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Research Article

Host plant preference and life table of *Brevicoryne brassicae* (Hemiptera: Aphididae)

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Abstract: The antibiosis, host preference in free-choice situation, and digestive enzyme activity of *Brevicoryne brassicae* L. (Hemiptera: Aphididae) were evaluated in the laboratory (25 ± 1 °C, 60 ± 5% R. H. with a 14-h day) on nine host plants: broccoli, canola (leaf, flower, and pod), cauliflower, kohlrabi, radish, red cabbage and white cabbage. The antibiosis test was based on life table parameters and the experiment started with 50 replicates for each host plant using clip cages. The immature survival varied from 34% on red cabbage to 78% on cauliflower. The viviparous aphids reared on rapeseed (flower) had the highest *GRR* and R_0 values, and those on red cabbage had the lowest *GRR* and R_0 values. Also, aphids reared on rapeseed (flower) had significantly higher r_m value. The lowest r_m value was obtained when individuals fed upon red cabbage. In host preference experiment, rapeseed (leaf) attracted the significantly higher number of adults as opposed to radish, which attracted the lower number of adults. Females who came from nymphs reared on rapeseed (flower) were heavier than other hosts. The growth index of nymphs varied from 0.035 to 0.103, with the minimum on red cabbage and the maximum on cauliflower. The amylolytic activity in adults was higher on rapeseed (flower) and the lowest on red cabbage. In addition, the highest and lowest proteolytic activity was on rapeseed (flower) and red cabbage, respectively. The results of this study indicated that red cabbage was an unsuitable host for feeding of *B. brassicae*.

Keywords: *Brassica* plants, digestive enzymes activity, life table parameters, plant resistance, the cabbage aphid.

Introduction

Brevicoryne brassicae L. (Hemiptera: Aphididae), the cabbage aphid, is one of the most destructive pests, causing damage at all growth stages of brassica plants directly by sucking and indirectly by secreting honeydew (Mirmohammadi *et al*., 2009; Bashir *et al*., 2013). Cabbage aphid is also known to be the vectors of various plant viruses (Dáder *et al*., 2017). Chemical insecticides are the primary tactic used to control the aphids (Tawfiq et al., 2010; Ali and Zedan, 2015). However, insecticide resistance and toxicity problems for human and environment caused by continuous insecticides usage have stimulated studies exploring alternative methods to control of insect pests (Foster *et al*., 2007; Saldo and Szpyrka, 2009). The study of the effects of various host plants on life table parameters and digestive physiology of pest

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can contribute to developing new control strategies such as producing plants with endogenous resistance and integrated pest management programs.

Feeding preference and performance of insects were reported to be affected by several factors. For many ectotherms, temperature and food are the primary environmental factors affecting growth and developmental rates (Ramalho *et al*., 2015; Borzoui *et al*., 2017). Plants contain all the nutrients insect herbivores require, although the amounts and ratios of macronutrients can be highly variable (Lee *et al*., 2004). The selection of host plant species relies on primary metabolites associated with the physiological conditions of the host plant, as well as, on the detection of secondary plant substances (Francis *et al*., 2001). However, insect herbivores are not always able to forage and choose between host plants. Dietary restriction in the form of intake of low-quality dietary macronutrients produces a higher mortality, as shown, for example, by recent observations in studies on aphids (Özgökçe and Athhan, 2005; Razmjou *et al*., 2006; Goldasteh *et al*., 2012; Araujo *et al*., 2016).

A life table is a convenient and fundamental method for summarizing the mortality, survival, development, age structure and fecundity of a population of animals. Using a life table, one can compare the growth potential of an insect on different host plants, under controlled environmental conditions (Razmjou *et al*., 2006; Modarres-Najafabadi *et al*., 2014; Borzoui *et al*., 2016). Ulusoy and Ölmez-Bayhan, (2006) investigated the biology of *B. brassicae* on leaves of six *Brassica* species and demonstrated that cabbage, cauliflower, and broccoli were susceptible host plants for the cabbage aphid. In contrast, rapeseed, turnip, and mustard showed resistance to the pest. Bashir *et al*., (2013) studied the effect of texture/morphology of host plants on the biology of *B. brassicae* and reported that Cauliflower is a suitable host for the development and feeding of this pest. Aziz *et al*., (2016) evaluated the effect of different *Brassica* vegetables on biology and demographic parameters of *B. brassicae* and reported a significantly higher intrinsic rate of increase (r_m) and finite rate of increase (λ) on China cabbage followed by Broccoli and Cabbage.

Although cited studies have dealt with biology and life table parameters of *B. brassicae*, results have been variable, and issues such as the relationship between life history and digestive physiology of insect have not been examined. For example, it is not known whether nitrogen content of leaves that the insects feed during their lifespan are important determinants of survival and offspring production. Such information, which takes into account the age structure of the population, is requisite to creating baseline population growth models. Our objectives were to examine the effect of seven brassicaceous host plants on the physiological and biological traits of cabbage aphid.

Materials and Methods

Plants

The seeds of various host plants including broccoli, canola (leaf, flower, and pod), cauliflower, kohlrabi, radish, red cabbage and white cabbage were obtained from the Plant and Seed Improvement Research Institute, Karaj, Iran.

The plants grown were carried out at 25 ± 5 °C with a natural photoperiod in a greenhouse, and they were irrigated as needed. Plants that individually planted in plastic pots (19cm in diameter by 21cm in depth) filled with a suitable mixture of soil (2: 1: 1 field soil, sand, and animal manure, respectively) were used for the experiments. When *Brassica* plants reached the six-leaf stage, the experiments were started. For rapeseed-flower and rapeseed-pod hosts, the plants were used in the reproductive stage. The pots were arranged in a randomized complete block design and protected by muslin (50 meshes) to prevent insect attack.

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Insects

A colony of *B. brassicae* used in the experiment was originally obtained from Kohlrabi fields in Ardabil (Iran), on Jun 2016. Stock culture was initiated on Chinese cabbage sown in plastic pots inside a growth chamber under experimental conditions (25 ± 1 °C, 60 ± 5% relative humidity with a 14h day length). Every 2 weeks, 10-15 aphids were transferred from an infested Chinese cabbage to a healthy Chinese cabbage to maintain the colony. After colonization for more than ten months, apterous virginoparous aphids were used for the experiments.

Bioassays

Experiments were conducted in a growth chamber at 25 ± 1 °C, 60 ± 1% relative humidity with a 14 h day length during the morning and afternoon mid-May to mid-July 2017.

