Research Article

Toxicity of garlic extract on Spined soldier bug, *Podisus maculiventris* (Hemiptera: Pentatomidae) in comparison to its two hosts

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Abstract: The toxicity of garlic is confirmed on some agricultural pests. The aim of this study was to comparatively evaluate the sensitivity of *Podisus maculiventris* (Say) to garlic extract and two insect pests: Mediterranean flour moth *Ephestia kuehniella* (Zeller) and Colorado potato beetle *Leptinotarsa decemlineata* (Say). LC₅₀ was calculated at 8.02% for *E. kuehniella*. The results showed toxic compounds in garlic extract delayed all developmental stages and reproduction parameters of *L. decemlineata*. In contrast, there were no considerable negative effects on many of the biological parameters of the predatory insect, *P. maculiventris*. The results suggest that garlic, as a green pesticide, could be considered an environmentally suitable alternative in pest management programs.

Keywords: Allium sativum, Biological control agent, Botanical pesticide, Ephestia kuehniella, Leptinotarsa decemlineata

Introduction

Agricultural systems remain heavily reliant on synthetic pesticides for pest control which can environmental and cause management problems (Isman, 2006). The first step towards successful integrated pest management is to alternative environmentally develop sustainable strategies (Ekesi, 2000; Jarial, 2001; Prowse et al., 2006; Marie et al., 2009; Mobki et al., 2014; Anwar et al., 2017). Recently, botanical derivatives have been used to control many pests including insects and mites, nematodes, bacteria, and fungi due to their low toxicity on the environment and humankind (Muhsin *et al.*, 2001; Bakri and Douglas, 2005; Prowse *et al.*, 2006; Castillo-Sanchez *et al.*, 2010; Bonsignore and Vacante, 2012; Anwar *et al.*, 2017).

Garlic Allium sativum is considered to have insecticidal properties (Prowse et al., 2006; Kalu et al., 2010; Attia et al., 2012; Baidoo and Mochiah, 2016; Beltagy and Omar, 2016; Niroumand et al., 2016; Anwar et al., 2017). Toxicity of garlic was elucidated for many pests including Coleoptera (Lu and Liu, 2003; Beltagy and Omar, 2016); Lepidoptera (Perez-Mendoza and Aguilera, 2004; Oparaeke et al., 2007; Sadeghi et al., 2008; Baidoo and Mochiah, 2016; Rizvi et al., 2016); Hemiptera (Jaastad et al., 2009; Barati et al., 2013; Saeed et al., 2016; Mamduh et al., 2017); Diptera (Prowse et al., 2006); and also for Acari (Hincapié et al., 2008; Attia et al., 2012). Additionally, garlic and the compounds in its

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extract possess repellent, antifeedant, and antimicrobial properties (Rahman and Motoyama, 2000; Bakri and Douglas, 2005; Mobki et al., 2014; Mamduh and Movahedi Fazel, 2015; Beltagy and Omar, 2016; Niroumand et al., 2016; Anwar et al., 2017). Nowadays, the main compounds of garlic are extracted and synthesized in products with different commercial names (for example, Garlic Barrie[®], Ecoguard[®] and Repel[®]); these are used as pesticides and repellents for pest control in greenhouse conditions in Iran and other countries, as cited by Moreau et al. (2006), Jahromi et al. (2011), Attia et al. (2012), EFSA (2012) and Kumar (2015). Also, garlic cloves has been added to pesticide registration lists in Brazil and Mexico (El-Wakeil, 2013).

Several previous studies have evaluated the toxicity of garlic on herbivorous insects; while the side effects of garlic on non-target organisms have not been completely understood. The application of garlic along with biological control agents for integrated pest management strategies may have an effect on the success of pest control. Therefore, it is important to investigate the side effects of garlic compounds on natural enemies as compared to their herbivore preys. This study aimed to investigate the side effects of Garlic extract (GE) on Podisus maculiventris (Say) (Hem.: Pentatomidae) in comparison with two pest species, a factitious host, Ephestia kuehniella (Zeller) (Lep.: Pyralidae) and insect pest, Leptinotarsa decemlineata (Say) (Col.: Chrysomelidae) as *P. maculiventris*'s preys. The Colorado potato beetle (L. decemlineata) is an economically important pest in potatoes and some Solanaceaeous plants (Alyokhin et al., 2008). The Mediterranean flour moth (E. kuehniella) is one of the major pests in industrial flour mills; the larvae reduce the product quality by their presence and cause direct damage by feeding and the production of frass (Mikhaiel, 2011). P. maculiventris is known as an important generalist predatory bug on some pests from different orders of insects such as decemlineata, Epilachna L. varivestis

Mulsant (Col.: Coccinellidae), *Pyrrhalta viburni* Paycull (Col.: Chrysomelidae), etc. (De Clercq, 2008). It was hypothesized that *Allium sativum* product is a friendly

environmental pesticide as it may have low side effects on biological parameters of the key predator *P. maculiventris* as compared to herbivore insects.

Experiment

Preparation of garlic extract (GE)

GE was prepared according to Meriga et al. (2012) with some modifications. Briefly, 20g fresh garlic cloves (Tarom cultivar) were blended and mixed with 100 ml methanol >99.9% (Merck Schuchardt, Germany). The mixture was shaken at 70 rpm for 60 min at room temperature and then centrifuged at 4000 rpm for 30 min at 4 °C. The supernatant was removed and centrifuged twice under the same conditions. The final supernatant was subjected to rotary evaporation (Rotavapor R-114, Buchi: Swiss) in order to evaporate the solvent. The condensed matter was considered to be the stock extract (100% concentration) and was kept in a dark glass container at-4 °C. Serial dilutions of 25, 15, 10, 5, 2%, and water (as control) were prepared by using distilled water. GE was freshly prepared before each bio-assay.

