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Research Article

Sub-lethal effect of combination of *Metarhizium anisopliae* and imidacloprid on life table of *Myzus persicae* (Hem.: Aphididae)

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Abstract: The sub-lethal effect of *Metarhizium anisopliae* and imidacloprid as well as combination of the two control agents was examined on life table parameters of *Myzus persicae* on different cultivars of canola under laboratory condition at 25 ± 1 ºC, 85% RH and photoperiod of 16L: 8D. The offspring resulting from fungus-infested adults were placed onto leaf discs in Petri dishes separately to record their development time till they reached to adulthood. The number of nymphs produced by each adult aphid was recorded daily. The intrinsic rate of increase (r_m) had no significant differences among the three cultivars, and was nearly similar to the net reproductive rate (R_0). The concurrent application of *M. anisopliae* and imidacloprid significantly shortened the aphid longevity on the RGS003 cv compared to the other cultivars. The type of cultivars had no impact on the finite rate of increase (λ) of green peach aphid in any of the treatments. The values of *T* showed that there was no significant difference among the treatments. Despite having no significant effect on life table characteristics of *M. persicae* by most of the treatments, the method would be a favorable procedure to control the aphid by raising the fungal concentration. Conducting such research would be worthwhile since there are no antagonistic interactions between the entomopathogenic fungus and the insecticide.

Keywords: Aphid, development time, fungus, insecticide, longevity

Introduction

Myzus persicae (Sulzer) (Hem.: Aphididae) is a cosmopolitan aphid pest which infests plants including Brassicaceae family. It causes two kinds of damage on its host plants: (i) direct damage by sucking plant sap and (ii) indirect one by virus transmission (Blackman and Eastop, 2000).

Imidacloprid, a neonicotinoid insecticide, is a contact and ingestive chemical which binds selectively to the nicotinic acetylcholine receptor (Roessink, 2013) to control sucking insects like aphids.

Application of wide range and high dose of insecticides has developed the green peach aphid resistance to the insecticides (Field and Blackman, 2003) and devastated biocontrol agents. Therefore, use of entomopathogenic fungi as bio-pesticides or in combination with sub-lethal dose of chemical agents should be considered.

Metarhizium anisopliae (Metsch.) Sorok. (Ascomycota, Hypocreales) has been reported to infect more than 200 insect species (Driver *et al*., 2000) and as a fungal biological control agent was efficient against *M. persicae* and provided

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complete mortality after a week in green peach aphids (Loureiro and Moino Jr, 2006).

Also, Roditakis *et al*. (2000) reported that sub-lethal dose of imidacloprid cause restlessness in aphids and enhance the likelihood of development of entomopathogenic conidia from their contaminated habitat. There are several evidences indicating that application of entomopathogenic fungi together with imidacloprid has increased the quality and quantity of insect pests control (Quintela and McCoy, 1997; Furlong and Groden, 2001; Pu *et al*., 2005).

The interactions between plants and insect pathogens could directly or indirectly decrease insect fitness (Young *et al*., 1977; Inyang *et al*., 1998; Inyang *et al*., 1999; Duetting *et al*., 2003). On the other hand, unsuitable plants could increase pest susceptibility to entomopathogens and/or change its behaviour as indirect effect and could consequently elevate insect pathogenic efficacy (Ali *et al*., 1998; Cory and Hoover, 2006).

The present research was aimed at determining the effect of the entomopathogenic fungus, *M. anisopliae*, the insecticide, imidaclopride separately and in combination interaction to control *M. persicae.* To this end, life table parameters of green peach aphid were calculated when the aphids were treated with each control agents alone and combined together. Considering that plant host influence on entomopathogen efficacy is scant, the role of different cultivars of canola to control *M. Persicae* was evaluated based on life table parameters.

Materials and Methods

Plant materials and aphid stock

Laboratory stocks of *M. persicae* (collected from *Convolvulus arvensis* L., Kerman, Iran) were created on three cultivars of canola namely RGS003, Licord and Zarfam prepared from Seed and Plant Improvement Institute, Karaj, Iran. The plants were individually cultured in two-litre plastic pots containing a mixture of clay, sand and manure (1: 2:1) kept in greenhouse. Both plants and aphid stock cultures were maintained at 25 ± 1 ºC, 60 ± 5% RH and 16L: 8D (Ohta and Ohtaishi, 2004). 45-day-old canola and one-day-old adults of *M. persicae* were used in all tests.