Antibiosis experiment A single young apterous female (within 24 h) from the stock colony was transferred onto each leaf caged with a Petri dish (6cm in diameter by 1cm in depth). The Petri dishes were attached to leaves by clips. Females were allowed to produce nymphs for 12h; after that, the adult aphid and all nymphs except for one nymph were removed from the cages. Individual nymphs were daily monitored to assess their developmental time and survival. After the immature became an adult, the duration of pre-reproductive, reproductive, post-reproductive time and adult longevity, as well as the reproduction of females, were daily recorded. During the reproductive period, all offspring were removed from the caged plant. Observations were continued until all females died. Experiments were started with 50 replicates for each host plant, but only the individuals that survived to adulthood were included in calculations of nymph development time.

Host preference experiment In order to determine the host preference of *B. brassicae* in a free-choice situation, plants that planted in plastic pans (40 cm in diameter by 15cm in depth) filled with a suitable mixture of soil (2: 1: 1 field soil, sand, and animal manure, respectively) were used for this experiment. The pots were arranged in a randomized complete block design and protected by muslin (50 meshes) to prevent insect attack. When *Brassica* plants reached the VI stage, the experiments were started. One hundred apterous females were randomly collected from the rearing chambers and starved for 2h. Aphids were released on a filter paper (11cm in diameter) placed at the center of the circle of plants. The number of apterous females on each plant was counted and recorded after 24h. This experiment was replicated five times.

Mass of females One hundred apterous females (within 24 h) came from nymphs reared on *Brassica* plants were randomly collected and weighed. This experiment was replicated five times.

Population growth index When *Brassica* plants reached the VI stage, caged hosts were infested with twenty 1^{st} instar nymphs (within 24h) per experimental cage. All the aphids remained on the upside of the leaves throughout the duration of the experiment. Population growth was measured in terms of the number of nymphs that became adults and the time is taken to reach the adult stage using the following formula (Saxena *et al.*, 1974; Carey, 1993): GI = l_x/T; where l_x = survival rate of nymphs, T = duration of the nymphal period. This experiment was replicated five times.

Enzyme activity in aphids

Chemicals

Substrates, buffers and reagents were purchased from Sigma Chemical Co. (St. Louis, USA).

Enzyme preparation The apterous female aphids (within 24-48h) fed on each *Brassica* plant were water rinsed and ice chilled for dissection in distilled water at 4 °C. The body of aphids was drilled in pre-cooled distilled

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water and homogenized on ice using a pre-cooled homogenizer (Teflon pestle). The extracts were subsequently centrifuged (Eppendorf Microcentrifuge 5415 R, Eppendorf Co., USA) at 15,000*g* for 15min at 4 °C and the resulting supernatant was used as the enzyme source.

Amylolytic activity The dinitrosalicylic acid (DNS) method (Bernfeld, 1955) was used to assay the digestive amylolytic activity of *B. brassicae* adults fed on various *Brassica* plants. In brief, 20µl of enzyme extract from 100 individuals along with 40µl of 1% soluble starch as substrate and 500µl of ice-cold 20 mM Tris-HCl buffer (pH 8.0; data not shown) containing 0.1mM $CaCl_2$ was incubated at 37 °C for 30min and reducing sugars formed was determined. The reaction was stopped by adding 100mL of DNS and heating in boiling water for 10min. The absorbance was read at 540nm after cooling on ice. Amylolytic activity was expressed as µg of producing maltose per individual. Blanks, in which enzyme extract was added after DNS, were prepared for each assay. This experiment was replicated five times.

Proteolytic activity The general proteolytic activity of *B. brassicae* adults fed on various *Brassica* plants was assayed by azocasein digestion method (Gatehouse *et al*., 1999; Elpidina *et al*., 2001). Azocasein (1.5% w/v) dissolved in 50 mM acetate buffer (pH 6.0; data not shown) was used as substrate. In brief, 50µl of enzyme extract from 100 individuals was incubated with 80µl of azocasein at 37 °C. The reaction was stopped 50min later by adding 100µl of 30% trichloroacetic acid (TCA). Precipitation was caused by cooling at 4 °C for 30min and the reaction mixture was centrifuged at 15000 *g* for 10min. At the end, 100µl of the supernatant was added to the equal amount of 2 M NaOH and the absorbance was read at 440nm. Blanks, in which TCA was added before the substrate, were prepared for each assay. This experiment was replicated five times.

Experimental design and statistical analysis
The development time, immature survival rate and adult fecundity were used to the calculation of life table parameters. Calculations were made for age-specific survival rate (l_x) and age-specific fecundity (m_x) of *B. brassicae* on various Brassica plants based on the method of Carey, (1993). Estimates were made for the intrinsic rate of natural increase (r_m) for *B. brassicae* on various *Brassica* plants (Birch, 1948). The other parameter obtained from the life table was the gross reproductive rate (*GRR*), net reproductive rate (R_0), intrinsic rate of increase (r_m), finite rate of increase (λ), mean generation time (*T*), and doubling time (*DT*), which was calculated as described by Birch, (1948) and Southwood and Henderson, (2000).

The duration of life stages of aphids, reproduction, the mass of females, growth index and physiological parameters were compared between the eight *Brassica* plants and one-way analysis of variance was done in Tukey's HSD test (0.05%) using SAS 9.2 software (PROC GLM; SAS Institute, 2009). Differences in r_m, R_0, *T*, DT, and λ values were tested for significance using the Jackknife procedure (Maia *et al*., 2000). Jackknife pseudo-values computed for life table parameters on eight *Brassica* plants were analyzed by one-way ANOVA and the means were compared using Tukey's test (0.05%) using SAS 9.2 software. Correlation analysis of the life table parameters, population growth index and feeding efficacy and enzyme activities of *B. brassicae* fed on various *Brassica* plants with the nitrogen content of host plants was performed using SPSS 16.0.

Results

Growth and reproductive capacity
Nymphal period and adult longevity of *B. brassicae* on the various host plants is given in Table 1. Nymphs reared on cauliflower (7.72 days) developed significantly faster than those on any other host plants. In

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contrast, the individuals reared on radish (10.71 days) had a significantly longer nymphal period. The longevity of females was also different on *Brassica* plants tested. The record for female longevity was longest when *B. brassicae* was reared on rapeseed (flower) (15.38 days) and were shortest when it was reared on red cabbage (4.94 days).

Most females began to reproduce nymphs after 24h of emergence. Various host plants significantly affected fecundity of *B. brassicae* (Table 1). The data revealed that the highest fecundity was recorded for female developed from nymphs reared on rapeseed (flower) (60.13 nymphs), while the lowest was on red cabbage (7.00 nymphs). Also, the mean number of nymphs produced per female per day on rapeseed (flower) (3.91 nymphs) was significantly higher than that of nymphs on the other *Brassica* plants (Table 1). In most cases, the reproduction periods were smaller than adult longevity.