Insect rearing

P. maculiventris insect predators were reared in containers $(10 \times 6 \times 5 \text{ cm})$ with cotton, soaked in distilled water. They were fed on factitious host, *E. kuehniella* larvae in a growth chamber at 24 ± 1 °C, $70 \pm 10\%$ Relative Humidity, and a photoperiod of 16:8 h (Light: Dark). The number of preys (*E. kuehniella*) for each predator was increased based on the growth of *P. maculiventris* insects. During the reproduction period, the eggs were removed and placed in Petri dishes (9 cm diameter) containing a filter paper (Schleicher and Schuell, Microscience, Ref. No. 10 311 610) moistened with distilled water.

E. kuehniella were reared on artificial food (10: 2: 1 mixture of oat bran: wheat germ: yeast) in plastic containers $(30 \times 20 \times 15 \text{ cm})$ at 27 ± 1 °C, $60 \pm 10\%$ RH, and 16:8 h (Light: Dark). Another host (insect pest), Colorado potato beetles were collected from the potato fields of Zanjan, Iran (37°8'N and 47°47'E), and were reared on potato leaves in greenhouse conditions at 25 \pm 3 °C and 60 \pm 10% RH. The 4th instar larvae in the pre-pupal stage were placed in special boxes containing sand in order to produce pupa. Fresh leaves were available to feed the larvae and adults every three days. The egg-containing leaves were removed to Petri dishes (9 cm diameter) containing a filter paper (Schleicher and Schuell, Microscience, Ref. No. 10 311 610) moistened with wet cotton soaked in distilled water.

Bioassay

Toxicity of GE on the predator and the preys

To investigate contact toxicity, the 4th instars of *E. kuehniella* (1-2 days old) were dipped for four seconds in GE dilutions of 25, 15, 10, 5, 2%, and control v/v. For each treatment, there were five replications and 15 larvae per replication. Treated insect larvae were air dried and transferred to Petri dishes containing some artificial food. Due to a majority of larval death, the mortality percentage was recorded three days after the treatment. The treated insects were kept under same rearing conditions.

Twenty-four-hour-old 4th instar nymphs of P. maculiventris were treated with the same method as explained above, with four replications and 15 nymphs per replication. Treated insects were air dried and transferred to plastic containers $(30 \times 20 \times 15 \text{cm})$ containing filter paper (Schleicher and Schuell, Microscience) and were fed with E. kuehniella under the same rearing conditions. In this assay, the mortality percentage was calculated after three days.

L. decemlineata larvae and adults cause more damage by feeding. Hence, oral toxicity was tested on Colorado potato beetle larvae.

Twenty-four-hour-old 4th instar larvae were placed in Petri dishes (10 cm diameter) and were fed on leaves treated with various concentrations of GE (25, 15, 10, 5, 2% v/v and water as control) in five replications with 15 larvae for each replication. The leaves were dipped in GE for five seconds and were available to the larvae after drying. The insects were kept in a growth chamber at $25 \pm$ 1 °C, $60 \pm 10\%$ RH, and 14: 10 (Light: Dark). The mortality percentage was calculated after three days.

In toxicity experiments, insects were considered to be dead when they did not move or respond to gentle touch.

Side effects of GE on biological parameters of *P. maculiventris*

To evaluate the influence of GE on biological parameters of *P. maculiventris*, 60 4th instar nymphs (24-hour-old) were treated at different concentrations of GE for 4 seconds; they were kept in the same rearing condition until all the insects died. Data was recorded every 24 h. The total mortality percentage was calculated on the 19th day when the insects had grown into sevenday-old adults. Moreover, the developmental time, sex ratio, longevity, and reproduction parameters were measured as impact factors of fitness.

Contact toxicity of GE on eggs of *P. maculiventris* and *L. decemlineata*

Twenty egg batches were selected to evaluate the toxicity of GE on the embryonic stages of P. maculiventris and its prey, L. decemlineata. The different egg ages (one, three, and fiveday-old eggs) were separated and treated in different concentrations of GE for 4 seconds as explained above, in five replications for the replications predator and six for L. decemlineata. After air drying, the egg batches were placed in Petri dishes containing filter paper and cotton moistened with distilled water until hatching time. The rearing condition was the same as mentioned above. The duration of the embryonic period and the hatching rate were recorded, daily.

Digestive toxicity of *L. decemlineata* larvae and adults

Different larval instars: first (one-day-old), second, third, and fourth stage larvae of L. decemlineata were tested separately; they were fed daily on treated leaves until they emerged as adults. Data was recorded every day and new leaves were placed for the insects. The total mortality percentage was calculated for all the immature stages in the treatment of different larval instars. After maturation, some treatments that had almost mortality (0, 5, 15, and less 25% concentrations of GE) were selected for investigating delayed effects on reproduction parameters. This experiment was done in five replications with two adults (a male and a female) per replication for four treatments. These adults were fed on non-treated leaves until the time of death. In addition to the developmental time and the daily feeding of treated larvae of L. decemlineata, other biological parameters such as sex ratio, longevity, pre-oviposition and oviposition fecundity, and fertility period. were measured. To investigate the toxicity of GE on adults, 24-h-old adults were separated and transferred to containers $(10 \times 6 \times 5 \text{ cm})$ in five replications with six insects (three females and three males) per replicate. The insects were fed daily with the treated leaves of different concentrations of GE as explained above. The mortality percentage of the adults was calculated after seven days. Moreover, all biological parameters, measured in the experiment on larvae, were calculated. The nutritional level of daily feeding was measured by a curvimeter.

