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Effects of sugar beet cultivar on development and reproductive capacity of *Aphis fabae*

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Abstract

Black been aphid, *Aphis fabae* Scopoli (Homoptera Aphididae) is recognized as a serious pest of sugar beet with worldwide distribution. Development and fecundity rates of this aphid were evaluated on six commonly growing cultivars under laboratory conditions in Ardabil County, Iran. The results obviously clarified significant differences in biology and life history characteristics of *A. fabae* reared on different sugar beet cultivars. The shortest developmental time for the immature stages was observed to be 11.32 days on 'Polyrave' and the longest 13.23 days on '7233'. There was the highest fecundity (14.33, nymphs/female) of *A. fabae* on 'Polyrave' and the lowest (7.32, nymphs/female) on '7233' cultivar. The r_m values of the aphid ranged from 0.1336 on '7233' to 0.2202 (nymphs/female/day) on 'Polyrave'. In general, Jackknife estimates of this aphid population parameters on cultivars examined showed the highest development and fecundity rates on 'Polyrave' and the lowest on '7233' cultivar.

Key words: *Aphis fabae*, developmental time, fecundity, sugar beet cultivar.

Introduction

Sugar beet, *Beta vulgaris* L. is planted mostly in Iran particularly in Khorasan Province, Moghan region, Ardabil County and etc. The crop is grown extensively in Ardabil County beet fields, providing of sugar beet seeds for cultivating in all sugar beet-growing areas of Iran. Various insect pests occur on the plants in the region where one of them is the black been aphid, *Aphis fabae* Scopoli (Homoptera Aphididae). The aphid is the most serious pests of sugar beet, distributed throughout in the world. This pest attacks a large number of host species from many plant families such as Leguminoseae and Chenopodiaceae as well as a quantity of weeds close to and within sugar beet fields as secondary hosts (Blackman and Eastop, 2000; Fernandez-Quintanilla *et al*., 2002; Hansen *et al*., 2008). The *A. fabae* promptly builds up a destructive population on host plants in particular on sugar beet and broad bean under good growing conditions in the fields (reviewed in Ehler *et al*., 1997; Blackman and Eastop, 2000; Khanjani, 2005; Hansen *et al*., 2008; Kuroli and Lantos, 2008). The black bean aphid damages sugar beet plants by feeding on leaves (resulting in leaf curling, distortion, leaf yellowing and wilting), the terminal of plants and their florescence and through the transmission of sugar beet viruses (Limburg *et al*., 1997; Blackman and Eastop, 2000). Therefore, primary sugar beet injuries may take place when the aphids are not suppressed in the fields. The majority of sugar beet producers often apply the toxic aphicides to manage black bean aphid, exhibiting a dispute to constant sugar beet plantation (Edwards *et al*., 2008). So, synthetic pesticides usages have shown to have many non-target effects in the agricultural systems and economic difficulties as well. Additionally, in recent years, resistance of different pest species especially the aphids against chemical compounds sprays has significantly enlarged in the world (Field and Devonshire, 1997; Devonshire, 1998; Ahmad *et al*., 2003; Edwards *et al*., 2008). To overcome these problems, some authors have been regularly looking for acquiring alternative safe methods for using in the fields (e.g., Edwards *et al*., 2008). It is well renowned that one of the best techniques to handle insect pests and aphid-borne viruses is the use of resistant cultivars whereas they are obtainable. This technique is one of the most significant components of integrated pest management programs which have a good prospective to develop IPM strategies against arthropod pests and decrease dependence to the pesticide applications in many agricultural systems (Robinson *et al*., 1991; Weathersbee and Hardee, 1994; Gu *et al*., 2008; Hansen *et al*., 2008).

In addition, despite elevated consequence of black bean aphid as a severe pest of economically important crops including sugar beet and broad bean but, based on our understanding, just a few investigations in relation to natural enemies and other biological aspects of this aphid were studied (Ahmad and Hodgson, 1997; Ehler *et al*., 1997; Goszczyński *et al*., 2002; Cichocka *et al*., 2002). As a result, only inadequate knowledge is available with reference to the effect of host species and cultivars on biology and population dynamics of black bean aphid in the world (Goszczyński *et al*., 2002; Cichocka *et al*., 2002; Hansen *et al*., 2008). On the other hand, in order to improve successful pest management programs against aphids, like *A. fabae,* a wide understanding of the aphid biological characteristics on host plants species and cultivars is needed.

Accordingly, the goal of our study was to reveal *A. fabae* population growth traits including development time and survival of immature stages, fecundity, longevity and life table attributes on six commonly growing sugar beet varieties including 'BR1', 'Zarghan', '7233', 'PP22', 'PP36', 'Polyrave' in Iran.