Table 1 Developmental time, adult longevity, mean number of nymphs, and fecundity of *Brevicoryne brassicae* reared on *Brassica* plants.

Brassica plants	n[1]	Nymphal period (day)	Adult longevity (day)	Mean number of nymphs/aphid/day	Total number of offspring/female
Broccoli	64	8.72 ± 0.22 bc	11.19 ± 0.35 b	2.64 ± 0.07 e	30.00 ± 1.50 de
Cauliflower	78	7.72 ± 0.17 c	14.20 ± 0.40 a	3.15 ± 0.04 bcd	44.70 ± 1.35 bc
Kohlrabi	56	8.93 ± 0.26 b	8.11 ± 0.26 c	2.92 ± 0.09 d	24.10 ± 1.40 e
Radish	48	10.71 ± 0.34 a	6.79 ± 0.33 c	2.29 ± 0.08 f	15.92 ± 1.10 f
Rapeseed (flower)	74	8.00 ± 0.17 bc	15.38 ± 0.34 a	3.91 ± 0.03 a	60.13 ± 1.45 a
Rapeseed (leaf)	72	8.33 ± 0.17 bc	15.28 ± 0.35 a	3.30 ± 0.04 b	50.89 ± 1.66 b
Rapeseed (pod)	62	8.61 ± 0.20 bc	12.52 ± 0.43 b	3.23 ± 0.04 bc	40.32 ± 1.34 c
Red cabbage	34	10.12 ± 0.51 a	4.94 ± 0.36 d	1.40 ± 0.06 g	7.00 ± 0.67 g
White cabbage	68	8.62 ± 0.20 bc	11.09 ± 0.25 b	2.99 ± 0.06 cd	33.47 ± 1.30 d
df		8, 269	8, 269	8, 269	8, 269
F		14.64	93.89	114.76	122.41
P		< 0.01	< 0.01	< 0.01	< 0.01

The means followed by different letters in the same column are significantly different (Turkey's test, $P < 0.05$).
[1] The n value shows the sample size for each parameter.

The age-specific survival rate (l_x) and age-specific fecundity rate (m_x) of *B. brassicae* on *Brassica* plants tested is presented in Fig. 1 and 2. The l_x of aphid started to drop earlier on radish and red cabbage in comparing with other hosts (Fig. 1). The width of the m_x peak, i.e., the fecundity period, was narrower on red cabbage than on other hosts (Fig. 2).

Life tables on various host plants

The gross reproductive rate (*GRR*), net reproductive rate (R_0), intrinsic rate of increase (r_m), finite rate of increase (λ), mean generation time (T), and doubling time (DT) were calculated for *B. brassicae* populations on *Brassica* plants tested (Table 2). The viviparous apterae reared on rapeseed (flower) (73.08 female/female) had the highest *GRR* value, and those on red cabbage (12.62 female/female) had the lowest *GRR* value. The R_0 was highest when *B. brassicae* was reared on rapeseed (flower) (60.13 female/female) and were shortest when it was reared on red cabbage (7.00 female/female).

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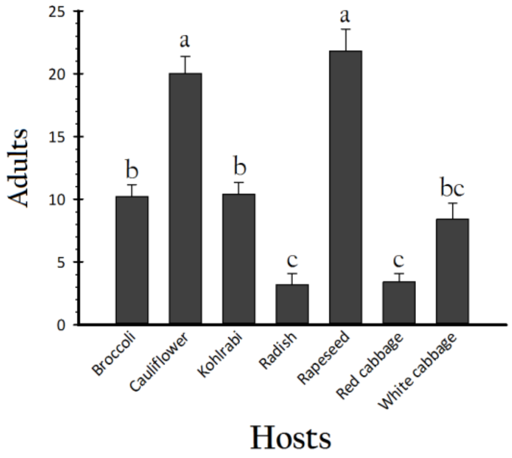

Figure 1 Age-specific survival rate of *Brevicoryne brassicae* caged on different *Brassica* plants.

The r_m values ranged from 0.33 to 0.16 female progenies per female per day on *Brassica* plants tested. Aphids reared on rapeseed (flower) had significantly higher r_m value. The lowest r_m value was obtained when individuals fed upon red cabbage. The variations in the finite rate of increase (λ) were similar to the intrinsic rate of increase, and the former parameter was significantly influenced by *Brassica* plants tested. The mean generation time (T) was lowest for *B. brassicae* reared on cauliflower (11.80 days), mainly because of the shorter developmental period. The time required for doubling the population (DT) was shorter on rapeseed (flower) (2.09 days).