Statistical analysis

The statistical program SPSS v.22.0 (2012) was used for statistical analysis. Before ANOVA, a normality test was done by using the Kolmogorov-Smirnov test. The data were set up in randomized complete designs. Normality data related to the mortality percentage were transformed in arcsine \sqrt{x} and other data were transformed in Ln. One-way

ANOVA was used for transformed data and multiple mean comparisons were performed using Tukey-Kramer's test (Tukey, 1953; Kramer, 1956). The data related to contact toxicity of GE on the eggs were carried out in a completely randomized two level factorial design; GE concentration (0, 2, 5, 10, 15 and 25%) and embryonic stage (1, 3, 5 day). Abbott's correction formula was used to assess natural mortality in untreated insects as control samples, and probit analysis was applied to estimate LC_{25} and LC_{50} values of *E. kuehniella* by using Polo-plus software (Robertson *et al.*, 2007).

Results

Toxicity of GE on the predator and the preys Data analysis showed а significant difference in the mortality percentage of the treated 4th instar larval of E. kuehniella $(F_{(5,29)} = 26.68, p < 0.01)$. LC₂₅ and LC₅₀ values were 2.59% and 8.02%, respectively, in the treated larvae after 48 h (Table 1). Total mortality percentage values after three days are shown in Fig. 1a. It was observed that the mortality rate increases with increasing GE concentration (Fig. 1a). Moreover, the effect of GE on the nymphs of *P. maculiventris* and the means of mortality percentage were significantly different as compared with the control insects (Fig. 1c). The mortalities of E. kuehniella and P. maculiventris at 25% GE concentration were 76% and 27%, respectively (Fig. 1). These results confirmed that the sensitivity of E. kuehniellais to contact toxicity was more than the predator. Fig. 1b shows the oral toxicity to L. decemlineata larvae. The highest mortality (36%) was observed at concentration of 25% GE after reducing of control samples mortality and which was followed by 5%. In contrast to E. kuehniella, the toxicity of GE on L. decemlineata and P. maculiventris didn't show a dose-dependent relationship and higher mortalities were obtained at some lower concentrations (Fig. 1).



Table 1 Probit analysis of the efficacy of garlic extract (GE) on 4th instar larvae of Ephestia kuehniella.

Figure 1 The efficacy of garlic extract (GE) on a predator insect, *Podisus maculicentris* in comparison to two insect pest, *Leptinotarsa deceplineata* and *Epestia kuehniella*. Mean of mortality of (A) 4th instar larvae of *E. kuehniella* and in contact toxicity (r = 0.97); (B) 4th instar larvae of *L. decemlineata* in oral toxicity (r = 0.86); (C) 4th instar nymph of *P. maculiventris* in contact toxicity treated (r = 0.95) by different concentrations of the GE after 3 days. Means followed by different letters are significantly different (Tukey-Kramer test, P < 0.05).

Side effects of GE on biological parameters

The efficacy of GE was evaluated on nymphs of P. maculiventris and larvae of L. decemlineata during the period of their development. Analyzed data showed increasing toxicity during that time (Fig. 2). However, the increasing slope of toxicity of GE on L. decemlineata was more than that of P. maculiventris (Fig. 2). The mortality percentage was recorded from the time of treatment in 24-hour-old fourth instar nymphs of the predator and 24-hour-old first stage larvae of L.

decemlineata until the emergence of seven-dayold adults. According to Fig. (2), the highest mortality was recorded in 10% concentrations of both insects. Fig. (3) shows the mean of total mortality of the immature stages of *L. decemlineata* (24-hour-old first larvae to emergence of adults) treated in different larval instars (1th-4th instar). The results in Fig. (3) showed a significant difference between GE concentrations in the treatment of 1st larvae (F_(5,29) = 7.80, p < 0.001), 2nd larvae (F_(5,29) = 10.56, p < 0.001), 3rd larvae (F_(5,29) = 7.95, p < 0.001), and 4th stage larvae ($F_{(5,29)} = 3.08$, p = 0.028) of *L. decemlineata*. Analyzed data in Table 2 determined that GE affects the developmental time of the Colorado potato beetle and increases this parameter ($F_{(5,71)} = 5.09$, p = 0.001).

Results showed no significant difference in the number of daily eggs, and in the total number of eggs per female of P. maculiventris during the oviposition period and their embryonic duration. However, there was a significant reduction in the hatching percentage ($F_{(5,232)} = 10.14$, p < 0.01) and the longevity of female adults $(F_{(5,35)} = 2.91, p)$ < 0.05), as shown in Table 3. ANOVA analysis showed no significant difference in developmental time, percentage of adult emergence, sex ratio, pre-oviposition period, oviposition period, and longevity of male adults of the predator insect. After maturation, abnormality was observed in the tarsus area of one or two legs of some P. maculiventris adults. Although, there were no significant differences in the percentage of abnormality between treated and control insects. Additionally, the pre-oviposition period, oviposition period, fertility, fecundity, and longevity of the abnormal adults were not significantly different as compared to the normal insects.



Figure 2 Cumulative mortality of (A): host, *Leptinotarsa decemlineata* [1st instar (1-d old) to adult (7-d old)] and (B): predator insect, *Podisus maculiventris* [4th instar (1-d old) to adult (7-d old)] treated by garlic extract (GE).



Figure 3 Mean mortality of total immature stages of *Leptinotarsa decemlineata* (1 day old first larvae to emergence of adult) treated in different larval instars (L1: first, L2: second, L3: third and L4: fourth instar larvae) by garlic extract (GE) concentrations. Means in each instar followed by different letters are significantly different by Tukey-Kramer test (P < 0.05).

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Table 2 The efficacy of garlic extract (GE) on the developmental time of *Leptinotarsa decemlineata*.

