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Biology and Life Table Parameters of *Brevicoryne brassicae* (Hemiptera: Aphididae) on Cauliflower Cultivars

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ABSTRACT. In this article, the biology and fertility life table parameters of the cabbage aphid, *Brevicoryne brassicae* (L.) (Hemiptera: Aphididae), were studied on cauliflower leaves, *Brassica oleracea* var. *botrytis* (Brassicales: Brassicaceae), of the cultivars Smilla, Snow mystique, White cloud, Buris, Galiblanka, Snow crown, SG, and Tokita. This study was conducted under controlled conditions: 25 ± 2°C, 65 ± 5% relative humidity (RH), and 16:8 (L:D) h photoperiods. Statistical analysis showed that there was a significant difference ($P < 0.05$) between the different growth stages and the mean number of laid nymphs. Further, the maximum and minimum growth periods were observed on Galiblanka and Buris cultivars, respectively. The shortest nymphal instar growth period was observed on the Smilla cultivar (6.70 d), and the longest lifespan was seen on the White cloud (8.10 d). The Smilla cultivar (39%), in an adult emergence stage, and the SG (88%) revealed the lowest and highest rates of survival, respectively. Aphids reared on the Smilla cultivar were found to have increased due to the high intrinsic (r_m) and finite (λ) rate of increase and the low doubling time (DT). The results indicated that the application of cultivars affecting adult reproductive parameters could be a good solution to cabbage aphid control management.

Key Words: *Brevicoryne brassicae*, biological cycle, reproduction rate, cauliflower

The cabbage aphid, *Brevicoryne brassicae,* is scattered in many parts of the world (Rivnay 1962) and is present in most parts of Iran, especially in the central areas (Khanjani 2006). Different plants belonging to the crucifer family (Brassicaceae) act as a host for this aphid. Pest damage occurs on the cabbage leaves and transmits plant viruses (Blackman and Eastop 2000). Pesticide application has been a primary method of fighting and controlling aphids; nevertheless, unsystematic pesticide use has had adverse effects on the environment and on nontarget organisms (Furk and Hines 1993, Saldo and Szpyrka 2009). Accordingly, other pest control methods, including resistant cultivars and biocontrol factors, have received more attention in recent decades (Blande et al. 2008). The use of insect-resistant cultivars has increased food production in some major agricultural areas of the world (Smith 2005). Reduction in the production of crops, like cauliflower, due to cabbage aphids reveals that studies on pests are crucial for data collection on the antibiosis resistance rate of different cultivars. Many researchers have studied the effects of host plants on the biological cycle of the cabbage aphid. Some of these researchers include Mirmohamadi et al. (2009), who studied the biological parameters of cabbage aphid on varieties of canola; Cividanes (2002), who studied the biological responses of cabbage aphid, *B. brassicae* on four varieties of *Brassica*; Satar et al. (2005), who studied the potential increase of the cabbage aphid population on white cabbage; and La Rossa et al. (2005), who reported that the type of host plant significantly impacts the biological stage of cabbage aphid. Despite this abundance of research, there exists a lack of studies on the biology of cabbage aphid in different cauliflower cultivars. Although the main intention of this article is to compare the population growth potential of cabbage aphid on eight cultivars, it will also predict the replacement role of appropriate cultivars within the population dynamics of this type of aphid. This study can help to better understand the biology of cabbage aphid and hence provide solutions to pest control management.

Materials and Methods

Rearing of Cabbage Aphid. Aphid samples were collected in the fall from a cauliflower field located at Shahed University. These samples, along with pieces of the host plants, were later moved to the laboratory. Upon removing the larvae and eggs of the syrphid flies and other predators, the remaining aphids were reared on the leaf of each cauliflower cultivar to three generations, 25 ± 2°C, 65 ± 5% relative humidity (RH), and 16:8 (L:D) h photoperiods. The leaves were individually placed in clear plastic containers (5 by 13 by 15 cm) and were covered by netted lids, permitting the flow of air.

Growing of Plants. In this experiment, eight cultivars of cauliflower were used: *Brassica oleracea* var. *botrytis* (Brassicales: Brassicaceae, Tehran Ramfar Co., Tehran, Iran) including Smilla, Snow mystique, White cloud, Buris, Galiblanka, Snow crown, SG, and Tokita. The seeds of each cultivar were provided by Seed and Plant Improvement Institute of Iran, Horticulture department and planted in small containers (flat wooden boxes), which, after about 5 wk (the 6–8 leaf stage), were individually transferred to small plastic pots containing sterilized soil. They were used in the 10–12 leaf stage for further research.