Entomopathogen culture and conidia production

Conidia of *Metarhizium anisopliae* (strain EUT115) from the culture collection at the Biological Control Laboratory, Institute of Environmental Sciences, Kerman (original conidia were isolated from soil) were used in experiments. The fungus was cultured on Potato Dextrose Agar (PDA) at 25 ± 1 ºC and the conidia were harvested after two weeks. The conidia with 96% viability were stored at 4 ºC, thereby, maintaining the viability for 11 months.

Sub-lethal concentrations of unformulated *M. anisopliae* equal to LC_{10} determined on each cultivar (cv) were sprayed onto green peach aphids by a trigger sprayer kept above them at 90º angle. Five fungal concentrations including 10^4, 10^5, 10^6, 10^7 and 10^8 conidia per ml were prepared. To make the target concentrations, the 0.02% Tween 80 was used as a surfactant. The third instar nymphs of *M. persicae* were sprayed with each concentration as treatment. Twenty nymphs were used per replication and the test was repeated 4 times. 0.02% Tween 80 was sprayed as control. The aphid mortality was recorded daily during 10 days for each cultivar of canola. The data were analyzed by POLO-PC program (LeOra Software, 1987) to calculate LC10 of the fungus.

Sub-lethal effects of *M. anisopliae* and imidacloprid

Sub-lethal suspensions (LC_{10}) of *M. anisopliae* and a commercial formulation imidacloprid 35% SC (Confidor®) (Golsam Gorgan Chemical CO) were sprayed on each cultivar. The estimated sub-lethal concentrations of *M. anisopliae* were 1.93×10^3, 2.55×10^3 and 2.97×10^3 conidia/ml on the RGS003, Zarfam and Licord cultivars, respectively. A commercial formulation of imidacloprid 35% (SC) was applied in this experiment. The sub-lethal rates of imidacloprid on the RGS003, Zarfam and Licord cultivars were equivalent to 1.55, 1.76 and 1.73 mg l^{-1}, respectively.

The influence of *M. anisopliae* strain EUT115 and imidacloprid against *M. persicae* was

independently examined on the three cultivars of canola by exposing thirty day-1 old adults to the fungus and the insecticide on filter paper put in a Petri dish (80 mm in diameter) to avoid picking up the extra conidia and insecticides by the aphids. Furthermore, the test was conducted by spraying thirty day-1 old adults with the sub-lethal concentration of the entomopathogenic fungus combined with the insecticide on each of the cultivars. To prepare the combination, fungal concentration for each cultivar was first constructed and then the insecticide was added to this suspension to make the sub-lethal rate of imidaclopride.

Then, the treated adults were individually transferred to Petri dishes (58 mm in diameter) containing 2% water-agar with the abaxial canola leaf surface exposed and the lids were sealed with parafilm (Parafilm M®). The treated adults were let produce nymphs in a 12-hour interval and the offspring only resulting only from fungus-infested adults were counted. Then thirty nymphs from each treatment were placed onto canola leaf discs in Petri dishes (58 mm in diameter) separately to record their development time till they reached to adulthood. The number of nymphs produced by each adult aphid was recorded daily. The life table experiment consisted of day-1 old adults initially sprayed with 0.02% Tween 80 as control. The trials were performed at 25 ± 1 ºC, 85% RH and 16L: 8D photoperiod.

Statistical analysis

All life table parameters of *M. persicae* on different cultivars were assessed using following formula (Carey, 1993) and analyzed using the age stage, two-sex life table procedures (Chi and Liu, 1985; Chi, 1988) in TWOSEX-MS Chart software (Chi, 2012):

$$R_0 = \sum_{x=0}^{\infty} l_x m_x$$

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

$$\lambda = e^r$$

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

where *lx* is the age-specific survival rate and m_x is age specific fecundity. The intrinsic rate of increase (*r*) and the net reproductive rate (R_0) are the mean number of aphids produced by an aphid during a day and one generation, respectively. λ and *T* parameters are finite rate of increase and mean generation time, respectively.