Concentrations (%)	Developmental time (day)
0	$26.8 \pm 0.3 \text{ b}$
2	$28.0 \pm 0.7 \text{ ab}$
5	29.8 ± 0.5 a
10	$26.7\pm0.9~b$
15	30.7 ± 0.9 a
25	28.9 ± 0.9 ab

Means in a column followed by different letters are significantly different by Tukey-Kramer test (P < 0.05).

Table 3 The efficacy of garlic extract (GE) on the hatching percentage (mean \pm SE) of laid eggs and longevity of females of *Podisus maculiventris* treated in nymphal instar by different concentrations.

Concentrations (%)	Egg hatching (%)	Longevity (day)
0	74.57 ± 1.22 a	52.11 ± 5.25 abc
2	$60.17\pm1.08~b$	$28.57\pm3.40\ c$
5	$35.86 \pm 1.34~c$	$61.00\pm14.53~ab$
10	$46.73 \pm 2.80 \text{ bc}$	$39.00\pm8.85\ bc$
15	$35.25\pm1.62~c$	75.67 ± 14.04 a
25	$44.11 \pm 3.84 \text{ bc}$	$30.83\pm3.77\ bc$

Means in a column followed by different letters are significantly different by Tukey-Kramer test (P < 0.05).

Conversely, garlic compounds had negative effects even post-maturation on L. decemlineata (Table 4) with immature stages treatment by GE. GE significantly decreased pre-oviposition $(F_{(3,19)} = 6.92, p = 0.002)$ and oviposition $(F_{(3,19)})$ = 79.62, p < 0.001) periods; fecundity (F_(3,19) = 3.96, p = 0.036) and fertility ($F_{(3,19)} = 56.71$, p < 0.001) parameters; and also, the longevity of female adults ($F_{(3,19)} = 15.02$, p = 0.002) (Table 4). The sex ratio showed no significant difference on this pest insect. The treatment of adults of L. decemlineata by GE decreased the survival rate $(F_{(5,29)} = 4.76, p = 0.004)$, oviposition period ($F_{(5,29)} = 11.78$, p < 0.001), and fecundity parameters ($F_{(5,29)} = 4.93$, p = 0.003) (Table 5). Other biological parameters (pre-oviposition period, fertility, and longevity), however, showed no significant difference with control adults in treatment on adults. GE led to a decrease in daily feeding in treated larvae $(F_{(5,119)} = 46.32, p < 0.001)$ and in treated adults of *L. decemlineata* (F_(5,179) = 10.32, p < 0.001) as shown in Fig. 4).

Table 4 The efficacy of garlic extract (GE) on reproduction parameters and longevity of females of *Leptinotarsa decemlineata* treated in larval instar by different concentrations.

Concentration (%)	Pre-oviposition period (day)	Oviposition period (day)	Fecundity (egg/female)	Fertility (%)
0	10.3 ± 0.9 a	28.8 ± 2.0 a	264.5 ± 15.7 a	95.1 ± 1.3 a
5	5.8 ± 0.5 b	$7.5\pm0.3\;b$	116.0 ± 26.3 ab	$82.5\pm3.3\ ab$
15	3.3 ± 0.3 b	$7.5\pm0.5\;b$	$68.7\pm10.7~ab$	$76.6\pm4.1\ b$
25	7.3 ± 1.5 ab	$6.3\pm0.8\ b$	$57.2 \pm 12.1 \text{ b}$	$15.7\pm5.0\ b$

Means in a column followed by different letters are significantly different by Tukey-Kramer test (P < 0.05).

Table 5 The efficacy of garlic extract (GE) on reproduction parameters and longevity of treated adults of *Leptinotarsa* decemlineata.

Concentration (%)	Mortality (%)	Oviposition period (day)	Fecundity (eggs/female)
0	$0.0\pm0.0\;b$	27.4 ± 2.2 a	206.4 ± 27.3 a
2	$13.3\pm6.2\ ab$	$15.0 \pm 1.8 \text{ bc}$	142.2 ± 50.3 ab
5	$6.7 \pm 4.1 \text{ b}$	$21.0\pm2.4~ab$	$54.4\pm5.6\ b$
10	$20.0\pm 6.2 \ ab$	$18.8 \pm 1.2 \; b$	$154.4\pm49.8~ab$
15	$10.0\pm4.1~\text{b}$	$10.4 \pm 0.2 \text{ c}$	$65.2\pm11.0\ b$
25	$36.7\pm9.7~a$	$17.2 \pm 1.3 \text{ bc}$	$92.6 \pm 6.8 \text{ ab}$

Means in a column followed by different letters are significantly different by Tukey-Kramer test (P < 0.05).



Figure 4 Mean of daily feeding (cm²) of larvae and adult of *Leptinotarsa decemlineata* treated by different garlic extract (GE) concentrations. Means followed by different letters are significantly different by Tukey-Kramer test (P < 0.05).

Contact toxicity of GE on eggs of *P*. *maculiventris* and *L*. *decemlineata*

According to ANOVA results, there were no significant differences in GE concentration on embryonic stage, and interaction effects of these factors on the hatching rate of P. maculiventris eggs. While, GE decreased the hatching rate of L. decemlineata ($F_{(5,107)}$ = 6.92, p < 0.001). Additionally, results in Table 6 show that the toxicity of garlic compounds on the egg hatching percentage of the Colorado potato beetle is affected by embryonic stage ($F_{(5,107)} = 8.10$, p = 0.001). However, the interaction of concentration \times embryonic age showed no significant effects on this insect. The highest hatching percentage was in the control samples of L. decemlineata treated in the one-day-old egg $(91.00 \pm 9.61\%)$ and the lowest percentage was observed in the three-days-old eggs treated by 10% concentration (16.33 \pm 9.61%).