Experimental Design. All experiments were undertaken in a growth chamber, which was set at 25 ± 2°C, 65 ± 5% RH, and 16:8 (L:D) h photoperiods. An adult female was placed on each cultivar leaf using a triple zero brush. Twelve hours later, upon examination of the containers, it was discovered that only one nymph remained, and the other nymphs and female aphids were removed. Ten replicates were considered for each cultivar. Experiment began with one first nymphal instar, the test containers were evaluated every 24 h, and the molting time was recorded after aphid maturation. The total number of nymphs produced was counted daily. These nymphs were later removed from the leaves, and this process continued until all aphids had died. In the life table, some biological parameters were calculated; these included the prereproduction period and the postreproduction period, adult longevity, aphid lifespan, the reproduction period, the mean number of produced nymphs, and the longevity of different nymphal instars.

Data Analysis. Age-specific survival rates (lx), as well as the average number of female offspring (mx), for each age interval (x) were used to construct the age-specific fertility life tables. Using survivorship and fertility schedules, the demographic parameters of cabbage aphid, including the net reproduction rate (Ro), the intrinsic rate of increase

(r_m), the finite rate of increase (λ), the mean generation time (T), the doubling time (DT), and the life expectancy (ex), were calculated. The terminology and formulae used to compute the demographic parameters were consistent with Carey (1993). The Jackknife method was used to estimate the standard error of the population growth parameter (Meyer et al. 1986). The intrinsic rate of increase (r_m) was calculated using the method proposed by Wyatt and White (1977).

$$r_m = 0.738(\ln(Md)/d)$$

In this method, d is the time period before nymph production, Md is the number of produced progenies in the time equal to d, and 0.738 is the correction constant. The results obtained from Brich (1948) and Wyatt and White methods were later compared. The data were submitted to analysis of variance, the means obtained were compared using the Duncan Multiple Range Test ($\alpha = 0.05$) using the SPSS version 15.0 (SPSS Software, 2006), and graphs were plotted by Excel 2007.

Results

Fertility Table Parameters. The cabbage aphid, *B. brassicae*, had four instars on all cauliflower cultivars. Nymphal instar longevity varied significantly ($P < 0.05$), ranging from 6.70 to 8.10 d on the Smilla and White cloud cultivars, respectively (Table 1). As listed in Table 2, a significant difference was observed between the various biological parameters of the aphids reared on different cultivars ($P < 0.05$). The highest prenymph period, nymph production period, mean number of laid nymphs, adult longevity, and total lifespan on the Galiblanka cultivar was calculated as 8.60, 13.50, 58.60, 17.30, and 25.90, respectively. The longevity of aphids reared on the Smilla and Buris cultivars was found to be significantly lower than aphids reared on other cultivars. There were no significant differences between the other cultivars. Based on the results obtained from the mean comparison, cabbage aphid was most fertile on the Galiblanka cultivar, and its difference with the Buris cultivar was statistically significant

(Tables 1 and 2; Fig. 1).

Life Table Parameters. As shown in Fig. 2, the SG cultivar revealed the highest life expectancy ($e_x = 8.26$) among the cultivars inspected. In this cultivar, life expectancy (e_x) was 18.61 at the beginning of the life cycle and reached 0.0 after 36 d. Similarly, this cultivar revealed the highest survival rate. The survival rate obtained at this stage was 88%, meaning that 12% of aphids died before the adult stage. Here, the mortality rate obtained at the preadult stage was lower than that of other cultivars. The lowest life expectancy ($e_x = 4.03$) was also observed in the Smilla cultivar, which was 9.20 at the beginning of life and reached 0.0 after 22 d

(Fig. 2).

Value of Intrinsic Rate of Increase. Table 3 depicts values of the intrinsic rate of increase of the cabbage aphid, *B. brassicae*, on eight cauliflower cultivars using two different methods. The comparison of these two methods revealed that the results of the application of the Brich method on Smilla, Snow crown, and SG–Tokita cultivars were similar to the Wyatt and White method. However, in other cultivars, i.e., Galiblanka, Buris, White cloud, and Snow mystique, r_m value calculated by the Wyatt and White method was lower than that calculated by the Brich method. Such discrepancies were rooted in differences in longevity, fertility, and preadulthood periods of *B. brassicae* on these cultivars. Statistical analysis, also, showed that there were significant differences between the cultivars ($P < 0.05$). The calculated intrinsic rate of increase showed that the cabbage aphid population had a growth rate equal to the exponential, constant rates of 0.27–0.35. The intrinsic rate of increase of *B. brassicae* on the Smilla cultivar (0.35 females/female/d) was significantly higher than other cultivars, and the lowest value of r_m of *B. brassicae* was calculated on the White cloud cultivar (0.27 females/female/d). Because of calculated r_m, the White cloud and Smilla cultivars were resistant and susceptible cultivars, respectively.

