

## Effects of host plants on the susceptibility of Cowpea Aphid, *Aphis craccivora* (Hemiptera: Aphididae) to the entomopathogenic fungus, *Beauveria bassiana* (Ascomycota, Hypocreales)

Z. Ezzatabadipoor<sup>1</sup>, A. Shirvani<sup>2</sup> and M. Rashki<sup>3&\*</sup>

1. Department of Plant Protection, Faculty of Agriculture, Shahid Bahonar University of Kerman, Kerman, Iran, 2. Department of Plant Protection, Faculty of Agriculture, Shahid Bahonar University of Kerman, Kerman, Iran, 3. Department of Biodiversity, Institute of Science and High Technology and Environmental Sciences, Graduate University of Advanced Technology, Kerman, Iran.

\*Corresponding author, E-mail: ma\_rashki@yahoo.com

### Abstract

In this study, susceptibility of the cowpea aphids, *Aphis craccivora* Koch (Hemiptera: Aphididae) to entomopathogenic fungus, *Beauveria bassiana* strain DEBI008 (Ascomycota, Hypocreales) originated from *Chorthippus brunneus* Tunberg (Orthoptera: Acrididae), fed on the three different bean varieties (pinto bean, kidney bean and cowpea), was investigated under laboratory conditions (at  $25 \pm 1$  °C, 85% RH and a photoperiod of 16L: 8D). One-day-old adult aphids were treated by sublethal concentrations ( $LC_{10}$ ) of the fungus including  $7.4 \times 10^4$ ,  $4.3 \times 10^4$ , and  $8 \times 10^4$  calculated on pinto bean, kidney bean, and cowpea, respectively. The biological properties of their progeny were analysed using a two-sex fertility life table and TWISEX-MSChart software. The results showed that the  $r_m$ ,  $T$  and  $\lambda$  values of their progeny were significantly different between pinto bean ( $0.17 \pm 0.02$ ,  $10.72 \pm 0.56$  and  $1.19 \pm 0.02$ , respectively) and cowpea ( $0.26 \pm 0.01$ ,  $9.26 \pm 0.25$  and  $1.30 \pm 0.02$ , respectively). There were no significant differences in the  $R_0$  values among the different plant varieties. We found that the fungal treatment significantly decreases fecundity, longevity and life span of the progeny fed on each plant variety. The results indicated that the most favourable effects of *B. Bassiana* was achieved when the aphids fed on pinto bean, implying the suitability of this variety for integrated management of *A. craccivora*. But the aphids that were fed on cowpea, suffered less fitness costs from fungal infection, which reflected the function of host plant in defence of *A. craccivora* against the pathogen.

**Key words:** *Aphis craccivora*, *Beauveria bassiana*, biological control, biological property, host plant

### چکیده

اثرات میزان گیاهی بر حساسیت شته لوبیا چشم بلبلی، *Aphis craccivora* Koch (Hemiptera: Aphididae) به قارچ بیمارگر حشرات، *Beauveria bassiana* (Ascomycota, Hypocreales)

زهره عزت آبادی پور، اصغر شیروانی و مریم راشکی قلعه نو

در این مطالعه، حساسیت شته لوبیا چشم بلبلی، *Aphis craccivora* Koch (Hemiptera: Aphididae) به قارچ بیمارگر حشرات،

*Beauveria bassiana* (Ascomycota, Hypocreales)، جداییه DEBI008، با منشأ *Chorthippus brunneus* Tunberg 1815

(Orthoptera: Acrididae) که روی سه وارپته لوبیای مختلف (لوبیا چیتی، لوبیا قرمز و لوبیا چشم بلبلی) تغذیه کردند در شرایط

آزمایشگاهی مورد بررسی قرار گرفت (دمای  $25 \pm 1$  درجه سلسیوس، رطوبت نسبی 85 درصد و دوره نوری 16/8 (تاریکی:روشنایی)).