The embryonic period of *P. maculiventris* was not affected by GE concentrations and selection of egg ages. On the contrary, GE concentrations increased the embryonic period of *L. decemlineata*, significantly ($F_{(5,107)} = 4.76$, p = 0.001) as shown in Table 6.

Table 6 The efficacy of garlic extract (GE) on hatching percentage and the embryonic period in treated eggs of *Leptinotarsa decemlineata*.

Entries	Egg	Embryonic		
	hatching (%)	period (day)		
Concentration (%)				
0	$78.61\pm2.96A$	$6.4\pm0.19~B$		
2	$64.50\pm5.55~ABC$	$6.6\pm0.29\;AB$		
5	$69.11\pm5.66~AB$	$6.3\pm0.32~B$		
10	$39.22\pm6.98\ C$	$7.3\pm0.30~AB$		
15	$53.89\pm6.81\ BC$	$6.4\pm0.26~B$		
25	$47.56\pm7.40\ BC$	$7.6\pm0.32\;A$		
Age (day)				
1	70.42 ± 3.97 a	$7.0\pm0.16~ns$		
3	$55.75\pm5.12~b$	6.7 ± 0.21 ns		
5	$50.28 \pm 4.55 \; b$	$6.6\pm0.25\ ns$		

Means in a column followed by different letters are significantly different by Tukey-Kramer test (P < 0.05). ns: non significant

Discussion

This study showed the toxicity of GE on a predator insect (*P. maculiventris*) and its two preys, *E. kuehniella* larvae as a model insect and *L. decemlineata* (Fig. 1). Our results were in accordance with previous studies in which garlic compounds were toxic on some insects (Singh and Singh, 1996; Prowse *et al.*, 2006; Kalu *et al.*,

2010; Mikhaiel, 2011; Vassiliou, 2011; Meriga et al., 2012; Mobki et al., 2014; Mamduh et al. 2017). Larvicidal effects of garlic were identified on Culex quinquefasciatus Say (Dip.: Culicidae), Delia radicum Linnaeus (Dip.: Anthomyiidae), Musca domestica Linnaeus (Dip.: Muscidae), Tribolium castaneum Herbst (Col.: Tenebrionidae) and Spodoptera litura Fabricius (Lep.: Noctuidae) (Prowse et al., 2006; Kalu et al., 2010; Mikhaiel, 2011; Meriga et al., 2012; Mobki et al., 2014). Mobki et al. (2014) reported contact and fumigant toxicity of GE on larvae and adults of T. castaneum. The studies showed that the leaves sprayed with 7.49 mg/l concentration of GE reduced half the density of **Tetranychus** urticae Koch (Acari: Tetranychidae) (Hincapié et al., 2008; Attia et al., 2012). Field studies on cabbage looper, Trichoplusia binotalis Hiibner (Lep.: Noctuidae) reported minimum infestation in the plots that were treated with 3% garlic extract as compared to ginger and tobacco extracts (Rizvi et al., 2016). Cultivation of garlic and some other plants, intercropped between wheat strips, led to reduction in the population dynamic of *Sitobean* avenae Fabricius (Hem.: Aphididae) (Saeed et al., 2016). According to Table 6, GE decreased the survival rate of L. decemlineata eggs. These results are confirmed by other researcher that showed toxicity effects of garlic on the eggs of some species such as S. litura and Helicoverpa armigera Hübner (Lep.: Noctuidae), Earias vitella Sherborn (Lep.: Noctuidae), Maruca vitrata Fabricius (Lep.: Cerambidae), Dysdercus Fabricius (Hem.: Pyrrhocoridae), koenigii tomentosicollis Clavigralla Stå1 (Hem.: Coreidae), L. decemlineata and D. radicum (Gurusubramanian and Krishna, 1996; Ekesi, 2000; Prowse et al., 2006).

According to previous studies, the toxicity effects of garlic were attributed to some sulfuric compounds including thiosulfinates and disulfinates, and a main compound called allicin (Rahman and Motoyama, 2000; Prowse et al., 2006; Ratti et al., 2007; Attia et al., 2012; Yousaf et al., 2012; Anwar et al., 2017). Allicin is a disulfide compound induced from alliin, inhibit which can the activity of acetylcholinesterase, lactate dehydrogenase, and alkaline phosphatase (Singh and Singh, 1996; Anwar et al., 2017). Moreover, some proteins of garlic (as leaf and bulb lectin) physiological disrupt certain processes. especially digestion and absorption, that play an important role in garlic toxicity as mentioned by (Upadhyay and Singh, 2012; Macedo et al., 2015; Niroumand et al., 2016). It appears that some compounds of the sulfide group can penetrate into eggs and bind to sulfidrylproteins, containing impairing vital physiological and biochemical processes in embryonic development as reported by Ekesi, (2000) and Prowse et al. (2006). Additionally, the prevention of egg hatching may be due to the intensification of the hardening process of egg shells by garlic compounds as confirmed by Prowse et al. (2006). The results of this study indicated that egg age affects the mortality L. decemlineata eggs; there can be two possible reasons for this-the change in thickness of egg shells of different ages, and the compounds present in the shells and inside the eggs as stated by Fogleman, (2000), Bakri and Douglas, (2005) and Meriga et al.(2012).