The SAS Software was used to distinguish variations in development time and longevity of *M. persicae*. The averages were then compared by Tukey's test at the 0.05 level (SAS Institute, 1989).

Results

All life table parameters of *M. persicae* were affected by various treatments including *M. anisopliae* alone, imidaclopride alone or together with sub-lethal concentration of *M. anisopliae,* and control on three different cultivars of canola (Table 1).

The intrinsic rate of increase (r_m) values showed no significant difference among the three cultivars in any of the treatments and the control ($P > 0.05$).

The r_m values on the Licord cv showed no significant difference between the various treatments of *M. anisopliae* and imidacloprid. Also, there was no marked difference between the treated green peach aphids and the control. On the Zarfam cv, the lowest value of the r_m occurred when the aphids were sprayed with sub-lethal rate of imidacloprid incorporated with sub-lethal concentration of *M. anisopliae* and was significantly lower than the control. The estimated values of r_m on the RGS003 cv were remarkably lower when the aphids were exposed to imidacloprid plus *M. anisopliae* compared with the control.

The R_0 value for the Licord cv was not significantly different from those of the Zarfam and RGS003 cultivars in the control ($P > 0.05$). The R_0 value of *M. persicae* resulting from the imidacloprid plus *M. anisopliae* treatment was not significantly different from the values separately obtained from imidacloprid and *M. anisopliae* treatments on each canola cultivar ($P > 0.05$). On the Licord cv, no significant variation was discovered in the R_0 values among treatments but the treatments differently affected the net reproductive rate (R_0) compared to the control ($F = 4.21$; $df = 11, 297$; $P = 0.0001$). The R_0 values of *M. persicae* caused by all treatments excluding *M. anisopliae* alone were effectively lower than that of the control on the Zarfam cv as well as the RGS003 cv while on the Licord cv, the highest R_0 value was recorded for control only.

Table 1 Life table parameters (Mean ± SE) of *Myzus persicae* influenced by various treatments of *Metarhizium anisopliae* (*Ma*) (LC_{10}) and imidacloprid (*Im*) (LC_{10}) on different canola cultivars.

Cultivar	Treatment	r_m (♀/♀/day)	R_0 (♀/♀/generation)	λ (day)	T (day)
Licord	Tween 80 (Control)	0.348 ± 0.010ab	67.38 ± 7.00a	1.42 ± 0.01a	12.11 ± 0.32a
	Ma	0.295 ± 0.010abc	41.12 ± 10.60bc	1.35 ± 0.02abcd	12.67 ± 0.62a
	Im	0.319 ± 0.010bc	36.88 ± 4.63bc	1.38 ± 0.02abcd	11.30 ± 0.48a
	Ma + Im	0.296 ± 0.012bc	33.76 ± 0.10bc	1.34 ± 0.01bcd	11.88 ± 0.28a
Zarfam	Tween 80 (Control)	0.345 ± 0.013ab	64.00 ± 8.82a	1.40 ± 0.01ab	12.08 ± 0.26a
	Ma	0.360 ± 0.018a	45.55 ± 10.20abc	1.42 ± 0.02a	10.63 ± 0.61a
	Im	0.295 ± 0.012bc	28.52 ± 4.61c	1.35 ± 0.01abcd	11.35 ± 0.44a
	Ma + Im	0.285 ± 0.012c	27.68 ± 4.02c	1.33 ± 0.01cd	11.65 ± 0.26a
RGS003	Tween 80 (Control)	0.347 ± 0.018ab	54.39 ± 10.79ab	1.40 ± 0.02ab	11.56 ± 0.35a
	Ma	0.309 ± 0.021abc	36.23 ± 8.69bc	1.36 ± 0.02abcd	11.66 ± 0.51a
	Im	0.282 ± 0.028c	22.98 ± 6.97c	1.32 ± 0.03d	12.50 ± 0.40a
	Ma + Im	0.271 ± 0.014c	21.16 ± 3.83c	1.31 ± 0.01d	13.00 ± 1.47a

Means followed by different letter in the same column are significantly different (Tukey's test, $P < 0.05$). r_m: intrinsic rate of increase, R_0: net reproductive rate, λ: finite rate of increase, T: mean generation time.

The results indicated that the λ value of the control like those of the other treatments for *M. persicae* were nearly the same on the three cultivars. That is cultivars had no effect on the finite rate of increase (λ) value of green peach aphid in any of the treatments. The values of T showed that there was no significant difference among the treatments ($P > 0.05$).