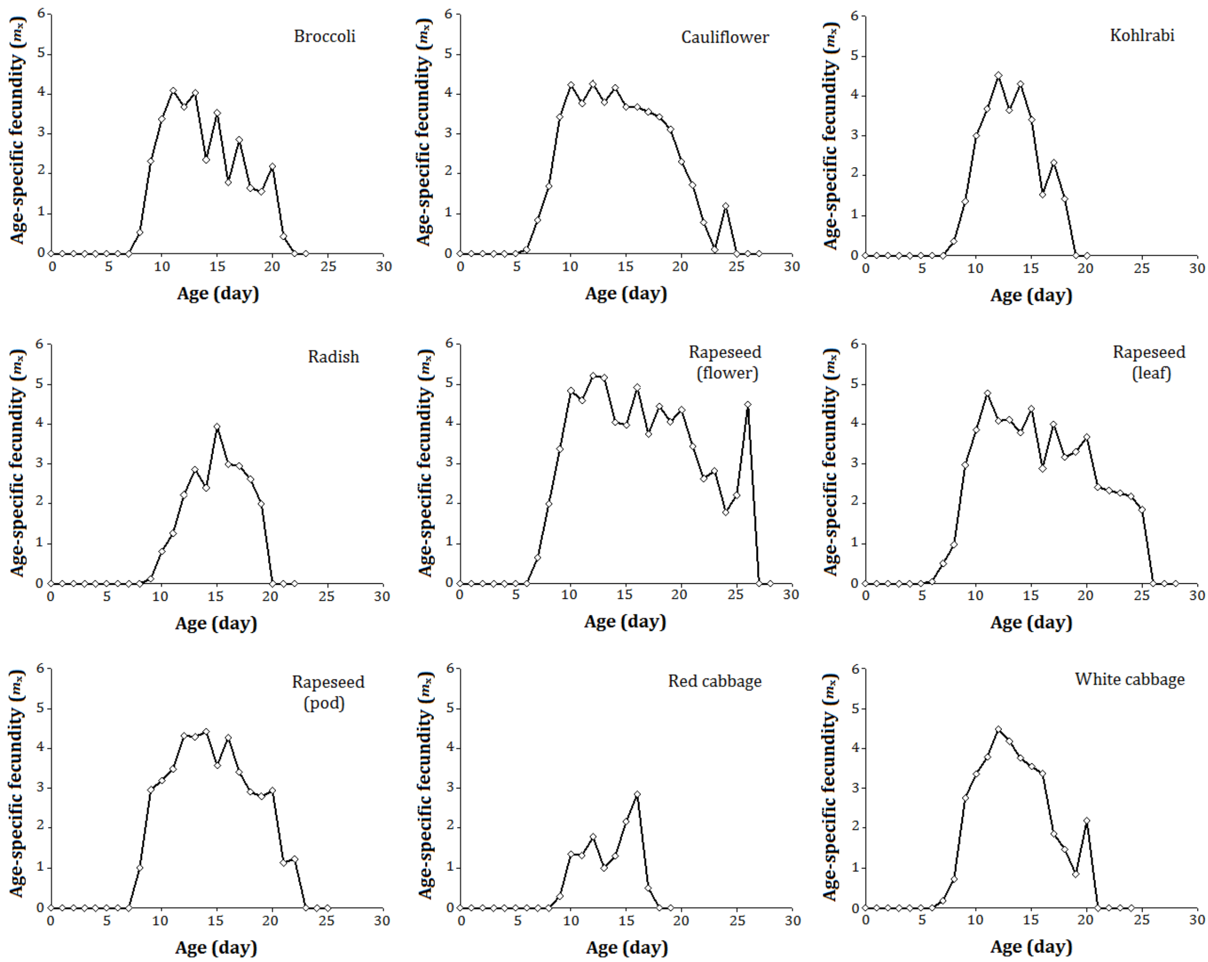

Figure 2 Female offspring production by *Brevicoryne brassicae* caged on different *Brassica* plants.

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Table 2 Life table parameters of *Brevicoryne brassicae* reared on *Brassica* plants.

Brassica plants	n^1	*GRR*	R_0	r_m	λ	*T*	*DT*
Broccoli	64	34.43 ± 1.57 d	30.00 ± 1.49 de	0.28 ± 0.03 cd	1.32 ± 0.05 cd	12.25 ± 0.21 b	2.50 ± 0.04 cd
Cauliflower	78	50.17 ± 1.96 bc	44.74 ± 1.36 bc	0.32 ± 0.05 a	1.38 ± 0.07 a	11.80 ± 0.22 b	2.15 ± 0.04 e
Kohlrabi	56	29.59 ± 1.27 de	24.07 ± 1.39 e	0.27 ± 0.03 d	1.30 ± 0.07 d	11.93 ± 0.26 b	2.60 ± 0.06 c
Radish	48	24.31 ± 1.51 e	15.92 ± 1.09 f	0.20 ± 0.05 e	1.22 ± 0.06 e	12.63 ± 0.40 a	3.41 ± 0.09 b
Rapeseed (flower)	74	73.08 ± 2.33 a	60.13 ± 1.45 a	0.33 ± 0.05 a	1.39 ± 0.07 a	12.38 ± 0.23 b	2.09 ± 0.04 e
Rapeseed (leaf)	72	57.68 ± 1.69 b	50.89 ± 1.66 b	0.31 ± 0.05 ab	1.36 ± 0.06 ab	12.65 ± 0.26 ab	2.23 ± 0.04 de
Rapeseed (pod)	62	46.00 ± 1.49 c	40.32 ± 1.34 c	0.29 ± 0.04 bc	1.34 ± 0.06 bc	12.54 ± 0.21 ab	2.35 ± 0.04 cde
Red cabbage	34	12.62 ± 1.00 f	7.00 ± 0.67 g	0.16 ± 0.08 f	1.17 ± 0.09 f	12.04 ± 0.44 b	4.27 ± 0.24 a
White cabbage	68	36.73 ± 1.72 d	3.47 ± 1.30 d	0.29 ± 0.04 bc	1.34 ± 0.05 bc	12.00 ± 0.17	2.37 ± 0.04 cde
df		8, 269	8, 269	8, 269	8, 269	8, 269	8, 269
F		95.30	122.41	85.60	81.77	4.15	85.82
P		< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01

The means followed by different letters in the same column are significantly different (Turkey's test, $P < 0.05$).
[1] The *n* value shows the sample size for each parameter.

Host preference in free-choice situation
The number of adult aphids attracted to various host plants showed that there was a significant difference among *Brassica* plants ($F_{6,28} = 38.97$; $P < 0.01$). In 24h, rapeseed (leaf) (21.8 aphids) attracted the significantly higher number of *B. brassicae* aphids as opposed to radish (3.2 aphids), which attracted the lower number of aphids (Fig. 3).

Mass of females
The results of females' weight of *B. brassicae* on different *Brassica* plants are shown in Table 3. The females which came from nymphs reared on rapeseed (flower) were heavier (108.68mg) than those reared on any other hosts. By contrast, the lowest mass of *B. brassicae* females was seen in the insects that came from nymphs reared on red cabbage (37.22mg).

Population growth index
The growth index of nymphs varied from 0.035 to 0.103, with the minimum on red cabbage and the maximum on cauliflower (Table 3).

Midgut enzymes activity on various host plants
Amylolytic Activity The amylolytic activity of the adults of *B. brassicae* on various host plants is given in Fig. 4. Tested *Brassica* plants significantly affected digestive α-amylase activity in this insect ($F_{8, 18} = 27.64$; $P < 0.01$). The amylolytic activity in females was higher on rapeseed (flower) (0.107 mU/min/individual) than on other hosts. However, amylolytic activity was the lowest when the insects were reared on red cabbage (0.034 mU/min/individual).

General proteolytic Activity The general proteolytic activity of the adults of *B. brassicae* on various host plants is given in Fig. 4. Tested *Brassica* plants also affected digestive proteolytic activity in this insect ($F_{8,18} = 6.02$; $P = 0.008$). The females reared on rapeseed (flower) (0.0083 OD/min/individual) demonstrated the highest level of proteolytic activity, whereas the lowest activity was in the females reared on red cabbage (0.0024 OD/min/individual).