In the present study, the sensitivity range was calculated based on the maximum mortality percentage of E. kuehniella that showed more sensitivity than P. maculiventris in contact toxicity. The mean of mortality percentage of E. kuehniella was calculated at 76% after three days, and for P. maculiventris at 24% after 19 days, with deduction of the control effect (Figs. 1 and 2). Hence GE is more toxicto E. kuehniella than to P. maculiventris. Moreover, the toxicity of GE to L. decemlineata caused considerably increased mortality rate as compared to the predator insect during the same period of time (Fig. 2). According to the results, the efficacy of garlic compounds did not show a linear relationship among the various concentrations (Fig. 1). Hence, mortality maximum occurred in lower concentrations-10% followed by 2% (Figs. 1, 2, and 3). This contradiction was observed in previous studies (Ekesi, 2000; Prowse et al., 2006). Prowse et al. (2006) reported that one reason for this phenomenon could be the presence

of various compounds in garlic and their interaction effects in certain concentrations. According to Fig. 3, GE toxicity on the larvae of the Colorado potato beetle was affected by treated larval instar, which could be due to the different sensitivity of larval instars and their different physiological agents; these results are similar with those obtained by (Ho et al., 1996; Prowse et al., 2006). Additionally, more feeding from treated leaves causes an aggregation of toxins in the insect body. As Fig. (4) shows, the maximum daily feeding of *L. decemlineata* larvae and adults relates to 10% concentration. There are other possible reasons for lower mortality in higher concentrations, which reduce the daily feeding due to the repellent effect of garlic (Rahman and Motoyama, 2000; Hincapié et al., 2008; Mobki et al., 2014) and also, because of the connection of garlic lectins with sensory receptors of mouth parts (Fig. 4) and the amount of toxic compounds in the body (Olmstead and Shelton, 2012; Upadhyay and Singh, 2012).

The efficacy of GE on biological parameters confirms delayed effects of garlic compounds, which require enough time for the aggregation of toxic compounds and the increase in toxicity as found by other researchers like Qi et al. (2001); Prowse et al. (2006) and Mamduh et al.(2017). Garlic compounds increase the developmental time of the Colorado potato beetle (Table 2), which could be due to the delay in the synthesis of chitin by lectin proteins (Cutler et al., 2006). According to a previous study, garlic oil may show antiecdysone activity and disrupt the development of insects (Beltagy and Omar, 2016). Moreover, the reaction of lectins with alkaline phosphatase enzymes may have bad impact on: growth process, metamorphosis, reproduction, neural connections, hormone synthesis, elemental metabolism, diapause, and cysticosis (Jurat-Fuentes et al., 2011). GE has an effect on reproduction parameters and fitness factors in treated larvae and adult of L. decemlineata (Tables 4 and 5). In critical conditions such as contact with pesticides, insects usually oviposit sooner than under normal conditions and reduce their reproduction rate-. So the pre-oviposition

and oviposition periods, and the total number of eggs per female decrease (Bandani, 2010); this was also observed in the present study. Moreover, the presence of nutritional inhibitors such as lectins in GE causes a slowdown in digestion and absorption of food, which could reduce the storage of energy sources, especially proteins, and prevent the growth of follicles (Beltagy and Omar, 2016).

Additionally, garlic lectin can disrupt metamorphosis and reproduction of insects by bonding with P450 cytochrome, halloween proteins, and alkaline phosphatase in the hemolymph, ovaries, and molting hormones, and cause embryo death, reduction of fertility, and efficacy for new cuticle synthesis (Namiki *et al.*, 2005; Upadhyay *et al.*, 2012; Upadhyay and Singh, 2012; Macedo *et al.*, 2015).

Comparing GE toxicity on P. maculiventris, E. kuehnialla, and L. decemlineata showed the predator's relative resistance to the toxic compounds of garlic on mortality rate, developmental time, longevity, and reproduction factors. In this study, garlic compounds were relatively safe on the predator. Saeed et al. (2016) elicited similar results in which the cultivation of garlic between wheat strips reduced the population of S. avenae, while the number of some predator insects increased. Fand et al. (2012) showed that the aqueous extract of garlic caused more than 60% mortality and inhibited the reproduction process of solenopsis *Phenacoccus* Tinsley (Hem.: Pseudococcidae); while it was almost safe on two Coccinellidae predator species-Hyperaspis Sicard and Cryptolaemus maindroni montrouzieri Mulsant. Some studies showed that using some plant extracts, including garlic and hot pepper, decreased the population of some major pests of cabbage, Brassica oleracea L. (Brassicaceae) in compared with control samples (Baidoo and Mochiah, 2016). While, the natural enemies sampled in the botanical extract-spraved plots were more than the insecticide-sprayed plots (Baidoo and Mochiah, 2016). Prowse et al. (2006) proposed that due to variations of some physiological factors of the species concerning ability of permeation of toxic compounds, isolation and disintegration, their sensitivity to toxic compounds will be different. On the other hand, the amount of toxic agents may have been less than the threshold of toxicity (Fogleman, 2000; Jarial, 2001; Bakri and Douglas, 2005; Meriga et al., 2012). Moreover, the resistance of P. maculiventris to some insecticides was reported (Tillman and Mullinix, 2004; Cutler et al., 2006); this could propose that the quantity and quality of monooxygenase enzymes in this insect may cause resistance to other pesticides (Tillman and Mullinix, 2004; Cutler et al., 2006). Our results were contradictory to previous studies (Namiki et al., 2005; Cutler et al., 2006; Cao et al., 2012; Olmstead and Shelton, 2012). Hence, our results support the minimum negative effects of GE on P. maculiventris.