The results presented in Figs. 1 and 2 show that the proportion of aphids surviving at time x (l_x) and number of offspring produced per aphid per day (m_x) similarly changed among various cultivars of canola in all treatments and the control. The simultaneous application of the entomopathogenic fungus, *M. anisopliae* and the insecticide, imidacloprid resulted in decreasing l_x on all cultivars compared to the other treatments.

The results of Table 2 reflected that shortest first nymphal stage of *M. persicae* was on the Licord and Zarfam cultivars treated with *M. anisopliae* and imidacloprid simultaneously. There was no significant difference between the first nymphal stage period on these cultivars. The highest period of first nymphal stage happened in the control for all three cultivars. The shortest first nymph development time was related to the aphids infested with the fungus added with imidacloprid on each cultivar. However, on RGS003 cv, the differences between *M. anisopliae*-infected aphids, imidacloprid-sprayed aphids and the aphids exposed to both *M. anisopliae* and imidacloprid were not meaningful ($P > 0.05$).

The highest and lowest values of duration of second nymphal stage belonged to RGS003 cv in the control and the Zarfam cv in *M. anisopliae*-infected aphids, respectively ($F = 1.96$; $df = 11, 256$; $P = 0.0332$). There was significant difference between the longest and shortest duration of third nymphal stage of *M. persicse* caused by *M. anisopliae* on the RGS003 cv and imidacloprid on the Licord cv, respectively ($F = 2.39$; $df = 11, 252$; $P = 0.0078$).

The simultaneous exposure of *M. persicae* to *M. anisopliae* and imidacloprid showed no variation in the fourth nymphal period between the Licord and Zarfam cultivars ($P > 0.05$) but they markedly differed from the

RGS003 cv (F = 16.21; df = 11, 244; P = 0.0001). The longest duration of nymph development belonged to aphids infected with *M. anisopliae* on the Licord cv (6.54 ± 0.05 days) and was significantly dissimilar to those of the Zarfam and RGS003 cultivars (F = 45.64; df = 11, 244; P = 0.0001). Also, the shortest time for *M. persicae* to develop to adult happened on the Licord cv when the aphids were sprayed with imidacloprid only and was 5.58 ± 0.05 days. The duration of nymph development of green peach aphids exposed to imidacloprid alone showed no difference between the Licord and RGS003 cultivars (P > 0.05).

The longest and shortest longevity of *M. persicae* were on the Licord cv in the control and on the RGS003 cv when the aphids were simultaneously treated with the fungus and imidacloprid, respectively. The longevity of adults was similar between the Licord and Zarfam cultivars in the control (P > 0.05) but was effectively different from the RGS003 cv (F = 51.50; df = 11, 244; P = 0.0001). The concurrent application of *M. anisopliae* and imidacloprid had no significant influence on the aphid longevity on the Licord cv compared with the Zarfam cv, however, the treatment significantly shortened aphid's longevity on the RGS003 cv compared with the other cultivars.