Population Growth Parameters. Table 4 lists population growth parameters with a 95% confidence level for each, using the Jackknife method. Statistical analysis illustrated significant differences between the net reproductive rates (R_0) of aphids on the studied cultivars ($P < 0.05$). This parameter indicated high reproductive ability and effective individuals within the generation. The net reproductive rate of aphids on the Galiblanka cultivar (56.55 females/female/d) was significantly higher than that on other cultivars. There were also significant differences between the finite rates of increase (λ), doubling time (DT), mean generation time (T), and weekly growth rate (r_w) on eight cultivars ($P < 0.05$). The white cloud cultivar revealed the lowest finite rate

Table 1. Mean longevity of different nymphal instars of the cabbage aphid, *B. brassicae,* on different cauliflower cultivars

	Different cultivars							
Parameter	Smilla	Snow mystique	White cloud	Buris	Galiblanka	Snow crown	SG	Tokita
First nymphal instar	1.30 ± 0.15 de	1.50 ± 0.17 de	2.40 ± 0.26 ab	1.00 ± 0.00 e	1.90 ± 0.23 bcd	1.60 ± 0.22 cde	2.20 ± 0.29 abc	2.70 ± 0.15 a
Second nymphal instar	1.60 ± 0.22 c	2.40 ± 0.22 ab	2.60 ± 0.16 a	2.10 ± 0.10 abc	2.00 ± 1.21 abc	2.50 ± 0.31 ab	1.70 ± 0.15 c	1.90 ± 0.18 bc
Third nymphal instar	2.10 ± 0.18 ab	2.00 ± 0.21 b	2.10 ± 0.18 ab	2.80 ± 0.36 a	1.80 ± 0.29 b	2.10 ± 0.18 ab	1.80 ± 0.25 b	1.60 ± 0.22 b
Fourth nymphal instar	1.70 ± 0.15 ab	1.80 ± 0.20 a	1.00 ± 0.00 c	1.30 ± 0.15 bc	1.90 ± 0.10 a	1.20 ± 0.20 c	1.30 ± 0.15 bc	1.00 ± 0.00 c
Total	6.70 ± 0.15 c	7.70 ± 0.21 ab	8.10 ± 0.46 a	7.20 ± 0.29 bc	7.60 ± 0.31 ab	7.40 ± 0.22 abc	7.00 ± 0.15 bc	7.10 ± 0.18 bc

Identical letters in each row are not significantly different at 5% level.

Table 2. Mean of different growth stages period of the cabbage aphid, *B. brassicae,* on different cauliflower cultivars

	Different cultivars							
Stage duration	Smilla	Snow mystique	White cloud	Buris	Galiblanka	Snow crown	SG	Tokita
Prereproduction period	7.70 ± 0.15 d	8.7 ± 0.21 ab	9.10 ± 0.46 a	8.20 ± 0.29 bc	8.60 ± 0.31 ab	8.40 ± 0.22 abc	8.00 ± 0.15 bc	8.10 ± 0.18 bc
Reproduction period	10.00 ± 0.83 bc	12.80 ± 0.77 a	13.00 ± 0.82 a	8.30 ± 0.42 c	13.50 ± 1.38 a	12.30 ± 1.16 ab	13.00 ± 0.56 a	13.00 ± 0.94 a
Postreproduction period	1.00 ± 0.21 b	2.80 ± 0.53 a	1.20 ± 0.42 b	1.00 ± 0.26 b	2.80 ± 0.63 a	1.70 ± 0.40 ab	1.90 ± 0.55 ab	2.80 ± 0.61 a
Adult longevity	12.00 ± 0.75 b	16.60 ± 1.09 a	15.20 ± 0.76 a	10.30 ± 0.42 b	17.30 ± 1.23 a	15.00 ± 1.34 a	15.90 ± 0.87 a	16.60 ± 1.19 a
Lifespan	18.70 ± 0.67 b	24.30 ± 1.14 a	22.30 ± 0.96 a	17.50 ± 0.65 b	24.90 ± 1.30 a	22.4 ± 1.23 a	22.9 ± 0.89 a	23.70 ± 1.12 a
Mean number of nymphs laid per female	45.70 ± 3.42 bc	50.00 ± 3.07 ab	36.30 ± 3.24 cd	30.90 ± 1.13 d	58.60 ± 4.05 a	40.10 ± 4.43 bcd	44.30 ± 3.85 bc	41.90 ± 2.66 bc

Identical letters in each row are not significantly different at 5% level.