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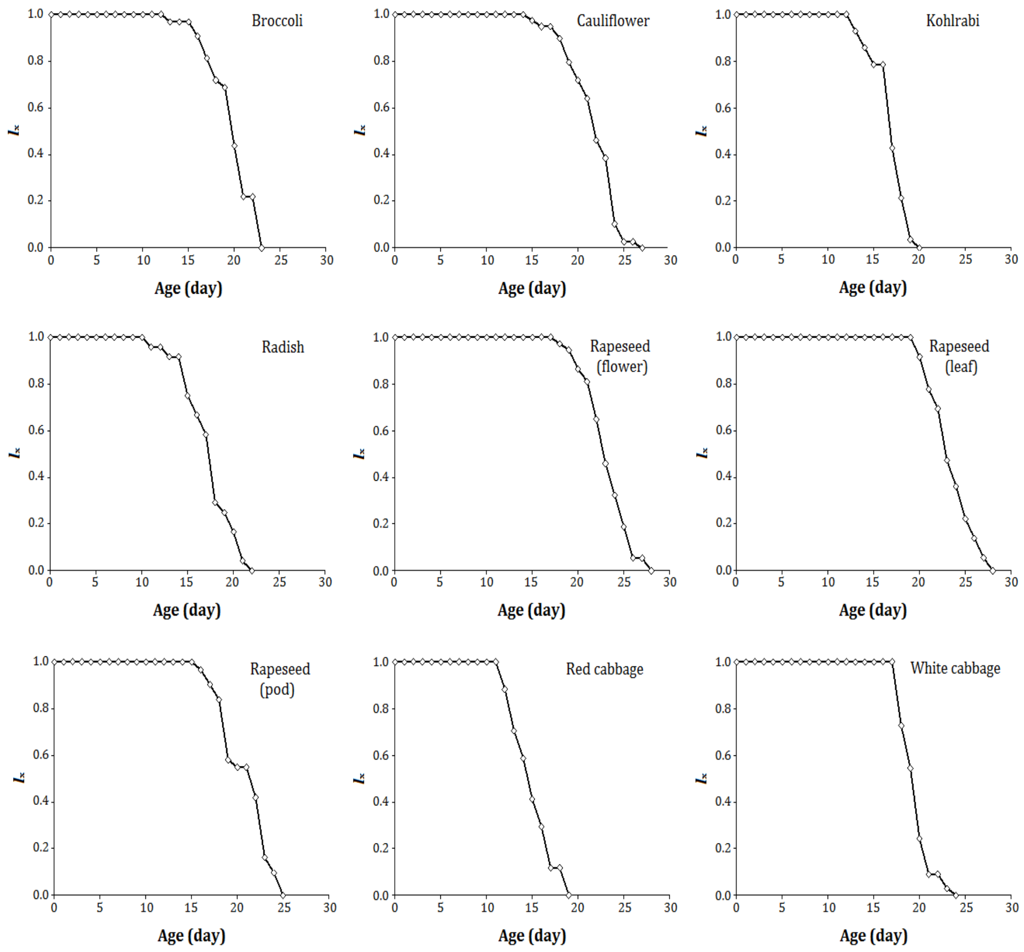

Figure 3 The number (mean ± SE) of *Brevicoryne brassicae* apterous adults (n = 5) selecting different *Brassica* plants after 24h.

Table 3 Mass of females and growth index of *Brevicoryne brassicae* reared on *Brassica* plants.

Brassica plants	n^1	Mass of females (mg)	n	Growth index
Broccoli	5	52.56 ± 46 d	64	0.075 ± 0.002 d
Cauliflower	5	96.48 ± 0.63 b	78	0.103 ± 0.002 a
Kohlrabi	5	46.38 ± 0.58 e	56	0.064 ± 0.002 e
Radish	5	45.34 ± 0.63 e	48	0.046 ± 0.001 f
Rapeseed (flower)	5	108.68 ± 1.28 a	74	0.094 ± 0.002 ab
Rapeseed (leaf)	5	94.06 ± 0.68 b	72	0.088 ± 0.002 bc
Rapeseed (pod)	5	74.40 ± 0.61 c	62	0.073 ± 0.002 de
Red cabbage	5	37.22 ± 0.59 f	34	0.035 ± 0.001 g
White cabbage	5	53.62 ± 0.73 d	68	0.080 ± 0.002 cd
df		8, 36		8, 269
F		133.52		101.64
P		< 0.01		< 0.01

The means followed by different letters in the same column are significantly different (Turkey's test, P < 0.05).
[1] The n value shows the sample size for each parameter.

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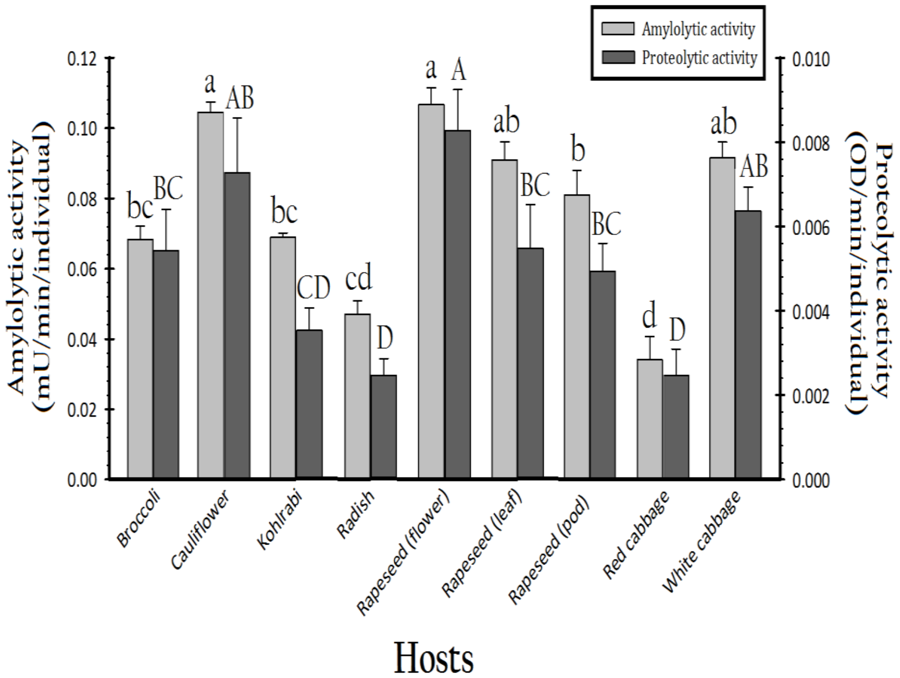

Figure 4 Mean (± SE) amylolytic and proteolytic activity (n = 5) in the gut extract of *Brevicoryne brassicae* adults reared on different *Brassica* plants.

