasht	5	5.21 ± 0.14^{ab}	19.85 ± 1.8^{abc}	47.63 ± 1.58^{c}	2.58 ± 0.12^{a}
Darab 2	15	5.53 ± 0.12^{a}	16.1 ± 1.83^{c}	40.65 ± 0.94^{d}	2.41 ± 0.11^{a}

[a] For each parameter, differences among wheat cultivars were examined by LSD tests. Means within columns followed by the same letters are not significantly different ($P < 0.05$)

[b] Sample size is 20 (apterous females tested) for each parameter

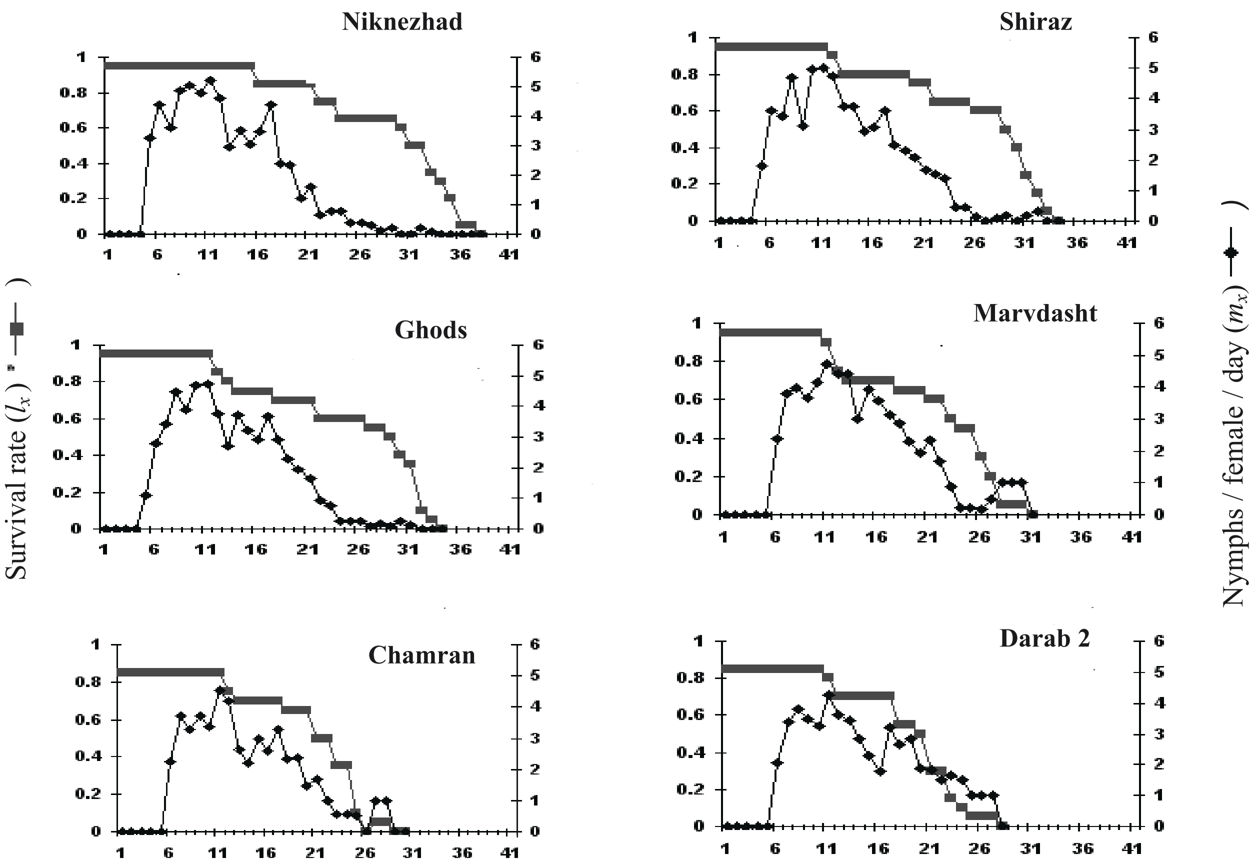

Figure 1. Survival rate (l_x) and fecundity (m_x) of *Rhopalosiphum padi* on six wheat cultivars at the greenhouse conditions