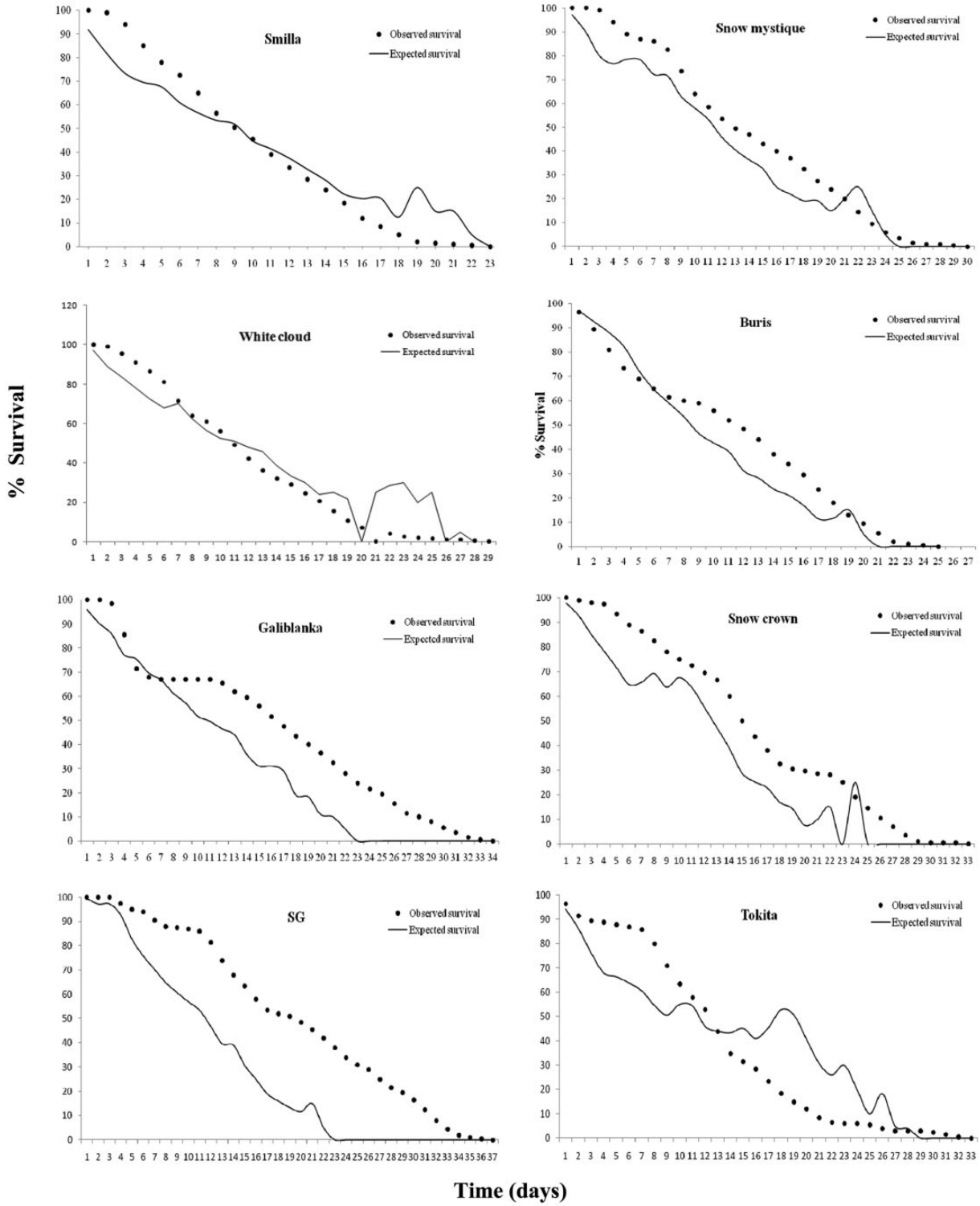

Fig. 1. Observed and expected survival of females of the cabbage aphid, *B. brassicae* created in cauliflower cultivars. Temperature (25 ± 2°C), RH (65 ± 5%), and photoperiod (16:8 [L:D] h). The difference between cultivars was 14 d.

of increase and weekly growth rate and the highest doubling time. Cabbage aphid populations on the Smilla cultivar showed the highest finite rate of increase and weekly growth rates, the lowest doubling, and the mean generation time.

Discussion

Based on the findings of this study, development, reproduction, and longevity of the cabbage aphid, *B. brassicae*, are shown to be influenced by the type of cauliflower cultivar. Many inherent characteristics of plants, i.e., food, chemical composition of secondary metabolites, and morphology, can affect insect survival, reproduction, and growth. Other researchers have also studied the impact of the host plant on the biological parameters of cabbage aphid (Fathipour et al. 2005, Mirmohamadi et al. 2009, Aslam et al. 2011); however, there is little information regarding the effect of other cauliflower cultivars.