Discussion

Quality of host plant affected both development and reproduction among individual *B. brassicae* in this study. Feeding on radish and rapeseed, as unsuitable hosts, was improved lower performance in *B. brassicae* as compared to other hosts. Nymphs developed slower on these hosts, suggesting that those had not relatively optimal nutrition and/or higher concentration of secondary metabolites. Cole, (1996) showed that increased concentrations of 2-phenylethylglucosinolate in *Brassica* species cause the resistance of plants to *B. brassicae*.

In the present study, females reared on red cabbage showed substantially reduced longevity and were not able to produce significant numbers of nymphs. Probably, quality of host plant plays a decisive role in reproduction of *B. brassicae*. Ulusoy and Olmez-Bayhan, (2006) reported that female longevity of *B. brassicae* varied between 6.2 days on turnip and 21.8 days on cauliflower. Ellis and Farrell, (1995) reported that different fecundity of *B. brassicae* on host plants can be attributed to differences in the levels of resistance or sensitivity of the plants.

In this study, the decreased age-specific survival rate (l_x) of *B. brassicae* on red cabbage and radish may be because of lower nutritional quality and the presence of inhibitors, as a more appropriate food usually increases survival rate (Goławska *et al*., 2012; Borzoui *et al*., 2017), as observed for the nymphal period of *B. brassicae* on both rapeseed (flower).

The low immature survival, low female longevity, and reduced reproduction of *B. brassicae* on red cabbage and radish observed in the present study may possibly be attributed to the presence of antibiosis in these hosts. Munthali and Tshegofatso, (2014) reported that the chemical contents of the sap and physical characteristics of plants affect development rate, survival, and the reproductive potential of *B. brassicae*.

The R_0 and r_m, both of which are important indicators of the combined effect of host plant on development, survivorship, and reproduction of aphids, were lowest on red cabbage. The lower values of those parameters on red

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cabbage were mainly due to longer development time, a later peak in reproduction, low daily nymph production, and low total fecundity. The results regarding the R_0 and r_m of *B. brassicae* did not agree with those achieved by Ulusoy and Olmez-Bayhan, (2006) on different *Brassica* plants. Such discrepancy might be attributed to genetic variation in populations, variation in quality of tested hosts, and variations in experimental conditions and cultivars used for the feeding of this pest. Population *DT* was longer for aphids reared on red cabbage than for those reared on rapeseed (flower) and cauliflower, due to the lower r_m on this plant. We believe that the differences in life table parameters of *B. brassicae* on experimental plants can be attributed to differences in the nutritional quality and the differences in the physiology and biochemical structure of the host plants tested.

In the antixenosis experiment, radish and red cabbage were host plants with the statistically lower number of females than the number of females found on the susceptible checks 24h after aphid release, indicating a strong antixenotic effect of these plants to *B. brassicae*. Factors responsible for such antixenotic in these plants against *B. brassicae* remain unknown. Several factors of plants including plant architecture, chemical structure, the color of leaf, and secondary metabolites probably cause host preference of *B. brassicae*. Diaz-Montano *et al*., (2006) reported that a strong less host preference may result in a reduction of antibiosis parameters.

Growth index and body weight is an important fitness indicator of population dynamics of insects (Liu *et al*., 2004; Hosseininejad *et al*., 2015). According to results of this study, growth index of individuals reared on red cabbage was also reduced and aphids were smaller at maturity than individuals reared on other host plants; suggesting that the quality of host plant have the main effect on the fitness of *B. brassicae*.

This study is the first attempt to characterize digestive α-amylase and general protease activity of *B. brassicae* in response to feeding on various host plants. Both amylolytic and proteolytic activity was detected in the gut of *B. brassicae* adults as reported for other aphids (Cristofoletti *et al*., 2003; Pyati *et al*., 2011; Darvishzadeh *et al*., 2014). Also, α-amylase and general protease differentially expressed between aphids grown on various host plants. Higher gut amylolytic and proteolytic activity in rapeseed (flower) and cauliflower–reared insects as compared to those reared on radish and red cabbage, i.e., the gut enzymes level was proportional to the quality of the host plans. This supports earlier observations that quality of food is the main factor that has a direct effect on digestive enzymes activity responsible for providing energy and nutrition to the growing insects (Sivakumar *et al*., 2006; Borzoui *et al*., 2018). In this case, the differences obtained in digestive enzyme activity may be due to the different concentrations of enzyme inhibitors, especially lectins (Cole, 1997; Napoleão *et al*., 2012; Kumar *et al*., 2012).

In conclusion, resistant plants play a key role in IPM programs. Therefore, identification of resistant plants is the first step in the development of an IPM program. According to results obtained in this study, rapeseed and cauliflower appeared to be the most favorable hosts for *B. brassicae* among the host plants tested. Also, we found a close and positive association between quality of the host plant suitability and the enzyme's activity. These findings might provide useful information for mass producing *B. brassicae* prey, in insectaries or under laboratory conditions, for release in augmentative biological control programs. However, additional studies are required on the chemical composition of the sap and the performance of *B. brassicae* on different host plants in the field, and the effect of the plants tested on the effectiveness of the natural enemies of this pest.

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References

Araujo, E. S., Benatto, A., Mógor, Á. F., Penteado, S. C. and Zawadneak, M. A. C. 2016. Biological parameters and fertility life table of *Aphis forbesi* Weed, 1889 (Hemiptera: Aphididae) on strawberry. Brazilian Journal of Biology, 76 (4): 937-941.

Aziz, M. A., Irfan, M., Bodlah, I. and Hanif, M. 2016. Effect of different brassica vegetables on biology and demographic parameters of *Brevicoryne brassicae* (Homoptera: Aphididae) under laboratory conditions. Asian Journal of Agriculture and Biology, 4 (1): 17-24.

Bashir, F., Azim, N. M., Akhter, N. and Muzaffar, G. 2013. Effect of texture/morphology of host plants on the biology of *Brevicoryne brassicae* (L.) (Homoptera: Aphididae). International Journal of Current Research, 5 (2): 178-180.

Bernfeld, P. 1955. Amylases, α and β. Methods in Enzymology, 1: 149-158.

Birch, L. C. 1948. The intrinsic rate of natural increase of an insect population. Journal of Animal Ecology, 17: 15-26.