شته‌های کامل یک روزه با غلظت‌های زیر کشنده ( $LC_{10}$ ) قارچ بیمارگر شامل  $7.4 \times 10^4$ ،  $4.3 \times 10^4$  و  $8 \times 10^4$  محاسبه شده روی

لوبیا چیتی، لوبیا قرمز و لوبیا چشم بلبلی تیمار و سپس، خصوصیات بیولوژیکی نتایج آن‌ها با استفاده از روش آنالیز جدول زندگی دو جنسی

ویژه سن-مرحله و نرم افزار TWISEX-MSChart تجزیه و تحلیل شدند. نتایج نشان داد در شته‌های تیمار شده با قارچ، مقادیر  $r_m$  و  $T$  و  $\lambda$

در نتایج آن‌ها بین لوبیا چیتی (به ترتیب  $0.17 \pm 0.02$ ،  $10.72 \pm 0.56$  و  $1.19 \pm 0.02$ ) و لوبیا چشم بلبلی (به ترتیب  $0.26 \pm 0.01$ ،  $9.26 \pm 0.25$  و  $1.30 \pm 0.02$ )

نداشت. به علاوه، پی برده شد که تیمار قارچی به طور معنی دار باعث کاهش باروری، طول عمر حشره کامل و طول زندگی نتایج شته با تغذیه

روی هر کدام از وارپته‌های گیاهی شد. در نهایت، نتایج نشان داد که بیشترین تأثیرات مطلوب قارچ *B. Bassiana* برای کنترل جمعیت

شته لوبیا چشم بلبلی زمانی به دست آمد که شته‌ها روی گیاه لوبیا چیتی تغذیه کردند. این مسأله حاکی از مناسب بودن این وارپته گیاهی برای

مدیریت تلفیقی شته *A. craccivora* می‌باشد. در مقایسه، شته‌های تغذیه شده روی گیاه لوبیا چشم بلبلی کم‌تر متحمل هزینه‌های کاهش

شایستگی در اثر آلودگی قارچی شدند که نشان‌دهنده نقش وارپته گیاهی در دفاع شته *A. Craccivora* مقابل بیمارگر بود.

واژگان کلیدی: *Beauveria bassiana* *Aphis craccivora*، کنترل بیولوژیک، ویژگی‌های زیستی، میزان‌های مختلف گیاهی

### Introduction

Herbivorous insects have a complex relationship with their host plants and any variation among host plants can deeply impact on their survival, growth, dispersal and reproduction abilities (Denno & McClure, 1983), leading to reduction of their fitness

with plant toxics or morphological structures (Rosenthal & Berenbaum, 1991).

In a more complex system, the relationships between herbivorous insects and their natural enemies have been frequently suggested to be influenced by different host plants (Brower *et al.*, 1967; Price *et al.*,

1980). Although most studies on the role of host plants on interactions of insects with their natural enemies have been focused on parasitoids and predators (Kennedy, 2003; Ode, 2006), some evidences have shown that the relationships between insects and entomopathogenic fungi may also be affected by host plant properties (Hare & Andreadis, 1983; Tanada & Kaya, 1993; Poprawski & Jones, 2000). For example, populations of the whitefly, *Bemisia argentifolii* (Hemiptera: Aleyrodidae), reared on cotton plants, were more susceptible to infection by the two entomopathogenic fungi, *Beauveria bassiana* (Bals.) Vuill. (Ascomycota, Hypocreales) and *Paecilomyces fumosoroseus* Wize (Ascomycota, Hypocreales), than those reared on melon plants. The sequestration of gossypol, and/or probably other cotton plant allelochemicals, has been hypothesized to influence insect's defence against pathogens (Poprawski & Jones, 2000).

Other findings showed that resistant host plants could enhance the susceptibility of *Spodoptera frugiperda* (J.E. Smith) (Lepidoptera: Noctuidae) to nuclear polyhedrosis virus (Hamm & Wiseman, 1986).

The plant quality can be related to secondary produced metabolites and it may influence the insect pathogenecity. Accordingly, some biological properties and resistance of *Diabrotica undecimpunctata howardi* Barber (Coleoptera: Chrysomelidae) to the pathogenic nematodes were affected by host plant species (Barbercheck, 1993; Barbercheck *et al.*, 1995).

Also, Coley *et al.* (2006) revealed that plant quality could alter the rate of herbivore growth and its resistance to the third trophic level.