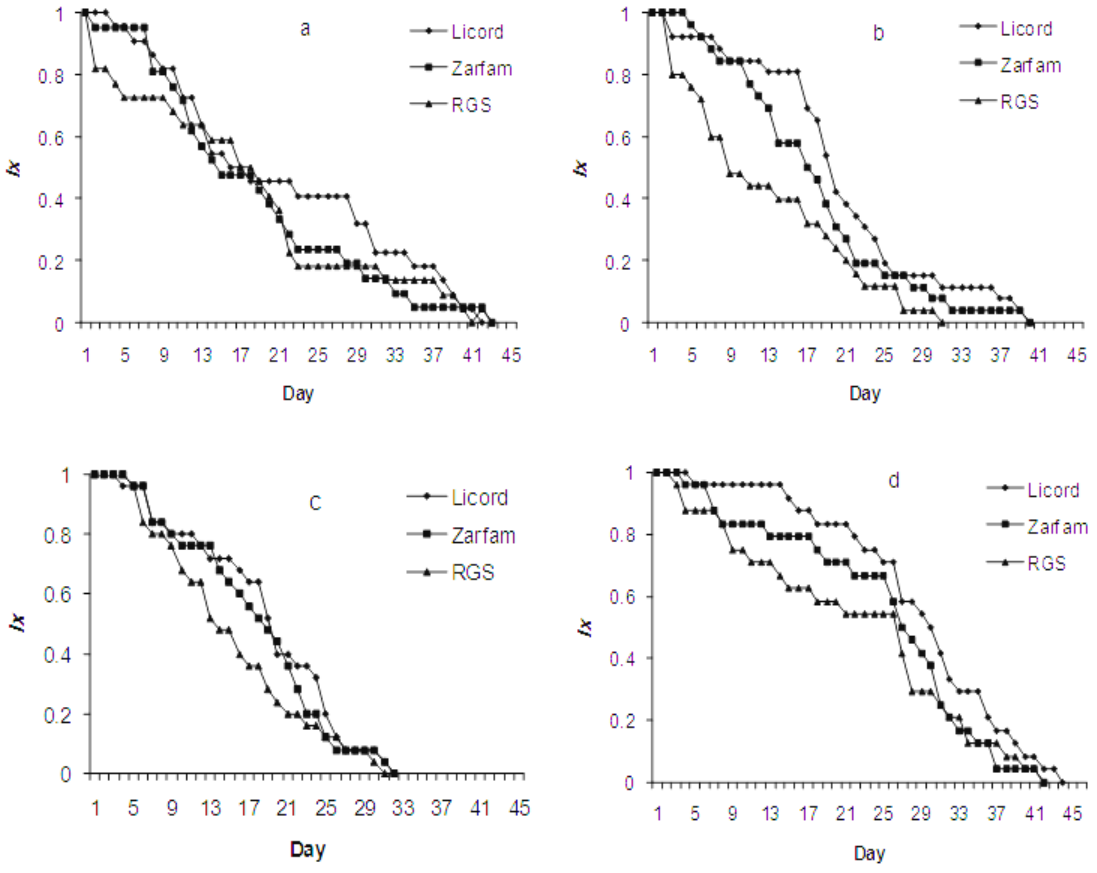

Figure 1 Survival rate (lx) of *Myzus persicae* treated with *Metarhizium anisopliae* (LC_{10}) (a), imidacloprid (LC_{10}) (a), *Metarhizium anisopliae* (LC_{10}) + imidacloprid (LC_{10}) (c) compared to control (d) on different canola cultivars.