Tawfiq, M., Ateyyat, M. A. and Abussamin, B. M. 2010. Toxicity of certain insecticides to the parasitoid *Diaeretiella Rapae* (Mcintosh) (Hymenoptera: Aphidiidae) and its host, the cabbage aphid *Brevicoryne Brassicae* L. (Homoptera: Aphididae). Australian Journal of Basic and Applied Sciences, 4 (6): 994-1000.

Kumar, K. K., Chandra, K L. P., Sumanthi, J., Reddy, G. S., Shekar, P. C. and Reddy, B. V. R. 2012. Biological role of lectins: A review. Journal of Orofacial Science, 4 (1): 20-25.

Borzoui, E., Bandani, A. R., Goldansaz, S. H. and Talaei-Hassanlouei, R. 2018. Dietary protein and carbohydrate levels affect performance and digestive physiology of *Plodia interpunctella*. Journal of Economic Entomology, In press.

Borzoui, E., Naseri, B. and Nouri-Ganbalani, G. 2017. Effects of food quality on biology and physiological traits of *Sitotroga cerealella* (Lepidoptera: Gelechiidae). Journal of Economic Entomology, 110 (1): 266-273.

Borzoui, E., Naseri, B., Abedi, Z. and Karimi-Pormehr, M. S. 2016. Lethal and sublethal effects of essential oils from *Artemisia khorassanica* and *Vitex pseudo-negundo* against *Plodia interpunctella* (Lepidoptera: Pyralidae). Environmental Entomology, 45 (5): 1220-1226.

Carey, J. R. 1993. Applied Demography for Biologists with Special Emphasis on Insects. Oxford University Press, New York.

Cividanes, E. J. 2002. Age-specific life tables of *Brevicoryne brassicae* (L.) (Hemiptera: Aphididae) under field conditions. Neotropical Entomology, 31 (3): 419-427.

Cole, R. 1996. Abiotic induction of changes to glucosinolate profiles in *Brassica* species and increased resistance to the specialist aphid *Brevicoryne brassicae*. In: Städler, E., Rowell-Rahier, M. and Bauer, R. (eds). Proceedings of the 9_{th} International Symposium on Insect-Plant Relationships. Series Entomologica, Vol 53. Springer, Dordrecht. pp. 228-230.

Cole, R. A. 1997. Comparison of feeding behaviour of two *Brassica* pests *Brevicoryne brassicae* and *Myzus persicae* on wild and cultivated brassica species. Entomologia Experimentalis et Applicata, 85 (2): 135-143.

Cristofoletti, P. T., Ribeiro, A. F., Deraison, C., Rahbe´, Y. and Terra, W. R. 2003. Midgut adaptation and digestive enzyme distribution in a phloem feeding insect, the pea aphid *Acyrthosiphon pisum*. Journal of Insect Physiology, 49 (1): 11-24.

Dáder, B., Then, C., Berthelot, E., Ducousso, M., Ng, J.C.K. and Drucke, M. 2017. Insect transmission of plant viruses: Multilayered interactions optimize viral propagation. Insect Science, 24 (6): 929-946.

Darvishzadeh, A., Bandani, A. R. and Mousavi, S. Q. 2014. Biochemical characterisation of α-amylase in two aphid species, *Aphis fabae* Scopoli (Hemiptera: Aphididae) and *A. gossypii* Glover (Hemiptera: Aphididae). Plant Protection Science, 5 0(2): 84-89.

[DOR: 20.1001.1.22519041.2019.8.2.1.3]

Ali, R. A. E. and Zedan, O. A. A. 2015. Selectivity of certain insecticides for controlling the cabbage aphid *Brevicoryne brassicae* (L.) and their effect on some predatory insects on cauliflower fields in El-Minia region-upper Egypt. Journal of Plant Protection and Pathology, 6 (10): 1427-1437.

Ellis, P. R. and Farrell, J. A. 1995. Resistance to cabbage aphid (*Brevicoryne brassicae*) in six brassica accessions in New Zealand. New Zealand Journal of Crop and Horticultural Science, 23 (1): 25-29.

Elpidina, E. N., Vinokurov, K. S., Gromenko, V. A., Rudenskaya, Y. A., Dunaevsky, Y. E. and Zhuzhikov, D. P. 2001. Compartmentalization of proteinases and amylases in *Nauphoeta cinerea* midgut. Archives of Insect Biochemistry and Physiology, 48 (4): 206-216.

Foster, S. P., Devine, G. and Devonshire, A. L. 2007. Insecticide resistance. In: van Emden H. F., and R. Harrington (eds) Aphids as crop pests. CAB International, Wallingford, pp. 261-278.

Francis, F., Haubruge, E., Hastir, P. and Gaspar, C. 2001. Effect of aphid host plant on development and reproduction of the third trophic level, the predator *Adalia bipunctata* (Coleoptera: Coccinellidae). Environmental Entomology, 30 (5): 947-952.

Gatehouse, A. M., Norton, E., Davison, G. M., Babbe, S. M., Newell, C. A. and Gatehouse, J. A. 1999. Digestive proteolytic activity in larvae of tomato moth, *Lacanobia oleracea*, effects of plant protease inhibitors *in vitro* and *in vivo*. Journal of Insect Physiology, 45 (6): 545-558.

Goławska, S., Łukasik, I., Wójcicka, A. and Sytykiewicz, H. 2012. Relationship between saponin content in alfalfa and aphid development. Acta Biologica Cracoviensia. Series: Botanica, 54 (2): 39-46.

Goldasteh, S., Talebi, A. A., Rakhshani, E. and Goldasteh, S. 2012. Effect of four wheat cultivars on life table parameters of *Schizaphis graminum* (Hemiptera: Aphididae). Journal of Crop Protection, 1 (2): 121-129.

Golizadeh, A., Abedi, Z., Borzoui, E., Golikhajeh, N. and Jafary, M. 2016. Susceptibility of five sugar beet cultivars to the black bean aphid, *Aphis fabae* Scopoli (Hemiptera: Aphididae). Neotropical Entomology, 45 (4): 427-32.

Hosseininejad, A. S. and Naseri, B. 2015. Nutritional and growth indices of *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) on different corn hybrids. Arthropod Plant Interaction, 9 (6): 633-640.

Lee K. P., Raubenheimer, D. and Simpson, S. J. 2004. The effects of nutritional imbalance on compensatory feeding for cellulose-mediated dietary dilution in a generalist caterpillar. Physiological Entomology, 29 (2): 108-117.

Liu, Z. D., Li, D. M., Gong, P. Y. and Wu, K. J. 2004. Life table studies of the cotton bollworm, *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae), on different host plants. Environmental Entomology, 33 (6): 1570-1576.