Life table statistics

The values of the net reproductive rate (R_0) of aphids indicated significant differences among all cultivars tested ($P < 0.05$). The aphids fed on Niknezhad had the highest R_0 values (58.95 aphids per aphid) and those on Darab2 and Chamran had the lowest values (34.55 and 36.35 aphids/aphid, respectively) (Table 2). The mean generation time (T) values of *R. padi* did not show any significant differences among the wheat cultivars ($P > 0.05$). In addition, doubling times of bird cherry-oat

Table 2. Life table parameters of *R. padi* reared on six wheat cultivars

Cultivar	Parameter (mean ± SD)				
	R_0	T (day)	DT (day)	λ	r_m
Niknezhad	58.95 ± 1.35[a]	10.69 ± 0.30[a]	1.82 ± 0.05[c]	1.464 ± 0.014[a]	0.381 ± 0.010[a]
Ghods	47.30 ± 1.24[c]	10.83 ± 0.38[a]	1.95 ± 0.06[b]	1.427 ± 0.016[abc]	0.356 ± 0.011[bc]
Chamran	36.35 ± 0.95[d]	10.87 ± 0.32[a]	2.10 ± 0.05[a]	1.391 ± 0.011[c]	0.330 ± 0.008[d]
Shiraz	52.75 ± 0.96[b]	10.91 ± 0.35[a]	1.91 ± 0.06[bc]	1.438 ± 0.015[ab]	0.363 ± 0.011[ab]
Marvdasht	45.25 ± 1.50[c]	11.06 ± 0.43[a]	2.01 ± 0.07[ab]	1.411 ± 0.016[bc]	0.344 ± 0.011[bcd]
Darab 2	34.55 ± 0.80[d]	10.78 ± 0.40[a]	2.11 ± 0.07[a]	1.388 ± 0.015[c]	0.328 ± 0.011[d]

Means followed by the same letter in a column are not significantly different using Student's t-test for pairwise group comparison at $P < 0.05$