The cowpea aphid, *Aphis craccivora* Koch 1854 (Hemiptera: Aphididae) is an important polyphagous pest attacking more than 50 plant species in 19 different families, with preference for legumes (Family Fabaceae) (Palumbo & Tickes, 2001; van Emden & Harrington, 2007). Its damage occurs not only by direct feeding of both nymphs and adults on phloem sap, but also by transmission of more than 30 plant pathogenic viruses as well as production of honeydew excessively,

which underlies the growth of sooty moulds (van Emden & Harrington, 2007).

Therefore, control of many aphid species, including *A. craccivora*, largely depends on the use of chemical insecticides such as chlorinated hydrocarbons, carbamates, organophosphates, and neonicotinoids (Jackai & Daoust, 1986; Pavela *et al.*, 2009; Souleymane *et al.*, 2013). Excessive application of synthetic insecticides, in recent decades, led to explore and adopt more environmentally friendly strategies against pests (Gunning *et al.*, 1991; Haq *et al.*, 2004).

Aphids have a wide variety of natural enemies including predators, parasitoids and pathogens that many of them are commercially available in both greenhouses and open cultivations (Mahr *et al.*, 2001). The entomopathogenic fungus, *B. bassiana*, for example, has long been considered as an important biocontrol agent of aphids (de Faria & Wraight, 2007; Amnuaykanjanasin *et al.*, 2013; Kim *et al.*, 2013).

In addition to biological control, the use of host plant resistance provides an efficient strategy for the control of cowpea aphid due to its low cost and compatibility with other control methods (Ofuya, 1997; Souleymane *et al.*, 2013).

This study was conducted to evaluate the effects of plant varieties on the susceptibility of *A. craccivora* progeny to sublethal concentration (LC<sub>10</sub>) of *B. bassiana* to select the best combination of plant varieties and *B. bassiana* against *A. craccivora*.

## Material and methods

### Host plants

Three leguminous plants, cowpea, *Vigna unguiculata* var. Mahalli, pinto bean, *Phaseolus vulgaris* var. Sadri and red kidney bean, *Ph. vulgaris* var. Akhtar, were used as hosts for rearing *A. craccivora*. Seeds were obtained from Khomein Research Institute, in plastic pots (15 cm in diameter, 18 cm in height) in greenhouse conditions at 27 ± 5 °C, 60 ± 10% RH and a photoperiod of 16L: 8D.

### Insects

Adult stages of *A. craccivora*, were identified on the basis of their waxy black coloration from a native colony on alfalfa in an experimental field located at Shahid Bahonar University of Kerman, Iran. The aphids were reared and monitored to avoid any contamination by parasitoids. The healthy aphids were separately released on 4-leaf stalks of the three host plants to establish a stock colony on each host plant under controlled conditions at  $25 \pm 1$  °C,  $60 \pm 5\%$  RH and a photoperiod of 16L: 8D.

### Entomopathogenic fungus

*B. bassiana* strain DEBI008, isolated from a native locust specimen, *Chorthippus brunneus* (Thunberg, 1815), was obtained from the culture collection of the Department of Agricultural Entomology, Iranian Research Institute of Plant Protection. The fungus was cultured in Petri dishes (8 cm in diameters) containing Sabouraud dextrose agar (SDA) medium supplemented with 1% (wt/vol) yeast extract (pH 7.0) (SDAY) and maintained at  $25 \pm 1$  °C. The cultures were scrapped after sporulation to obtain conidia according to the method of Goettel & Inglis (1997).

### Bioassays

Dry conidia of *B. bassiana* isolate DEIB008 were suspended in 0.02% Tween-80. Initial concentration of conidia was measured using a hemocytometer and further concentrations including  $10^8$ ,  $10^7$ ,  $10^6$ ,  $10^5$  and  $10^4$  conidia/ml prepared to assess the sublethal concentration ( $LC_{10}$ ). We sprayed the third nymphal instars of aphids with 1.5 ml of conidia using a fine mist held above the aphids with 90° angle. For control, the aphids were treated with 0.02% of Tween-80. The treated aphids were air-dried and transferred to Petri dishes containing leaf discs on 2% water-agar. The sealed Petri dishes, after 24 h, were supplied with new lids bearing a 3-cm-diameter hole for ventilation. During the experiment, the aphids were transferred to fresh leaf discs every three days.