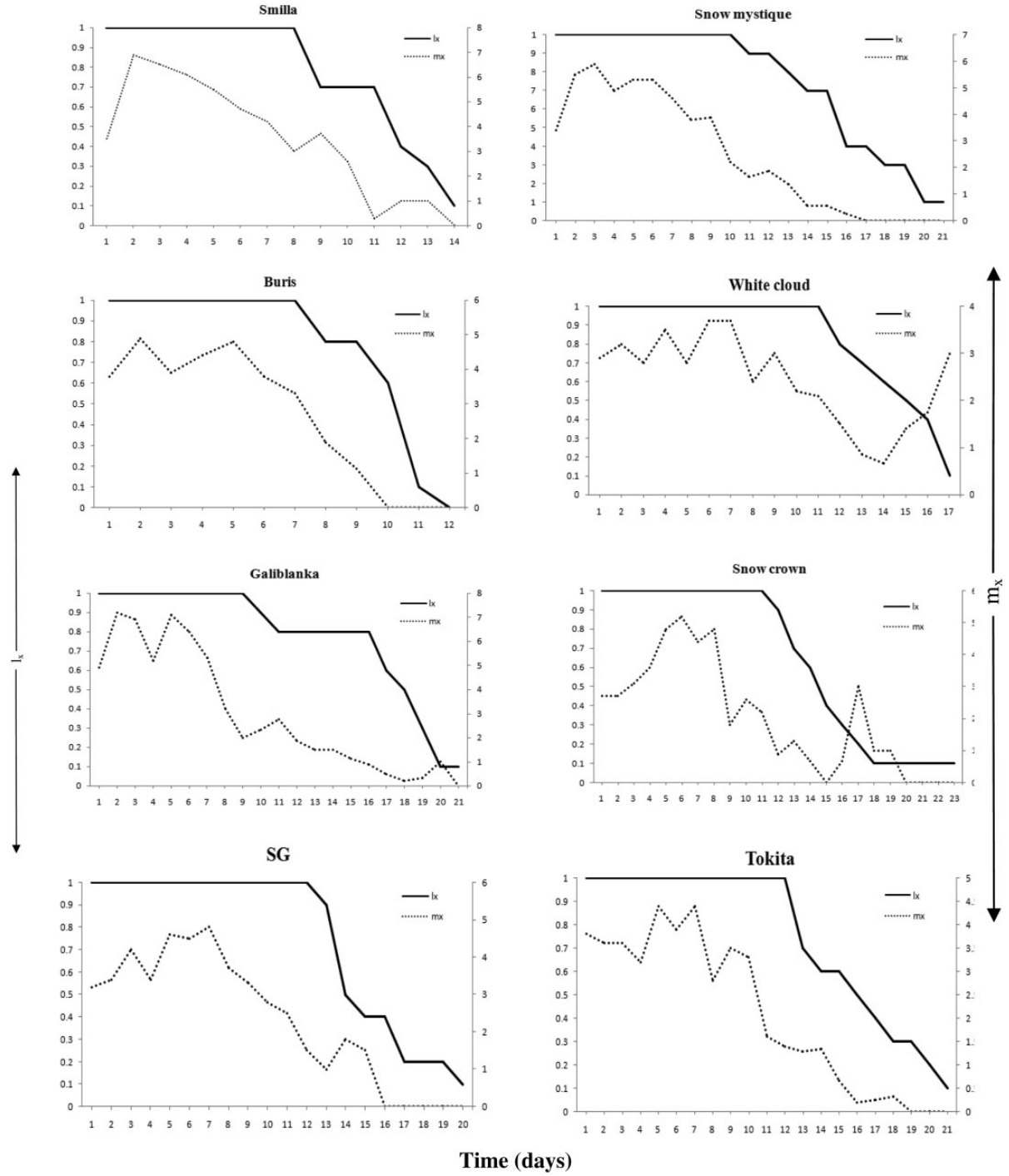

Fig. 2. Observed and expected survival of females of the cabbage aphid, *B. brassicae* created in cauliflower cultivars. Temperature (25 ± 2°C), RH (65 ± 5%), and photoperiod (16:8 [L:D] h). The difference between cultivars was 14 d.

Because it has been shown that the White cloud cultivar increased the nymphal development period of *B. brassicae*, this could be a likely reason for the reduction in the intrinsic rate of increase on this cultivar. The findings of this article, regarding the nymphal development period of cabbage aphid, are consistent with those presented by Ulusoy and Olmez-Bayhan (2006), who reported that the development of the immature stages of the cabbage aphid on cauliflower takes 8.90 d. In this study, the mean number of cabbage aphid nymphs laid per female lasted between 30.90 and 58.60 on different cauliflower cultivars. As reported by other researchers (Satar et al. 2005, Mirmohamadi et al. 2009), the mean number of *B. brassicae* nymphs laid per female on eight cultivars was less than its value on the canola; however, similar to that on the white cabbage. Mirmohamadi et al. (2009) showed that *B. brassicae* on the canola (Hyola 401 cultivar) produced an average of 60.08 nymphs per female. Satar et al. (2005) calculated that the mean number of nymph production of the cabbage aphid on white cabbage is equal to 47.10 nymphs per female, similar to results that we obtained on the Smilla cultivar (45.70 nymphs per female).