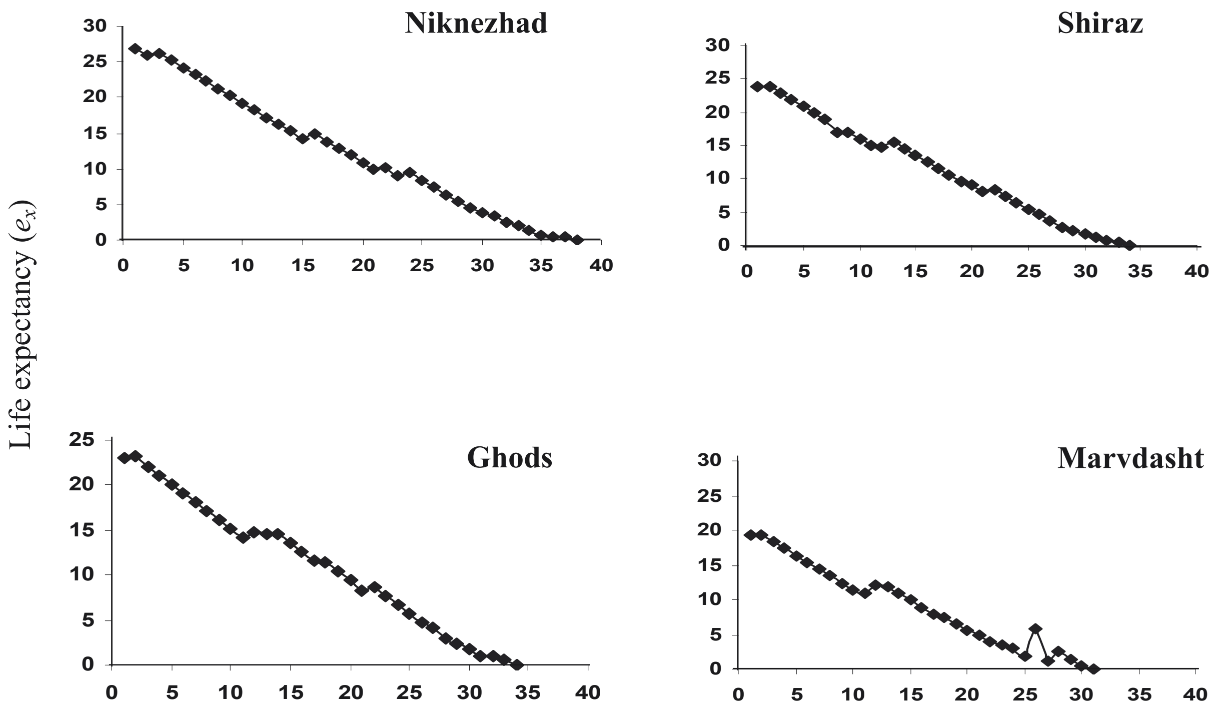

Figure 2. Life expectancy (e_x) of *Rhopalosiphum padi* on six wheat cultivars at the greenhouse conditions

aphid populations differed among the cultivars significantly ($P < 0.05$) and ranged from 1.8 on Niknezhad to 2.1 (day) on Darab2. Furthermore, the finite rate of increase (λ) values of *R. padi* indicated significant differences ($P < 0.05$), being higher on Niknezhad and Shiraz than on Darab2, Chamran and Marvdasht (Table 2).

The intrinsic rate of natural increase (r_m) for *R. padi* living on Niknezhad and Shiraz varieties was found significantly higher (0.381 and 0.368 nymphs per aphid/day, respectively) compared to the aphids reared on Darab2 and Chamran (0.328 and 0.330 nymphs/aphid/day, respectively) cultivars ($P < 0.05$). Consequently, the r_m values estimated on the six wheat varieties in the present study varied from 0.328 to 0.381 females per female per day (Table 2). Finally, the lowest r_m value – considered as a very good indicator of aphid performance on its host plants – was attained when the aphid populations were reared on Darab2 whereas the highest value was obtained when the aphids were feeding on Niknezhad variety.

DISCUSSION

The knowledge of population growth parameters of any pest would facilitate the designing of a comprehensive pest management program for its host plant. So, a further understanding of biology and life history traits of a pest on host cultivars is essential for the development of effective management strategies. These parameters provide the population growth rate of an insect pest in the current and next generations (Frel *et al.* 2003). Therefore, local studies on aphid biology on different cultivars are necessary to provide information in order to improve the aphid management and cultivar fitness under related environment conditions (Xia *et al.* 1999; Razmjou *et al.* 2006). Furthermore, for development of forecasting models, it is also necessary to investigate the bionomics of native populations in order to keep away from invalid data resulting from adaptation to different ecoclimatic conditions (Kersting *et al.* 1999; Morgan *et al.* 2001). Hence, we investigated the bionomics of the *R. padi* population collected on six wheat cultivars in the Fars province.

The acquired data obviously document that various wheat varieties examined here differ considerably in terms of their quality as hosts for the bird cherry-oat aphid, an important pest of wheat. In this study, the variety Niknezhad was the most proper host for *R. padi*. On Niknezhad, aphids attained an intrinsic rate of natural increase of 0.381 as compared to 0.328 on Darab2, the least favourable variety. These results and the values are similar to those estimated for the *R. padi* reared on other host plants and wheat cultivars (Simon *et al*. 1991; Asin & Pons 2001). The high performance of the aphid on Niknezhad mostly results from the longest adult longevity and the highest number of nymphs produced on this variety. Conversely, the poor performance of *R. padi* on Darab2 is correlated with the lowest fecundity and the longest developmental time. The exact rationale concerning the differences considered in the present study is unknown and requires additional assessment. However, previous studies on aphids found that the population growth variation might be related to plant nutrition, leaf age, leaf surface structure and secondary compounds (Emden & Bashford 1969; Weathersbee & Hardee 1994).

The use of crop cultivars that support only the low pest population growth or even of moderately resistant varieties is an important part of integrated pest management (IPM). Hence, our results may present valuable information for the management of the bird cherry-oat aphid in Iranian wheat cultures. They suggest that by growing wheat varieties that are more or less tolerant to the *R. padi* population growth, pest outbreaks may be suppressed or delayed, reducing the need for chemical control measures.

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