### Life table parameters

Thirty leaf discs for each host plant variety were prepared by placing the leaves on agar 2% in Petri dishes (8 cm diameter) and later, a 1-day-old adult of *A. craccivora* sprayed and released on each leaf disc. The aphids were sprayed with the sublethal concentration ( $LC_{10}$ ) of the fungus as determined in the bioassay test. The leaf discs were covered by their lids and maintained in a growth chamber at  $25 \pm 1$  °C, 85% RH and a photoperiod of 16L: 8D. After 12 h, only one newly born nymph was kept in each Petri dish and monitored every 24 h. The progeny were maintained at the same conditions and after adult emergence, the number of nymphs produced by each female recorded daily until the death of all adults. In the control, 1-day-old adults were sprayed with 0.02% of Tween-80.

### Data analysis

The lethal concentration ( $LC_{10}$ ) of the fungus for *A. craccivora* was calculated for each host plant variety using POLO-PC 2002 software. The pre-adult developmental time, longevity, life span and fecundity were analysed using ANOVA (SAS institute, 2002) and the averages compared with Tukey's test at the 0.05 level. The life table parameters were based on two-sex life table (Chi & Liu, 1985; Chi, 1988) using TWSEX-MSChart software (Chi, 2015). We used paired bootstrap test to compare differences among the cultivars (Akkopru *et al.*, 2015). The population parameters included age-specific survival rate ( $l_x$ ), age-specific fecundity ( $m_x$ ), net reproductive rate ( $R_0$ ), intrinsic rate of increase ( $r_m$ ), finite rate of increase ( $\lambda$ ), and mean generation time ( $T$ ). The net reproductive rate ( $R_0$ ):

$$R_0 = \sum l_x m_x$$

The intrinsic rate of increase ( $r_m$ ) was estimated using the iterative bisection method and the Euler-Lotka equation with the age indexed from 0 (Goodman, 1982):

$$\sum_{x=0}^{\infty} e^{-r(x+1)} l_x m_x = 1$$

The finite rate of increase ( $\lambda$ ) and the mean generation time (T):

$$\lambda = e^r$$

$$T = \frac{\ln(R_0)}{r}$$

### Results

The probit analyses for *A. craccivora* treated with *B. bassiana* strain DEBI008 resulted in the  $LC_{10}$  values of  $7.4 \times 10^4$ ,  $4.3 \times 10^4$ , and  $8 \times 10^4$  conidia/ml for the aphids reared on pinto bean, kidney bean, and cowpea, respectively after 10 days of exposure of third nymph instars of *A. craccivora* (Table 1).

Effects of the lethal concentration ( $LC_{10}$ ) of the fungus on the biological parameters of *A. craccivora* fed on the three different host plants and the control (0.02% Tween-80) have been summarized in table 2. Significant differences were found in pre-adult developmental time of the aphids in both control and *B. bassiana* treatments (df = 96, F = 8.65, P < 0.05). The longest developmental time was observed for the progeny of infected aphids reared on kidney bean followed by pinto bean and cowpea.

The adult longevity of the progeny in the infected aphids was also affected by feeding on different host plant varieties (df = 149, F = 9.04, P < 0.05). The longest longevity was observed in the progeny of the infected aphids fed on kidney bean, while the aphids reared on pinto bean showed the shortest longevity. But, cowpea variety caused elongating the adult longevity compared with pinto bean when the aphids were sprayed with Tween 80.

The progeny life span of the fungus-treated aphids was significantly lower than non-treated ones in all studied host plants (df = 147, F = 10.54, P < 0.05). There were nearly no significant differences in life span of the aphids fed on different host plants in both

control and *B. bassiana* treatments (P > 0.05). The shortest life span was related to the progeny fed on pinto bean variety in *B. bassiana* treatment.