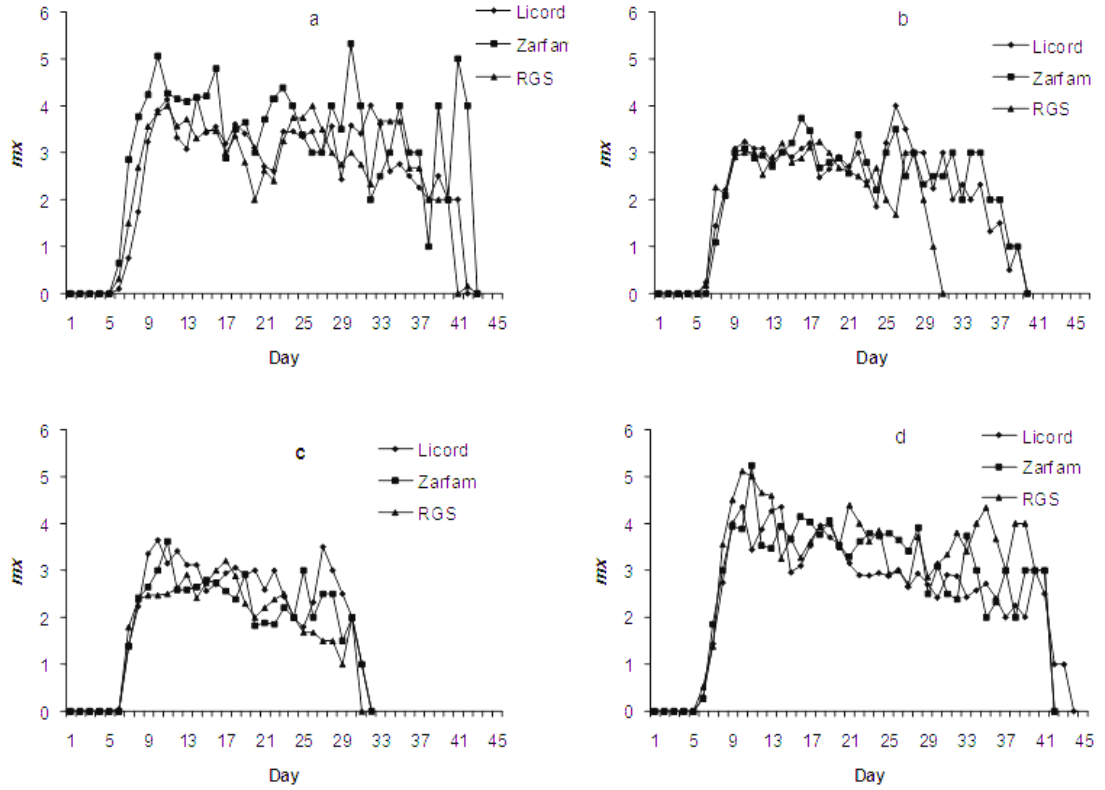

Figure 2 Number of females produced per female per day (m_x)by *Myzus persicae* treated with *Metarhizium anisopliae* (LC_{10}) (a), imidacloprid (LC_{10}) (b), *Metarhizium anisopliae* (LC_{10}) + imidacloprid (LC_{10}) (c) compared to control (d) on different canola cultivars.

Table 2 Development time of different life stages of *Myzus persicae* influenced by various treatments of *Metarhizium anisopliae* (*Ma*) (LC_{10}) and imidacloprid (*Im*) (LC_{10}) on different canola cultivars.

Cultivar	Treatment	Development time (Mean ± SE) (days)					
		Nymph I	Nymph II	Nymph III	Nymph IV	Nymph I-IV	Adult
Licord	Tween 80 (Control)	1.67 ± 0.01a	1.49 ± 0.02abc	1.64 ± 0.02a	1.38 ± 0.02e	6.17 ± 0.04bc	28.13 ± 0.49a
	Ma	1.67 ± 0.02a	1.59 ± 0.03ab	1.53 ± 0.02abc	1.76 ± 0.02ab	6.54 ± 0.05a	22.97 ± 0.59bc
	Im	1.42 ± 0.02cd	1.42 ± 0.03bc	1.38 ± 0.02c	1.37 ± 0.01e	5.58 ± 0.05g	20.49 ± 0.28de
	Ma + Im	1.08 ± 0.06f	1.42 ± 0.10bc	1.58 ± 0.10ab	1.90 ± 0.07a	5.96 ± 0.04e	14.30 ± 0.30f
Zarfam	Tween 80 (Control)	1.55 ± 0.03ab	1.44 ± 0.02bc	1.60 ± 0.03ab	1.53 ± 0.02cd	6.12 ± 0.05cd	27.92 ± 0.39a
	Ma	1.24 ± 0.02e	1.33 ± 0.03c	1.50 ± 0.01abc	1.67 ± 0.02bc	5.73 ± 0.04f	18.25 ± 0.39e
	Im	1.46 ± 0.02bc	1.54 ± 0.01ab	1.58 ± 0.03ab	1.58 ± 0.02cd	6.16 ± 0.05bc	18.20 ± 0.30e
	Ma + Im	1.04 ± 0.04f	1.48 ± 0.10bc	1.48 ± 0.10abc	1.90 ± 0.07a	6.00 ± 0.02de	13.14 ± 1.32f
RGS003	Tween 80 (Control)	1.60 ± 0.02a	1.68 ± 0.02a	1.55 ± 0.03abc	1.60 ± 0.03cd	6.43 ± 0.06a	24.98 ± 0.51bc
	Ma	1.34 ± 0.02de	1.48 ± 0.02bc	1.68 ± 0.03a	1.76 ± 0.02ab	6.25 ± 0.04b	22.02 ± 0.40cd
	Im	1.32 ± 0.02de	1.48 ± 0.03bc	1.41 ± 0.03bc	1.47 ± 0.02de	5.67 ± 0.06fg	18.94 ± 0.37e
	Ma + Im	1.28 ± 0.09e	1.52 ± 0.10abc	1.67 ± 0.10a	1.55 ± 0.11cd	6.00 ± 0.02de	10.85 ± 1.49g

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

Discussion

Several researches have indicated the effect of entomopathogenic fungi (Baverstock *et al*., 2006; Seyed-Talebi *et al*., 2012; Rashki and Shirvani, 2013) or insecticides (Lashkari *et al*., 2007; Barati *et al*., 2013) separately on growth parameters of arthropod pests. This study also demonstrated the incorporated sub-lethal effects of the chemical insecticide, imidacloprid and the entomopathogenic fungus, *M. anisopliae* on life table parameters of green peach aphid, *M. persicae*.