Conclusion

Garlic extract with contact and digestive toxicity can affect a range of biological function of insects. Its anti-nutritional compounds can reduce the damage of *L. decemlneata*. Although the acute toxicity effects of GE is not satisfactory on Colorado beetle, it can lengthen the embryonic and growth period, as well as reduce survival rate, weight, fecundity, fertility, oviposition period, and longevity. The GE showed high mortality on larvae of E. kuehniella. Conversely, this study showed lower sensitivity of P. maculiventris, as a generalist predator, to garlic compounds. The observations on the toxicity of different concentrations could be considered for use of lower economical yet effective concentrations. In this study, 10% and 15% concentrations may be proposed instead of higher concentrations. On the other hand, garlic extract is considered to be a safe botanical pesticide for application on the natural enemy, P. maculiventris in integrated pest management strategies. These results provide evidence that GE (as a botanical insecticide) has considerable promise for effective use as an environmentally friendly alternative to synthetic, chemical insecticides against various destructive pests such as the Colorado potato beetle, while still being reasonably safe to its predatory insects. Nevertheless, more research is

needed to elucidate any side effects of GE on other predators and natural enemies and also to get information on physiological aspects of mortality and morbidity effects of GE on the two pest hosts and their predator.

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References

- Alyokhin, A., Baker, M., Mota-Sanchez, D., Dively, G. and Grafius, E. 2008. Colorado potato beetle resistance to insecticides. American Journal of Potato Research, 85: 395-413.
- Anwar, A., Gould, E., Tinson, R., Groom, M. and Hamilton, C. J. 2017. Think yellow and keep green-role of sulfanes from garlic in agriculture. Antioxidants, 6: 1-12.
- Attia, S., Grissa, K. L., Mailleux, A. S., Lognay, G., Heuskin, S., Mayoufi, S. and Hance, T. 2012. Effective concentrations of garlic distillate (*Allium sativum*) for the control of *Tetranychus urticae* (Tetranychidae). Journal of Applied Entomology, 136: 302-312.
- Baidoo, P. K. and Mochiah, M. B. 2016.
 Comparing the effectiveness of garlic (*Allium sativum* L.) and hot pepper (*Capsicum frutescens* L.) in the management of the major pests of cabbage *Brassica oleracea* (L.). Sustainable Agriculture Research, 5: 83-91.
- Bakri, I. M. and Douglas, C. W. I. 2005. Inhibitory effect of garlic extract on oral bacteria. Archives of Oral Biology, 50: 645-651.
- Bandani, A. R. 2010. Insect Physiology (Homeostasis, Cuticle, Fat body, Blood, P450, Thermoregulation). Tehran University Press, Iran. pp. 457.

- Barati, R., Golmohammadi, G., Ghajarie, H., Zarabi, M. and Mansouri, R. 2013. The effects of some botanical insecticides and pymetrozine on life table parameters of silver leaf whitefly *Bemisia tabaci* Gennadius (Hemiptera: Aleyrodidae). Journal Pesticides and Phytomedicine, 28: 47-55.
- Beltagy, B. I. and Omar, G. A. 2016. Alteration in some biological and biochemical parameters in *Tribolium castaneum* (Coleoptera: Tenebrionidae) due to garlic oil effect.Journal of Advances in Biology, 9: 1704-1714.
- Bonsignore, C. P. and Vacante, V. 2012. Influences of botanical pesticides and biological agents on *Orius laevigatus-Frankliniella occidentalis* dynamics under greenhouse conditions. Journal of Plant Protection Research, 52: 15-23.
- Cao, Y., Zhi, J. and Kong, Y. 2012. Life tables for experimental populations of *Frankliniella occidentalis* on 6 vegetable host plants. Acta Ecologica Sinica, 32: 1249-1256.
- Castillo- Sánchez, L. E., Jiménez-Osornio, J. J. and Delgado-Herrera, M. A. 2010. Secondary metabolites of the Annonaceae, Solanaceae, Meliaceae families used as biological control of insects. Tropical and Subtropical Agroecosystems, 12: 445-462.
- Cutler, G. C., Scott-Dupree, D. C., Tolman, J. H. and Harris, C. R. 2006. Toxicity of the insect growth regulator novaluron to the non-target predatory bug *Podisus maculiventris* (Heteroptera: Pentatomidae). Biological Control, 38: 196-204.
- De Clercq, P. 2008. Spined soldier bug, *Podisus* maculiventris Say (Hemiptera: Pentatomidae: Asopinae). In: Capinera J. L., (Eds.). Encyclopedia of Entomology, 4. Springer, Heidelberg, pp: 3508-3510.
- EFSA. 2012. Conclusion on the peer review of the pesticide risk assessment of the active substance garlic extract. European Food Safety Authority (EFSA), EFSA Journal, 10: 9-14.
- Ekesi, S. 2000. Effect of volatiles and crude extracts of different plant materials on egg

viability of *Maruca vitrata* and *Glavigralla tomentosicollis*. Phytoparasitica, 28: 305-310.

- El-Wakeil, N. E. 2013. Botanical pesticides and their mode of action. Gesunde Pflanzen, 65: 125-149.
- Fand, B. B., Gautam, R. D., Kamra, A., Suroshe, S. S. and Mohan, Sh. 2012.
 Bioefficacy of aqueous garlic extract and a symbiotic bacterium, *Photorhabdus luminescens* against *Phenacoccus solenopsis* Tinsley (Homoptera: Pseudococcidae).
 Biopesticide International, 8: 38-48.
- Fogleman, J. C. 2000. Response of *Drosophila melanogaster* to selection for P₄₅₀-mediated resistance to isoquinoline alkaloids. Chemico-Biological Interactions, 125: 93-105.
- Gurusubramanian, G. and Krishna, S. S. 1996. The effect of exposing eggs of four cotton insect pests to volatiles of *Allium sativum* (Liliaceae). Bulletin of Entomological Research, 86: 29-31.
- Hincapiée, A. C., Lopez, E. G. and Torres, R. C. P. 2008. Comparison and characterization of garlic (*Allium sativum* L.) bulbs extracts and their effect on mortality and repellency of *Tetranychus urticae* KOCH (Acari: Tetranychidae). Chilean Journal of Agricultural Research, 68: 317-327.
- Ho, S. H., Koh, L., Ma, Y., Huang, Y. and Sim, K.
 Y. 1996. The oil of garlic, *Allium sativum* L.(Amaryllidaceae), as a potential grain protectant against *Tribolium castaneum* (Herbst) and *Sitophilus zeamais* Motsch. Postharvest Biology and Technology, 9: 41-48.
- Isman, M. B. 2006. Botanical insecticides, deterrents, and repellents in modern agriculture and an increasingly regulated world. Annual Review of Entomology, 51: 45-66.
- Jaastad, G., Trandem, N., Hovland, B. and Morgan, S. 2009. Effect of botanically derived pesticides on mirid pests and beneficials in apple. Crop Protection, 28: 309-313.
- Jahromi, M. G., Pourmirza, A. A. and Safaralizade, M. H. 2011. Evaluation of the mortality of two stored-product insects by garlic emulsion (Sirinol) in combination with low air pressure. African Journal of Biotechnology, 10: 19650-19657.