The fecundity of *A. craccivora* was also reduced in the progeny of individuals treated by the fungus regardless of the host plant they fed on. However, there was no significant difference in the number of progeny produced by aphids fed on the three host plants in both control and *B. bassiana* treatments (df = 93, F = 8.21, P > 0.05).

The life table parameters of the aphids fed on the three host plants were showed in table 3. The intrinsic rate of increase ( $r_m$ ) in progeny of the fungus-treated aphids decreased only in individuals fed on pinto bean and kidney bean. For the aphids fed on cowpea, however, fungal treatment did not affect  $r_m$  value compared with the control. The most reduction in  $r_m$  value was happened in the aphids fed on pinto bean. The progeny net reproductive rate ( $R_0$ ) of the aphids treated with the fungus was significantly lower than the control regardless of fed on different host plant. Similar to  $r_m$ , the most reduction in the  $R_0$  was observed in the aphids fed on pinto bean.

The mean generation time (T) significantly decreased as a result of the fungal treatment only in the aphids fed on cowpea. The shortest generation time was observed in the fungus-treated aphids fed on cowpea as well. The T value was not statistically different among other treatments.

Finally, the finite rate of increase ( $\lambda$ ) was not statistically different among the progeny of the fungus-treated aphids fed on pinto and kidney bean. Also, no significant difference was observed in finite rate of increase among these two host plants in control. The finite rate of increase after the fungal treatment significantly decreased only in the aphids fed on pinto bean and kidney bean. The progeny of the fungus-infected aphids fed on cowpea had a significantly higher  $\lambda$  contrasted to pinto and kidney bean.

Changes in the age-specific survival ( $l_x$ ) of the aphids fed on the three host plant varieties have been shown in fig. 1. As the figure illustrates, the age-

specific survival ( $l_x$ ) of the progeny in the fungus-treated aphids is constantly lower than that of non-treated ones irrespective of variety of host plant. In the aphids fed on pinto bean and kidney bean, however, an earlier reduction in age-specific survival was observed compared with those fed on cowpea implying on the role of these host plant varieties on

susceptibility of *A. craccivora* to infection by *B. bassiana*. The fungal treatment caused a decrease in the age-specific fecundity ( $m_x$ ) of *A. craccivora* progeny on all host plant varieties; however, the  $m_x$  fluctuation of the aphid on the three plant varieties was nearly the same in the fungus-sprayed treatment and control (fig. 2).

**Table 1.** Results of the probit analyses for *Aphis craccivora* treated with *Beauveria bassiana* strain DEBI008.

Cultivars	n	Slope ± SE	b ± SE	LC <sub>10</sub> (CI) conidia/ml	LC <sub>50</sub> (CI) conidia/ml	χ <sup>2</sup>	HF
pinto bean	225	1.14 ± 0.20	-6.83 ± 1.30	$7.4 \times 10^4$ ( $7.0 \times 10^3$ – $2.4 \times 10^5$ )	$9.9 \times 10^5$ ( $3.3 \times 10^5$ – $2.0 \times 10^6$ )	2.23	0.74
kidney bean	225	0.99 ± 0.17	-5.87 ± 1.10	$4.3 \times 10^4$ ( $2.9 \times 10^3$ – $1.6 \times 10^5$ )	$8.5 \times 10^5$ ( $2.5 \times 10^5$ – $1.5 \times 10^6$ )	2.15	0.54
cowpea	225	1.14 ± 0.21	-6.84 ± 1.30	$8 \times 10^4$ ( $5.6 \times 10^3$ – $2.7 \times 10^5$ )	$1.0 \times 10^6$ ( $3.2 \times 10^5$ – $2.2 \times 10^6$ )	1.51	0.50

n = number of treated nymphs; b = intercept; CI = confidence intervals (95% probability); HF = heterogeneity factor.

**Table 2.** Effects of host plant variety and sub-lethal concentration (LC<sub>10</sub>) of *B. bassiana* on some biological properties of *Aphis craccivora* progeny.