Materials and methods

Plants

Six sugar beet (*B. vulgaris*) cultivars used in this study were provided from Sugar beet Seeds Improvement

Center, Ardabil, Iran. The cultivars are commonly grown in the sugar beet growing areas of Iran and they were selected based on visual observation in the fields of region because some cultivars were severely infested but some cultivars seemed to be attacked at low density through the black been aphid. The cultivars of used consisted of 'BR1', 'Zarghan', '7233', 'PP22', 'PP36' and 'Polyrave'. The seeds were sown into the plastic pots (30 cm in diameter and 30 cm in height) crammed with appropriate field soil. Each pot consisted of at least three seeds but when the seedlings were emerged, the plants were thinned and maintained only one plant into the each pot. The potted plants were grown in a greenhouse at 30/20 °C (day/night temperatures, respectively), 60-70 % RH and an ambient light. The plants were watered when required. When the sugar beet seedlings reached into the four or six leaf stages, they were transferred and placed in a growth chamber under conditions of 25 ± 1 °C, 60 ± 10 % RH and a photoperiod of 16: 8 (L: D) in order to conduct the experiments.

Insects

The aphids used in the experiments were collected from sugar beet field of Ardabil County, Iran. The colonies were reared on broad been seedlings (local variety) in the greenhouse according to the method previously mentioned. The aphid populations were reared for several months before conducting the experiments.

Experiments

We conducted the whole related experiments in a growth chamber under the 25 ± 2 °C, 60 ± 10% R.H. and a photoperiod of 16:8 (L:D). In order to assess the development duration and survivorship of immature stages, fecundity and adult longevity, adult apterous aphids were randomly selected from the aphids source and placed on the leaf surface inside the leaf clip cages (9 cm in diameter 1.5 cm in height) as previously described conditions using a fine-hair brush. They were then allowed to produce nymphs for 24 hours period. After this time, the adults were omitted and only a cohort of three or four newly born nymphs retained together into each clip cage (Razmjou *et al*., 2006). These remaining nymphs were monitored daily until reaching adult to assess developmental time and survivorship on all cultivars. The immature become adults, they were observed for reproduction and survival. In this regard, we selected and transferred only one newly emerged adult to another new leaf clip cage as mentioned above. Mortality and the number of nymphs produced by the apterous aphid were recorded and the offsprings discarded daily until the death of the adult. In this way we evaluated the fecundity of 21-24 adult aphids per each cultivar (table 1).

Data analyses and statistics

The survival of apterous aphids and of nymphs was monitored and recorded at 24-h periods. Then, the percentage of survival of nymphs as well as the longevity and fecundity of apterous aphids was determined on six cultivars tested. We calculated the intrinsic rate of natural increase (r_m) of apterous aphids on various sugar beet cultivars according to the formula specified by Birch (1948):

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

Additionally, other life table parameters including net reproductive rates ($R_0 = \sum l_x m_x$), mean generation time ($T = \ln R_0/r$), doubling time (DT), and finite rate of increase ($\lambda = e^r$) for black bean aphid on sugar beet cultivars were examined, where x is the age in days, r is the intrinsic rate of natural increase, l_x is the proportion of living females on a given day, and m_x is the mean number of female offspring produced at the same day (Southwood, 1978; Carey, 1993).

Data concerning developmental time, survivorship of nymphal stage, adult longevity, and fecundity were analyzed using the analysis of variance (ANOVA). The comparisons of the data, obtained with different cultivars, were done–using Tukey Honesty Significant Difference (HSD) test at $\alpha < 0.05$ (Minitab lnc. 1994 Philadelphia, PA). Furthermore, life table parameters including intrinsic rate of 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 procedure (Meyer *et al*., 1986; Carey, 1993; Maia *et al*., 2000) using the SAS System ver. 8.2. (SAS Institute, 1989). When significant differences were observed between mean values of life table parameters, they were separated using student's t-test pairwise comparisons (Maia *et al*., 2000).

Table 1. Developmental time, survivorship of nymphs, sample size of each parameter, reproductive period, mean number of nymphs/aphid/day, mean nymphs per female and adult longevity of *A. fabae* cultured on six sugar beet cultivars.