Aslam et al. (2011) found that the mean number of nymph production of the cabbage aphid was 30.79 nymphs per female, similar to our

Table 3. Mean values of intrinsic rate of increase (r_m) of *B. brassicae* on the different cultivars calculated by Brich and Wyatt and White methods

	Different cultivars							
	Smilla	Snow mystique	White cloud	Buris	Galiblanka	Snow crown	SG	Tokita
a	0.3525 ± 0.0069 a	0.3137 ± 0.0059 bc	0.2758 ± 0.0181 d	0.2971 ± 0.0038 bcd	0.3329 ± 0.0054 ab	0.2837 ± 0.0070 cd	0.3207 ± 0.0119 ab	0.3169 ± 0.0205 bc
b	0.3365 ± 0.0011 a	0.3176 ± 0.0011 c	0.2702 ± 0.0017 f	0.3040 ± 0.0013 e	0.3325 ± 0.0015 b	0.3075 ± 0.0013 de	0.3190 ± 0.0008 c	0.3089 ± 0.0009 d

Identical letters in each row are not significantly different at 5% level.
[a]Brich method.
[b]Wyatt and White method.

Table 4. Population growth parameters of the cabbage aphid, *B. brassicae,* on the cauliflower cultivars using Jackknife method with 95% confidence level

	Parameter					
Different cultivars	r_m	R_0	λ	T	DT	r_w
Smilla	0.35(0.33–0.36) a	43.89(36.07–51.70) abc	1.42(1.40–1.44) a	10.83(8.70–12.94) c	1.97(1.87–2.05) d	11.80(10.50–13.08) a
Snow mystique	0.31(0.30–0.32) bc	49.17(41.52–56.81) ab	1.36(1.28–1.44) abc	12.41(12.00–12.82) ab	2.21(2.11–2.30) bcd	8.99(8.15–9.82) bcd
White cloud	0.27(0.23–0.31) d	34.59(27.21–41.96) bc	1.32(1.26–1.37) c	12.83(11.46–14.23) ab	2.51(2.12–2.90) a	6.90(4.99–8.80) d
Buris	0.29(0.28–0.30) bcd	30.83(28.71–32.93) c	1.35(1.33–1.35) bc	11.54(11.11–11.95) bc	2.33(2.26–2.40) abc	8.00(7.55–8.45) cd
Galiblanka	0.33(0.32–0.34) ab	56.55(46.50–66.59) a	1.40(1.37–1.41) ab	12.12(11.54–12.69) abc	2.08(2.00–2.15) cd	10.28(9.38–11.18) ab
Snow crown	0.28(0.26–0.29) cd	39.71(30.93–48.47) bc	1.33(1.30–1.34) c	12.97(12.46–13.30) a	2.44(2.30–2.58) ab	7.29(6.48–8.10) cd
SG	0.32(0.29–0.34) ab	43.41(34.85–51.96) abc	1.38(1.34–1.41) abc	11.79(11.17–12.33) abc	2.17(1.95–2.37) bcd	9.44(7.69–11.19) bc
Tokita	0.31(0.27–0.36) bc	38.89(14.90–62.88) bc	1.37(1.30–1.43) abc	11.54(10.58–12.22) bc	2.19(1.89–2.51) bcd	9.20(6.36–12.14) bc

Identical letters in each row are not significantly different at 5% level.

results on Buris cultivar, 30.90 nymphs per female. In our study, the lowest lifespan of the cabbage aphid (17.50 nymphs per female) was reported to take place on the Buris cultivar. The mean lifespan of *B. brassicae* on different cultivars was similar to those reported by Hajgozar (2002) on canola (17.4 d). We also found that the lifespan of the cabbage aphid was longer than that reported by Eskuruchi et al. (2010), on two local populations of *B. brassicae* (16.85–18.89 d), and Ulusoy and Olmez-Bayhan (2006) on mustards and rapeseed (6.2 d). Furthermore, the lifespan of *B. brassicae* on the Grees Cornet cultivar was shorter than that on the Savoy cabbage (Fathipour et al. 2005). Jamaya and Ronald (1998) reported that the lifespan of the cabbage aphid is between 16 and 60 d. Like other biological parameters, the host plant and growing conditions affect the longevity of an aphid. It is probable that the cabbage aphid has a longer life expectancy than its host on some cauliflower cultivars, such as Snow mystique and Galiblanka. The net reproduction rate (R_0) of the cabbage aphid was shown to be relatively high on the studied cauliflower cultivars (30.83–56.55 females/female/d). Cividanes (2002) calculated that the value of (R_0) of the cabbage aphid, *B. brassicae*, was between 14.65 and 32.80 females/female/d on four varieties of *Brassica,* whereas Fathipour et al. (2005) stated that the value of (R_0) of the cabbage aphid was 15.92 females/female/d on the Green Cornet cultivar. Our results show that the intrinsic rate of increase of the cabbage aphid on the common cauliflower cultivars in Iran is equal to 0.27 or more, confirming the susceptibility of the noted cultivars to the aphid. Statistical variables, including fertility and intrinsic rate of natural increase, are valid criteria to determine aphid performance.