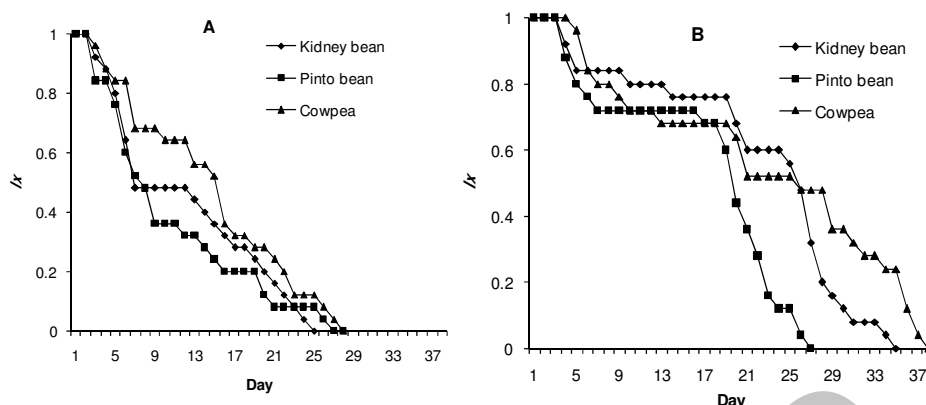
Parameter	Tween-80			<i>B. bassiana</i> (LC <sub>10</sub> )		
	Pinto bean	Kidney bean	Cowpea	Pinto bean	Kidney bean	Cowpea
Pre-adult	5.61 ± 0.12 <sup>c</sup>	5.85 ± 0.07 <sup>bc</sup>	5.90 ± 0.14 <sup>bc</sup>	6.33 ± 0.14 <sup>ab</sup>	6.58 ± 0.15 <sup>a</sup>	5.11 ± 0.15 <sup>d</sup>
Longevity	15.22 ± 0.52 <sup>bc</sup>	18.75 ± 1.19 <sup>ab</sup>	20.45 ± 1.88 <sup>a</sup>	10.66 ± 1.04 <sup>c</sup>	12.5 ± 0.76 <sup>c</sup>	11.76 ± 1.00 <sup>c</sup>
Life span	16.12 ± 1.61 <sup>b</sup>	21.08 ± 1.91 <sup>a</sup>	22.08 ± 2.41 <sup>a</sup>	8.64 ± 1.45 <sup>c</sup>	12.04 ± 1.50 <sup>bc</sup>	12.60 ± 1.55 <sup>bc</sup>
Fecundity	28.66 ± 1.70 <sup>a</sup>	35.33 ± 2.98 <sup>a</sup>	32.76 ± 2.81 <sup>a</sup>	18.33 ± 1.99 <sup>b</sup>	20.83 ± 1.76 <sup>b</sup>	17.23 ± 1.70 <sup>b</sup>

Means followed by the same letter in the same row are not significantly different (Tukey's test, P < 0.05).

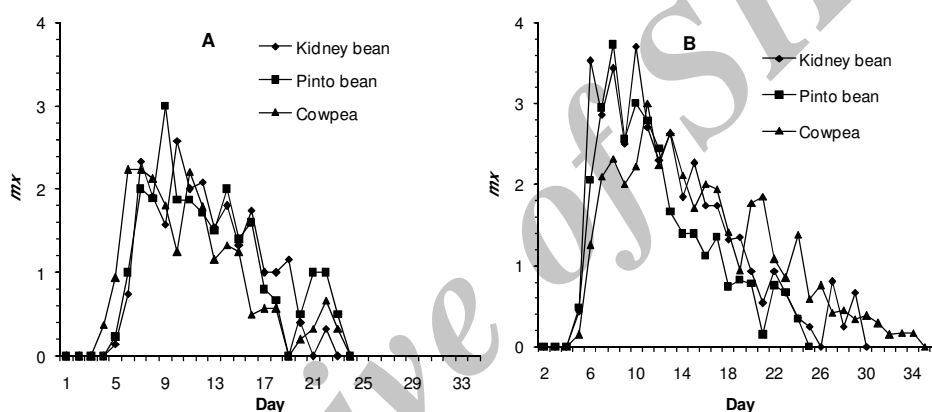
**Table 3.** Life table parameters (Mean ± SE) of *Aphis craccivora* developed on various host plant varieties and their preceding generation treated with sub-lethal concentration (LC<sub>10</sub>) of *Beauveria bassiana*.