Cultivar	Parameter (Mean ± SD)						
	Developmental time	Survivorship of nymphs (%)	*N*	Reproductive period (days)	Mean number of nymphs/aphid/d	Mean number of nymphs/female	Adult longevity
BR1	12.48 ± 2.44abc	89 (45)	21	6.14 ± 2.18a	1.41 ± 0.48c	8.38 ± 3.54b	7.76 ± 1.64a
Zarghan	11.96 ± 2.36abc	82 (44)	23	6.00 ± 1.81a	1.44 ± 0.38c	8.52 ± 2.83b	7.09 ± 1.73a
7233	13.23 ± 1.63a	79 (47)	22	5.55 ± 2.13a	1.38 ± 0.34c	7.32 ± 2.77b	7.46 ± 1.92a
PP22	12.82 ± 2.20abc	93 (40)	22	5.68 ± 2.36a	1.24 ± 0.33c	7.36 ± 4.08b	7.36 ± 2.34a
PP36	11.42 ± 2.24c	91 (57)	24	5.79 ± 1.59a	1.76 ± 0.63b	10.54 ± 5.23b	7.58 ± 1.44a
Polyrave	11.32 ± 1.91c	93 (41)	22	6.36 ± 1.89a	2.16 ± 0.63a	14.32 ± 7.29a	8.18 ± 2.09a

Differences among sugar beet cultivars were evaluated by HSD of Tukey test. In each column, means accompanied by different letters significantly differed at P < 0.05. The *N* value is the sample size related parameter. But the sample sizes of developmental time and immature stages survival are appeared in the parenthesis.

Results

Developmental time and survivorship of nymphal stages, reproductive rates and adult longevity as well as life table parameters of *A. fabae* are reported in tables 1 and 2, respectively.

Developmental time and survivorship of nymphal stages

The development time of immature stages of *A. fabae* varied significantly among six sugar beet varieties examined (F = 2.87; df = 5,128; P < 0.05). The mean number of developmental time ranged from 11.42 and 11.32 days on 'PP36' and 'Polyrave' to 13.23 days on '7233'. This assessment on other cultivars tested was intermediate (table 1).

Survival of nymphal stages was recorded to be dissimilar on six sugar beet cultivars. Percentage of survivorship varied from 79% for '7233' to 93% for 'Polyrave' and 'PP22' (table 1).

Fecundity and adult longevity

Significant differences in mean number of *A. fabae* nymphs were observed between the sugar beet cultivars tested (F = 7.54; df = 5, 128; P <0.05). The mean numbers of offspring per aphid were reported in table 1. Similarly, the number of nymphs/ female/day was significantly different (F = 10.97; df = 5, 128; P < 0.001) among cultivars (table 1).

However, no significant differences were detected in relation to reproductive period (F = 0.51; df = 5, 128; P > 0.05) or adult longevity (F = 0.91; df = 5, 128; P > 0.05) of *A. fabae* on six sugar beet cultivars. The time of reproductive ranged from 5.55 days for '7233' to 6.64 for 'BR1' and adult longevity from 7.09 days for 'Zarghan' to 8.18 days for 'Polyrave' (table 1).

Life table parameters

Significant variation in net reproductive rate (R_0) of *A. fabae* aphids was identified among various sugar beet cultivars (P < 0.05). The aphids reared on 'Polyrave' had the highest R_0 value and those on '7233', 'Zarghan' and 'PP22' had the lowest R_0 values while on 'PP36' and 'BR1' R_0 were intermediate (table 2). The intrinsic rate of natural increase (r_m) of *A. fabae* indicated to be significantly different, (P < 0.05). The r_m values of *A. fabae* was the largest on 'Polyrave' and the smallest on '7233' (table 2). Also, the finite rate of increase (λ) of *A. fabae* indicated significant differences (P < 0.05) among sugar beet cultivars tested. The λ values were higher on 'Polyrave' and 'PP36' than those on '7233', 'PP22', 'Zarghan' and 'BR1' cultivars (table 2). The doubling time (DT) of *A. fabae* was recognized to be significantly different among the sugar beet cultivars (P < 0.05). The DT values were higher on '7233' than those on 'Polyrave' and 'PP36' (table 2). Finally, mean generation times (T) of the apterous aphid on '7233', were significantly higher (P < 0.05) than on 'PP36', 'Polyrave' and 'Zarghan' cultivars (table 2).

Discussion

Our results from the experiments clarified that sugar beet cultivars had the significant influences on the biology and life history characteristics of *A. fabae* in the laboratory conditions mentioned. These effects were observed on developmental time, nymphal mortality, adult longevity and fecundity of *A. fabae* in the leaf clip cages of potted plants of different sugar beet varieties in a growth chamber. Our study clearly showed that 'Polyrave' and 'PP36' sugar beet varieties were the most suitable hosts and the '7233' variety the worst one for development of black bean aphid among cultivars examined. The achieved development and fecundity rates of *A. fabae* on sugar beet in our study fall inside the range estimated by previous studies. For instance, Goszczyński *et al.* (2002) indicated that the mean fecundity of apterous aphid *A. fabae* varied from 7.9 to 17.0 nymphs/female in terms of aphid generations and beet cultivars. However, the highest fecundity (15.3-59.2 nymphs/female) and longevity were obtained on broad bean plants (as the most proper host) by Cichocka *et al.* (2002). Life table characteristics obtained in the present study, suggest that black been aphid has a high potential to increase its population density in a relatively short period. The 'PP36' and 'Polyrave' cultivars seems to be more favourable for the development of this pest, in particular when the insects are living under proper situations including the better host quality and optimal climatic conditions (e.g., temperature and photoperiod).