Plants on which aphid populations have a lower intrinsic rate of increase and a lower rate of reproductivity are more resistant than plants on which aphid populations show a higher rate of increase (Zarpas et al. 2006). Moharramipour et al. (2003) tested the antibiosis properties of four canola cultivars on cabbage aphid and found that the highest intrinsic rate of increase (r_m) was for the Boomrang cultivar (0.29 females/female/d). This study showed that difference in susceptibility between the studied canola cultivars and the cabbage aphid were related to nonuniform structural and physiological characteristics for feeding and growth. Many ecological factors, such as the host plant (Bhatt and Singh 1991), temperature (Force and Messenger 1964), and experiment method (Cohen and Mackauer 1987), affect the intrinsic rate of population increase of insects. These factors justify the difference in value of this parameter within different experiments. Fathipour et al. (2005) reported that the rate of r_m was 20, 25, and 30°C, which is equal to 0.187, 0.226, and 0.042, respectively, whereas Satar et al. (2005) reported that the value of (r_m) of the cabbage aphid, *B. brassicae*, was 0.31 at 25°C on the white cabbage, similar to the intrinsic rate of increase (r_m) of cabbage aphid on the Snow mystique cultivar. In another study, Rivera-Ruiz et al. (1993) found that the intrinsic rate of increase (r_m) of *B. brassicae* on three cabbage cultivars was between 0.05 and 0.21. Lastly, La Rossa et al. (2005) found that the highest intrinsic and finite rate of increase of cabbage aphid on four species of Brassica was discovered on the Lzlco cultivar (0.11 and 1.12).

Nutritional quality or antibiosis resistance could account for the low value of r_m on the white clouds cultivar. The chemical content belonging to the host leaf also affects the survival and reproduction of pests. The intrinsic rate of population increase of aphids who feed on high-quality hosts is higher than that found in low-quality hosts (Dixon 1987). Cole (1997) also proposed that there was a significant relationship between the intrinsic rate of aphid and glucosinolate concentration. In summary, the low value of r_m could be justified by the high value of glucosinolate concentration in some *Brassica* cultivars.

The use of resistant cultivars is a major pest management strategy, and the resistance of cauliflower can be an effective method of reducing the intrinsic rate of population increase of cabbage aphid. According to our results, because of the high intrinsic rate of increase, finite rate of increase, and the lowest doubling time, the Smilla cultivar has been shown to be the most suitable for the purposes of cabbage aphid population growth. On the other hand, the White cloud cultivar (with the lowest rate of intrinsic increase, finite rate of increase, and high doubling time) has been shown to reduce the population of aphids on cauliflower, due to higher nymphal instar longevity of *B. brassicae*. Therefore, this cultivar can be used in pest management for aphid control and the reduction of pesticide consumption. However, because the present research was conducted under laboratory conditions, it is important to note that to attain more accurate results, further studies need to be

implemented in field conditions and on the different developmental stages of the host plant.

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References Cited

Aslam, M., M. Razaq, S. Hussain, and A. K. Pathan. 2011. Biology of cabbage aphid under laboratory conditions. Pak. J. Zool. 43: 1009–1012.

Bhatt, N., and R. Singh. 1991. Bionomics of an aphidiid parasitoid *Trioxys indicus* Subba Rao & Sharma (Hym., Aphidiidae). J. Appl. Entomol. 111: 263–269.

Blackman, R. L., and V. F. Eastop. 2000. Aphids on the world's crops: an identification and information guide, 2nd ed., 466 pp. John Wiley & Sons, Chichester, UK.

Blande, J. D., J. A. Pickett, and G. M. Poppy. 2008. Host foraging for differentially adapted Brassica-feeding aphids by the braconid parasitoid *Diaeretiella rapae*. Plant Signal. Behav. 3: 580–582.

Brich, L. C. 1948. The intrinsic rate of natural increase of an insect population. J. Anim. Ecol. 17: 15–26.

Carey, J. R. 1993. Applied demography for biologists with special emphasis on insects, 206 pp. Oxford University Press, New York, NY.

Cividanes, F. J. 2002. Age-specific life tables of *Brevicoryne brassicae* (Hemiptera: Aphididae) under field conditions. Neotrop. Entomol. 31: 419–427.

Cohen, M. B., and M. Mackauer. 1987. Intrinsic rate of increase and temperature coefficients of the aphid parasite *Ephedrus californicus* Baker (Hymenoptera: Aphidiidae). Can. Entomol. 119: 231–237.

Cole, R. A. 1997. The relative importance of glucosinolates and amino acids to the development of two aphid pests *Brevicoryne brassicae* and *Myzus persicae* on wild and cultivated *Brassica* species. Entomologia Experimentalis et Applicata 85: 121–133.

Dixon, A.F.G. 1987. Cereal aphids as an applied problem. Agric. Zool. Rev. 2: 1–57.