According to sub-lethal dosage of the fungus and the insecticide presented above, *M. persicae* was susceptible to direct application of both control agents. Sensitivity of *M. persicae* to the fungal pathogen *M. anisopliae* (Loureiro and Moino Jr, 2006; Shan and Feng, 2010) and the neonicotinoid insecticide, imidacloprid (Ye *et al*., 2005) was similarly manifested.

Different results were achieved when the indirect sub-lethal effect of the fungus on the aphid was assessed and the fungal concentration did not change the fecundity of *M. persicae.* The only significant consequence of sub-lethal effect of *M. anisopliae* was the R_0 value reduction of the aphid on the Licord cv in contrast with the uninfected control aphids. Moreover, a preceding study showed that the sub-lethal concentration of *B. bassiana* strain DEBI008 had no influence on life table parameters of *Aphis gossypii* Glover (Hem.: Aphididae) (Rashki and Shirvani, 2013). Baverstock *et al*. (2006) also found that the r_m value of the pea aphids infected with *Pandora neoaphidis* (Remaudie`re and Hennebert) Humber or *Beauveria bassiana* (Balsamo) Vuillemin was not different from that of the control.

Imidacloprid-induced hormesis phenomenon in the green peach aphid, *M. persicae,* proved that dosages more than 0.1 mg kg^{-1} decreased the fecundity of aphids (Yu *et al*., 2010) and the present results confirmed it on the RGS003 cv when the r_m value affected by the insecticide was significantly lower than that of the control. Nevertheless, no reduction in the r_m values of the aphid was observed on the Licord and Zarfam cultivars rather than the related controls and the canola cultivars did not affect the r_m value. The indirect insecticide function (sub-lethal dosage) differently decreased the R_0 value compared to the control on each cultivar but the different cultivars of canola had no impact on the parameter.

Synergistic interactions between entomopathogenic fungi and imidacloprid have been declared (Furlong and Groden 2001) and high compatibility of the insecticide (Xu *et al*., 2002) has been realized. In some cases, application of pathogenic fungi together with imidacloprid has improved the pathogenic functions (Kaakeh *et al*., 1997; Pu *et al*., 2005).

This is congruent with the present results on the Zarfam cv and clarified that simultaneous use of sub-lethal concentration of the two control agents against *M. persicae* decreased the intrinsic rate of increase (r_m). This could result from compatibility of imidacloprid and *M. anisopliae* and synergistic interaction between them in comparison to the fungal application alone. In addition, the synergistic interaction was discovered when it differently reduced the total development time for all cultivars except the Zarfam cv and longevity of green peach aphids on all cultivars.

Similarly, Quintela *et al*. (2013) showed the increased adult sensitivities of *Tibraca limbativentris* Stal. (Hem.: Pentatomidae) to *M. anisopliae* in combination with sub-lethal doses of thiamethoxam and lambda-cyhalothrin as well as Jaramillo *et al*. (2005) who demonstrated that sub-lethal dosage of imidaclopride prompted great mortality on *Cyrtomenus bergi* Froeschner (Hem.: Cydnidae). Also, low rates of insect growth regulators (IGR) such as diflubenzuron and novaluron had additive interaction jointed with fungal pathogen, *B. bassiana* to suppress *Locusta migratoria migratorioides* (Sauss.) (Orth.: Acrididae) (Bitsadze *et al*., 2013).