Maia, A. H. N., Alferdo, J. B. L. and Campanhola, C. 2000. Statistical inference on associated fecundity life table parameters using jackknife technique: computational aspects. Journal of Economic Entomology, 93 (2): 511-518.

Mirmohammadi, S., Allahyari, H., Nematollahi, M. R. and Saboori, A. 2009. Effect of host plant on biology and life table parameters of *Brevicoryne brassicae* (Hemiptera: Aphididae). Annals of the Entomological Society of America, 102 (3): 450-455.

Modarres-Najafabadi, S. S., Vafaei Shoushtari, R., Zamani, A. A., Arbabi, M. and Farazmand, H. 2014. Life parameters of *Tetranychus urticae* (Acari: Tetranychidae) on six common bean cultivars. Journal of Economic Entomology, 107 (2): 614-622.

Munthali D. C. and Tshegofatso, A. B. 2014. Factors affecting abundance and damage caused by cabbage aphid, *Brevicoryne brassicae* on four brassica leafy vegetables: *Brassica oleracea* var. *acephala*, *B. chinense*, *B. napus* and *B. carinata*. The Open Entomology Journal, 8: 1-9.

[DOR: 20.1001.1.22519041.2019.8.2.1.3]

Napoleão, T. H., Pontual, E. V., Lima, T. A., Santos, N. D. L., Araújo Sá, R., Coelho, L. C. B. B., Navarro, D. M. A. F. and Paiva, P. M. G. 2012. Effect of *Myracrodruon urundeuva* leaf lectin on survival and digestive enzymes of *Aedes aegypti* larvae. Parasitology Research, 110 (2): 609-616.

Özgökçe, M. S. and Athhan, R. 2005. Biological features and life table parameters of the mealy plum aphid *Hyalopterus pruni* on different apricot cultivars. Phytoparasitica, 33 (1): 7-14.

Pyati, P., Bandani, A. R., Fitches, E. and Gatehouse, J. A. 2011. Protein digestion in cereal aphids (*Sitobion avenae*) as a target for plant defense by endogenous proteinase inhibitors. Journal of Insect Physiology, 57 (7): 881-891.

Ramalho F. S., Malaquias, J. B., Lira, A. C. S., Oliveira, F. Q., Zanuncio, J. C. and Fernandes, F. S. 2015. Temperature-dependent fecundity and life table of the fennel aphid *Hyadaphis foeniculi* (Passerini) (Hemiptera: Aphididae). PLoS ONE 10 (4): e0122490.

Razmjou J., Moharramipour, S., Fathipour, Y. and Mirhoseini, S. Z. 2006. Effect of cotton cultivar on performance of *Aphis gossypii* (Hom.: Aphididae) in Iran. Journal of Economic Entomology, 99 (5): 1820-1825.

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

SAS Institute. 2009. SAS/STAT 9.2 User's guide, 2nd edn. SAS Institute Inc, Cary, NC, USA.

Saxena, K. N., Gandhi, J. R. and Saxena, R. C. 1974. Patterns of relationship between certain leafhoppers and plants. Part I. Responses to plants. Entomologia Experimentalis et Applicata, 17 (2): 303-318.

Sivakumar, S., Mohan, M., Franco, O. L. and Thayumanavan, B. 2006. Inhibition of insect pest α-amylases by little and finger millet inhibitors. Pesticide Biochemistry and Physiology, 85 (3): 155-160.

Southwood, T. R. E. and Henderson, P. A. 2000. Ecological Methods, 3rd edition. Blackwell Sciences, Oxford, 592 Pp.

Ulusoy, M. R. and Ölmez-Bayhan, S. 2006. Effect of certain brassica plants on biology of the cabbage aphid *Brevicoryne brassicae* under laboratory conditions. Phytoparasitica, 34 (2): 133-138.

ترجیح میزبانی و جدول زندگی شته مومی کلم *Brevicoryne brassicae* (Hemiptera: Aphididae)

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چکیده آنتی‌بیوزی، ترجیح میزبانی در وضعیت انتخابی و فعالیت آنزیم‌های گوارشی *Brevicoryne brassicae* L. (Hemiptera: Aphididae) روی میزبان‌های مختلف کلمیان شامل تربچه، کلزا (برگ، گل و غلاف)، کلم بروکلی، کلم سفید، کلم قرمز، کلم قمری و گل کلم در شرایط آزمایشگاهی (دمای ۱ ± ۲۵ درجه سلسیوس، رطوبت نسبی ۵ ± ۶۵ و دوره نوری ۱۴ ساعت روشنایی و ۱۰ ساعت تاریکی) بررسی شد. آزمایش آنتی‌بیوزی براساس آماره‌های جدول زندگی انجام و آزمایش با ۵۰ تکرار برای هر میزبان با استفاده از قفس برگی شروع شد. بقای مراحل نابالغ از ۳۴ درصد روی کلم قرمز تا ۷۸ درصد روی گل کلم متغیر بود. شته‌های پرورش یافته روی کلزا (گل) بالاترین مقدار *GRR* و R_0 را داشتند و افراد پرورش یافته روی کلم قرمز کم‌ترین مقادیر *GRR* و R_0 را داشتند. هم‌چنین، مقدار r_m برای شته‌های پرورش یافته روی کلزا (گل) به‌طور معنی‌داری بالاتر بود. کم‌ترین مقدار r_m وقتی به‌دست آمد که افراد روی کلم قرمز تغذیه کردند. در آزمایش ترجیح میزبانی، کلزا (برگ) به‌طور معنی‌داری تعداد بیش‌تری از بالغین را نسبت به تربچه جذب کرد. ماده‌هایی که از پوره‌های پرورش یافته روی کلزا (گل) آمده بودند، نسبت به سایر میزبان‌ها وزن بیش‌تری داشتند. نرخ رشد شته‌ها از ۰/۰۳۵ تا ۰/۱۰۳ متغیر بود که بیش‌ترین روی گل کلم و کم‌ترین روی کلم قرمز بود. بالاترین فعالیت آمیلولیتیک در بالغین پرورش یافته روی کلزا (گل) و پایین‌ترین آن روی کلم قرمز بود. هم‌چنین، بالاترین و پایین‌ترین فعالیت پروتئولیتیک به‌ترتیب روی کلزا (گل) و کلم قرمز بود. نتایج این مطالعه نشان داد که کلم قرمز میزبان نامناسب برای شته مومی کلم می‌باشد.

واژگان کلیدی: گیاه چلیپائیان، فعالیت آنزیم‌های هضم، آماره‌های جدول زندگی، مقاومت گیاهان، شته مومی کلم