Eskuruchi, F., A. A. Talebi, A. Hajgozar, and S. Goldasteh. 2010. Comparison of the biological characteristics of two local populations of *Brevicoryne brassicae* (Hom.: Aphididae) on rape seed in laboratory conditions. J. Entomol. Res. Soc. Iran 2: 155–163.

Fathipour, Y., A. Hosseini, A. A. Talebi, S. Moharramipour, and S. Asgari. 2005. Effects of different temperatures on biological parameters of cabbage aphid, *Brevicoryne brassicae* (Hom.: Aphididae). J. Sci. Technol. Agric. Nat. Resour. Water Soil Sci. 9: 185–194 [In Persian].

Force, D. C., and P. S. Messenger. 1964. Fecundity, reproductive rates and innate capacity of increase of three parasites of *Therioaphis maculata* (Buckton). Ecology 45: 706–715.

Furk, C., and C. M. Hines. 1993. Aspects of insecticide resistance in the melon and cotton aphid, *Aphis gossypii* (Hemiptera: Aphididae). Ann. Appl. Biol. 123: 9–17.

Hajgozar, A. 2002. Study of biology of cabbage aphid and effect of its natural enemy in Shiraz Kolza's farms. Ph.D. dissertation, Islamic Azad University, Science and Research Branch, 145 pp [In Persian], Tehran, Iran.

Jamaya, L. M., and F. L. Ronald. 1998. *Brevicoryne brassicae* Linn. Department of Entomology, Honolulu University, HI. (http://www.extento.hawai.edu/kbase/crop/type/brevicor.htm).

Khanjani, M. 2006. Vegetable pests in Iran, 468 pp. Bu-Ali Sina University, Hamedan, Iran.

La Rossa, F., A. Vasicek, M. Lopez, M. Mendy, and A. Paglioni. 2005. Biology and demography of *Brevicoryne brassicae* (L.) on four cultivars of *Brassica oleracea* L. under laboratory condition (II). Revista de Investigaciones Agropecuarias 34: 105–114.

Meyer, J. S., C. G. Igersoll, MacL. L. Donlad, and M. S. Boyce. 1986. Estimating uncertainty in population growth rates: jackknife vs. bootstrap techniques. Ecology 67: 1156–1166.

Mirmohamadi, S. H., H. Allahyari, M. Nematolahi, A. Sabouri, S. Zarghami, and S. H. Khaghni. 2009. Effect of four oilseed rape cultivars on biological parameters and intrinsic rate of increase of cabbage aphid, *Brevicoryne brassicae* L. (Hemiptera: Aphididae). J. Sci. Technol. Agric. Nat. Resour. Water Soil Sci. 13: 749–755.

Moharramipour, S., A. Monfared, and Y. Fathipour. 2003. Comparison of intrinsic rate of increase and mean relative growth rate of cabbage aphid (*Brevicoryne brassicae* L.) on four rapeseed (*Brassica napus* L.) varieties in growth room. Agric. Sci. (Tabriz) 13: 79–86.

Rivera-Ruiz, P., N. Bautista-Martinez, M. Golunga-Garcia, and J. L. Carrillo-Sanchez. 1993. Effect of three varieties of *Brassica oleracae* on the mortality and reproduction of cabbage aphid, *Brevicoryne brassicae.* Agrociencia Serie Proteccion Vegetal 5: 25–31.

Rivnay, E. 1962. Field crop pests in the Near East.W, 450 pp. Junk Publication, Den Haag, The Netherlands.

Saldo, S., and E. Szpyrka. 2009. Ecotoxicological view of protection of apple orchards against insect pests in Poland. Pestycydy/Pesticides. (1-4): 15–26.

Satar, S., U. Kersting, and M. R. Ulusoy. 2005. Temperature dependent life history traits of *Brevicoryne brassicae* L. (Hom.: Aphididae) on white cabbage. Turk. J. Agric. Forestry 29: 341–346.

Smith, C. M. 2005. Plant resistance to arthropods. Springer, Dordrecht, The Netherlands.

SPSS Software. 2006. SPSS base 15.0 user's guide. SPSS, Chicago, IL.

Ulusoy, M. R., and S. Olmez-Bayhan. 2006. Effect of certain *Brassica* plants on biology of the cabbage aphid, *Brevicoryne brassicae* under laboratory conditions. Phytoparasitica 34: 133–138.

Wyatt, I. J., and P. F. White. 1977. Simple estimation of intrinsic increase rates for aphid and tetranychid mites. J. Appl. Ecol. 14: 757–766.

Zarpas, K. D., J. T. Margaritopoulos, L. Stathi, and J. A. Tsitsipis. 2006. Performance of cotton aphid *Aphis gossypii* (Hemiptera: Aphididae) lineages on cotton varieties. Int. J. Pest Manage. 52: 225–232.

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