Many authors have showed that some host plant varie-

Table 2. Life table parameters of *A. fabae* reared on six sugar beet cultivars under laboratory conditions.

Cultivar	*N*	Parameter (Mean ± SD) Net reproductive rate (*R_0*)	Intrinsic rate of increase (*r_m*)	Mean generation time (*T*)	Doubling time (*DT*)	Finite rate of increase (*λ*)
BR1	21	7.36 ± 0.68cd	0.1637 ± 0.0099b	12.21 ± 0.29	4.22 ± 0.26b	1.178 ± 0.012b
Zarghan	23	6.94 ± 0.48d	0.1637 ± 0.0076b	11.84 ± 0.26	4.23 ± 0.20b	1.178 ± 0.009b
7233	22	5.76 ± 0.46d	0.1336 ± 0.0068c	13.13 ± 0.26	5.18 ± 0.27a	1.143 ± 0.007c
PP22	22	6.69 ± 0.79d	0.1538 ± 0.0114bc	12.39 ± 0.22	4.48 ± 0.34ab	1.166 ± 0.013bc
PP36	24	9.61 ± 0.97bc	0.2027 ± 0.0134a	11.17 ± 0.31	3.40 ± 0.23c	1.225 ± 0.016a
Polyrave	22	13.26 ± 1.44a	0.2202 ± 0.0107a	11.76 ± 0.22	3.14 ± 0.16d	1.246 ± 0.013a

Differences comparisons between sugar beet cultivars were applied by t-test pairwise. In the each column, the means accompanied by the different letters significantly differed at P < 0.05. The *N* value is the sample size for each parameter.

ties (Weathersbee and Hardee, 1994; Satar and Yokomi, 2002; Goszczyński *et al*., 2002; Cichocka *et al*., 2002; Razmjou *et al*., 2006; Silva *et al*., 2006; Ulusoy and Olmez-Bayhan, 2006; Bayhan, 2009) and species (Wang and Tsai, 2001) have a major effects on bionomics of aphids in the laboratory conditions and fields (Awmack and Leather, 2002; Hansen *et al*., 2008) Therefore, a comprehensive knowledge of the population growth characteristics of *A. fabae,* in particular on various sugar beet cultivars, might has significant implications in its management. The cultivars supporting low population density of aphid together with natural enemies and pesticides applications could have a key role in the integrated pest management programs.

Previous research showed that coccinellids, chrysopids and parasitoids as major natural enemies of black bean aphid, have not more effects on its populations, suppressing them in the late growing season alone. Regrettably, these insects have a tendency to settle sugar beet fields where aphid populations are vigorous and thus they have inadequate effects in IPM strategies of this aphid alone (Ehler *et al*., 1997; Volkl and Stechmann, 1998). However, the combination of host plant resistance, even partial, with other methods including natural enemies and cultural control has clearly declined the populations of the *A. fabae* on the faba bean (Shannag and Obeidat, 2008; Hansen *et al*., 2008) and of the *Aphis craccivora* Koch on the cowpea plants (Ofuya, 1997). Thus, the use of resistant host plants even partially resistant cultivars to the black bean aphid is one procedure of stabilizing production which can reduce the infestation of aphids (Hansen *et al*., 2008). Thereafter, the lessening in pesticides application will facilitate to maintain natural enemies' populations in the agricultural systems as well (van Steenis and El-Khawass, 1995; Zehnder *et al*., 2007; Desneux *et al*., 2007). Moreover, the existence of the legumes and cereals resistance against aphids, sorghum midge resistance, as well as canola varieties resistance to arthropod pests have demonstrated the good outlooks of host plant resistance for expanding IPM programs against various pests in grain crops (Gu *et al*., 2008). Hence, the search for resistance sources and cultivars selection to decrease the black bean aphid populations as well as incidence of its related plant viruses in the field has been a leading precedence in breeding programs for sugar beet. Consequently, the achievement of this environmental favourable procedure could result in the reduced use of chemical pesticides, and promoting efficiency of integrated pest management strategies (Croft, 1990; Desneux *et al*., 2007) in order to prevent the damage caused by sugar beet aphids and other pests.

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