Parameter	Tween-80			<i>B. bassiana</i> (LC <sub>10</sub> )		
	Pinto bean	Kidney bean	Cowpea	Pinto bean	Kidney bean	Cowpea
$r_m$	0.26 ± 0.01 <sup>a</sup>	0.32 ± 0.01 <sup>a</sup>	0.26 ± 0.01 <sup>ab</sup>	0.17 ± 0.02 <sup>c</sup>	0.20 ± 0.02 <sup>bc</sup>	0.26 ± 0.01 <sup>ab</sup>
$R_0$	20.62 ± 2.93 <sup>ab</sup>	29.68 ± 3.63 <sup>a</sup>	24.96 ± 6.63 <sup>a</sup>	6.60 ± 1.67 <sup>c</sup>	10.00 ± 2.39 <sup>bc</sup>	11.70 ± 2.07 <sup>bc</sup>
$T$	10.40 ± 0.26 <sup>b</sup>	10.54 ± 0.30 <sup>b</sup>	12.13 ± 0.40 <sup>a</sup>	10.72 ± 0.56 <sup>b</sup>	11.14 ± 0.40 <sup>ab</sup>	9.26 ± 0.25 <sup>c</sup>
$\lambda$	1.34 ± 0.02 <sup>ab</sup>	1.38 ± 0.02 <sup>a</sup>	1.30 ± 0.1 <sup>b</sup>	1.19 ± 0.02 <sup>c</sup>	1.23 ± 0.02 <sup>c</sup>	1.30 ± 0.02 <sup>b</sup>

The standard errors were calculated using the bootstrap procedure with 100,000 bootstraps. The means followed by different letters in the same row are significantly different between cultivars using the paired bootstrap test at 5% significance level.  $r_m$ , intrinsic rate of increase,  $R_0$ , net reproductive rate,  $\lambda$ , finite rate of increase,  $T$ , mean generation time.



**Fig. 1.** Survival rate ( $lx$ ) of *Aphis craccivora* that their preceding generation was influenced by sub-lethal concentration (LC<sub>10</sub>) of *Beauveria bassiana* (A) compared to control (B) on different host plant varieties.



**Fig. 2.** Number of females produced per female per day ( $m_x$ ) of *Aphis craccivora* that their preceding generation was influenced by sub-lethal concentration (LC<sub>10</sub>) of *Beauveria bassiana* (A) compared to control (B) on different host plant varieties.

## Discussion

The pathogenicity and virulence of the tested isolate in the current study have been previously analysed in several studies. For example, studying on the pathogenicity of 17 isolates of *B. bassiana*, Alizadeh *et al.* (2007) found that the isolate DEBI008 was the most virulent one against the pistachio psyllid, *Agonoscena pistachiae* Burckhardt & Lauterer (Hemiptera: Psyllidae). Similarly, TalaeiHasanloui (2005) proposed that the isolate DEBI008 of *B. bassiana* caused the highest mortality in the two common destructive pests, *Leptinotarsa decemlineata* (Say) (Coleoptera: Chrysomelidae) and *Plutella xylostella* (Linnaeus, 1758) (Lepidoptera: Plutellidae). As these insects belonged to non-related taxa with independent evolutionary origins, it seemed that this

isolate of *B. bassiana* was not host-specific, but might attack a wide variety of insects including aphids. Feng & Johnson (1990) showed that strain DEBI008 killed the Russian wheat aphid, *Diuraphis noxia* (Mordvilko) (Hemiptera: Aphididae), with a lower dose and in a shorter time compared with the other isolate, SGBB601.

Results of the current study showed that different biological parameters of *A. craccivora* were affected by *B. bassiana*. Additionally, it was discovered that host plant varieties could play an important role in interactions between *A. craccivora* and *B. bassiana*.