The reason why the interactions had no influences on all life table parameters on various cultivars of canola, might be due to low concentration of the fungus, significant impact of host plants on interaction between *M. anisopliae* and imidacloprid was only observed on duration of different life stages of *M. persicae*. In most cases, where the differences were significant, the treatments resulted in

shorter development time and adult longevity excluding the fungal treatment alone for fourth nymph stage and consequently for total nymph stage on the Licord cv. Chen *et al*. (2010) found that host plant had differently influence not only on life table parameters of *Homalodisca vitripennis* (Germar) (Hem.: Cicadellidae) but also on its nymph development time and nymph development time was markedly prolonged on euonymus and shortened on sunflower. The reason could be due to concentration of nutritional elements like nitrogen, therefore, nymph development time of *Trialeurodes vaporariorum* (Hem.: Aleyrodidae) declined when the nitrogen concentrations were elevated in two different cultivars (Park *et al*., 2009).

Some studies showed that host plant could change the mortality caused by insecticides (Wang *et al*., 2002; Liang *et al.*, 2007; Salehi *et al*., 2013) or entomopathogenic fungi (Inyang *et al*., 1998; Inyang *et al*., 1999; Duetting *et al*., 2003). It was in contrast with the present results, because in those researches, direct effect of control agents and completely different host plant species were tested while the present study tested the indirect influence of *M. anisopliae* and imidacloprid on dissimilar host plant cultivars.

To control the green peach aphid, different combinations of insecticides and entomopathogenic fungi should be tested, because of their various interaction impacts.

For instance, mixed application of *B. bassiana* and diflubenzuron against *M. persicae* should be avoided to elevate the fungus effectiveness (Olson and Oetting, 1999).

Despite having no significant effect on life table characteristics of *M. persicae* by sub-lethal rate of *M. anisopliae* and imidacloprid alone orin combination, the method would be a favorable procedure to control the green peach aphid by raising the fungal concentration. Moreover, field experiments will be necessary to further confirm the compatibility of the two control agents as well as testing different host plant species of the green peach aphid. Conducting such a research is worthwhile because there are no antagonistic interactions between the entomopathogenic fungus and the insecticide.

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اثر زیرکشنده ترکیب *Metarhizium anisopliae* و ایمیداکلوپرید روی جدول زندگی شته سبز هلو *Myzus persicae* (Hem.: Aphididae)

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چکیده: اثر زیرکشندهٔ *Metarhizium anisopliae* و ایمیداکلوپرید همراه با ترکیب این دو عامل کنترل روی پارامترهای جدول زندگی شته سبز هلو *Myzus persicae* روی ارقام مختلف کلزا تحت شرایط آزمایشگاهی دمای ۱ ± ۲۵ درجه سلسیوس، رطوبت نسبی ۸۵ درصد و دورهٔ نوری ۱۶ ساعت روشنایی و ۸ ساعت تاریکی انجام شد. نتاج به‌دست آمده از افراد کامل آلوده به قارچ روی دیسک‌های برگی به‌طور جداگانه در ظروف پتری قرار گرفتند تا طول دورهٔ رشدی آن‌ها تا رسیدن به مرحله حشره کامل بررسی شود. تعداد پوره‌های تولید شده توسط هر شته کامل به‌طور روزانه ثبت شد. مقادیر نرخ ذاتی افزایش جمعیت (r_m) تقریباً مشابه نرخ خالص تولید مثل، اختلاف معنی‌دار میان ارقام مختلف در تمام تیمارها و کنترل نداشتند. کاربرد هم‌زمان *M. anisopliae* و ایمیداکلوپرید به‌طور معنی‌دار باعث کوتاه‌تر شدن طول عمر شته روی رقم RGS003 نسبت به سایر ارقام شد. نوع رقم اثری روی نرخ متناهی افزایش جمعیت (λ) شته سبز هلو در تمام تیمارها نداشت. مقادیر طول دوره یک نسل (T) نشان داد که اختلاف معنی‌دار میان تیمارها وجود ندارد. علی‌رغم عدم وجود اثر معنی‌دار اکثر تیمارها روی ویژگی‌های جدول زندگی شته سبز هلو، این روش می‌تواند روش مناسبی برای کنترل شته با افزایش غلظت قارچ باشد. انجام این چنین تحقیقی به‌خاطر عدم وجود برهم‌کنش‌های تضعیف‌کننده میان این قارچ بیمارگر حشرات و حشره‌کش ارزنده می‌باشد.

واژگان کلیدی: شته، طول دورهٔ رشدی، قارچ، حشره‌کش، طول عمر حشرهٔ کامل