The prolonged pre-adult developmental time is favoured by growers because it retards the reproduction of aphids, thus leads to a relatively lower

population density in a given time. In contrast with pre-adult developmental time, the shortened adult life longevity time might decrease the reproductive potential of the aphid, thus it would be favoured for integrated management programs of the pest. Those aphid progeny fed on pinto bean had shortest life span compared with those fed on kidney bean and cowpea in the fungal treatment and control. The evidences might imply on the relative resistance of pinto bean to *A. craccivora*. Treatment of the aphids with *B. bassiana* led to significant decrease in their fecundity regardless of the host type they fed on. Duetting *et al.* (2003) demonstrated that host plant had an influence on mortality of *Acyrtosiphon pisum* (Harris) (Hemiptera: Aphididae) infected with *Pandora neoaphidis* (Remaudière & Hennebert) Humber (Zygomycetes: Entomophthorales). Similarly, the other investigation declared that various host plants affected the efficiency of nucleopolyhedrovirus (NPV) to control cotton bollworm and tobacco budworm (Ali *et al.*, 1998). Nevertheless, Ethel (2007) found that various host plants had no impact on interaction between *Bemisia afer* (Priesner & Hosny) (Hemiptera: Aleyrodidae) and the two entomopathogenic fungi, *P. fumosoroseus* and *Lecanicillium lecanii* (Zimm.) Zare & W. Zare & Gams. (Ascomycota, Hypocreales).

Altogether, results of the current study showed that different biological parameters of *A. craccivora* progeny were affected by *B. bassiana*, so that the host plant varieties caused some degrees of differences in susceptibility of the treated aphids. Several researches have revealed that host plants play important roles in the evolution of insect-pathogen interactions, thus a tritrophic view should be included into the investigation of insects and their pathogens (Cory & Hoover, 2006; Brady & White, 2013). Indeed, differences in plant chemistry and/or structure may alter the susceptibility of insects to infection with pathogens. For example, the larvae of gypsy moth, *Lymanthria dispar* (L.) have been found to be more susceptible to the NPV when fed on white oak *Quercus alba* Linnaeus (Fagales: Fagaceae) compared with the

larvae when fed on red oak *Q. rubra* (Fagales: Fagaceae) (Dwyer *et al.*, 2005). Similarly, the mortality of the Pine Beauty moth, *Panolis flammea* (Denis & Schiffermüller) (Lepidoptera: Noctuidae), caused by NPV, has been suggested to be affected by the host plants which they fed on (Hodgson *et al.*, 2002).

In addition to altering the insect susceptibility, host plant may differentially affect pathogen traits, such as speed of killing, productivity and host mortality (Cory & Hoover, 2006). Even, the suitability of different host plants belonging to the same species may also affect the susceptibility and performance of insects (Cory & Hoover, 2006). An excellent example for this scenario has been documented in the cabbage looper moth, *Trichoplusia ni* (Hübner) (Lepidoptera: Noctuidae), which the costs of its resistance to the bacterial pathogen, *Bacillus thuringiensis* Berliner (Bacillales: Bacillaceae) increased by lower suitability of the host plant (Janmaat & Myers, 2005).

There exist another experiment clarified that two plant species in family Asteraceae differentially influenced entomopathogenic nematodes on their insect host, *Grammia incorrupta* (=geneura) (Hy. Edwards) (Lepidoptera: Arctiidae). When the larvae fed on *Senecio longilobus* Benth. (Asterales: Compositae), their resistance to the nematodes elevated and caused to be produced lower offspring by entomopathogen (Gassmann *et al.*, 2010).

In this study, the most favourable effects of *B. bassiana* strain DEBI008 were observed in the aphids fed on pinto bean. The aphids fed on cowpea, in contrast, experienced less effects of *B. bassiana*. *A. craccivora* has been considered to be the most important pest of cowpea in the world including Africa and some parts of Asia (Singh & Jackai, 1985; Quan, 1996; Sarutayophat *et al.*, 2007), while it has less importance on other legume plants such as different varieties of bean (*Ph. vulgaris*). Therefore, the suitability of cowpea as a food resource may enable *A. craccivora* progeny to better withstand against the entomopathogenic fungus and suffer less fitness costs

compared with the aphids fed on less suitable hosts such as pinto bean. Results of this study indicated that pinto bean was the most suitable host plant, in terms of interaction with *B. bassiana*, thus may be of especial importance in integrated management programs of *A. craccivora*.

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