- Jarial, M. S. 2001. Toxic effect of garlic extracts on the eggs of *Aedes aegypti* (Diptera: Culicidae): a scanning electron microscopic study. Journal of Medical Entomology, 38: 446-450.
- Jurat-Fuentes, J. L., Karumbaiah, L., Jakka, S. R. K., Ning, C., Liu, C., Wu, K., Jackson, J., Gould, F., Blanco, C., Portilla, M., Perera, O. and Adang, M. 2011. Reduced levels of membrane-bound alkaline phosphatase are common to lepidopteran strains resistant to Cry toxins from *Bacillus thuringiensis*. PlosOne6: e 176.
- Kalu, I. G., Ofoegbu, U., Eroegbusi, J., Nwachukwu, C. U. and Ibeh, B. 2010. Larvicidal activities of ethanol extract of *Allium sativum* (garlic bulb) against the filarial vector, *Culex quinquefasciatus*. Journal of Medicinal Plants Research, 4: 496-498.
- Kramer, C. Y. 1956. Extension of multiple range tests to group means with unequal number of replications. Biometrics, 12: 307-310.
- Kumar, V. 2015. A review on efficacy of biopesticides to control the agricultural insect's pest. International Journal of Agricultural Science Research, 4: 168-179.
- Lu, Y. J. and Liu, F. J. 2003. Study on effect of garlic and Aloe extract against stored grain insect. Foodstuff Storage, 32: 14-17.
- Macedo, M. L., Oliveira, C. F. and Oliveira, C. T. 2015. Insecticidal activity of plant lectins and potential application in crop protection. Molecules, 20: 2014-2033.
- Mamduh, Z. and Movahedi Fazel, M. 2015. The Efficacy of Garlic Extraction on Some Physiological Parameters in Colorado Potato Beetle, *Leptinotarsa decemlineata* Say. (Col.: Chrysomelidae). Journal of Animal Research, 28: 244-255.
- Mamduh, Z., Hosseininaveh, V., Allahyari, H. and Talebi-Jahromi, Kh. 2017. Side effects of garlic extract on the life history parameters of thepredatory bug, *Podisus maculiventris* (Say) (Hemiptera: Pentatomidae). Crop Protection, 100: 65-72.
- Marie, S. S., Amr, E. M. and Salem, N. Y. 2009. Effect of some plant oils on biological, physiological and biochemical

aspects of *Spodoptera litoralis* (Boisd.). Research Journal of Agriculture and Biological Science, 5: 103-107.

- Meriga, B., Mopuri, R. and MuraliKrishna, T. 2012. Insecticidal, antimicrobial and antioxidant activities of bulb extracts of *Allium sativum*. Asian Pacific Journal of Tropical Medicine, 5: 391-395.
- Mikhaiel, A. A. 2011. Potential of some volatile oils in protecting packages of irradiated wheat flour against *Ephestia kuehniella* and *Tribolium castaneum*. Journal of Stored Products Research, 47: 357-364.
- Mobki, M., Safavi, S. A., Safaralizadeh, M. H. and Panahi, O. 2014. Toxicity and repellency of garlic (*Allium sativum* L.) extract grown in Iran against *Tribolium castaneum* (Herbst) larvae and adults. Archives of Phytopathology and Plant Protection, 47: 59-68.
- Moreau, T. L., Warman, P. R. and Hoyle, J. 2006. An evaluation of companion planting and botanical extracts as alternative pest controls for the Colorado potato beetle. Biological Agriculture and Horticulture, 23: 351-370.
- Muhsin, T. M., Al-Zubaidy, S. R. and Ali, E. T. 2001. Effect of garlic bulb extract on the growth and enzymatic activities of rhizosphere and rhizoplane fungi. Mycopathologia, 152: 143-146.
- Namiki, T., Niwa, R., Sakudoh, T., Shirai, K., Takeuchi, H. and Kataoka, H. 2005. Cytochrome P450 CYP307A1/Spook: a regulator for ecdysone synthesis in insects. Biochemical and Biophysical Research Communications, 337: 367-374.
- Niroumand, Ch. M., Farzaei, M. H., Karimpour-Razkenari, E., Amin, Gh., Khanavi, M., Akbarzadeh, T. and Shams-Ardekani, M. R. 2016. An evidence-based review on medicinal plants used as insecticide and insect repellent in traditional Iranian medicine. Iranian Red Crescent Medical Journal, 18: 1-8.
- Olmstead, D. L. and Shelton, A. M. 2012. Evaluation of insecticide chemistries against the Leek moth (Lepidoptera: Acrolepiidae), a new pest in north America. Florida Entomologist, 95: 1127-1131.

- Oparaeke, A. M., Dike, M. C. and Amatobi, C. I. 2007. Effect of application of different concentrations and appropriate schedules of aqueous garlic bulb extracts against *Maruca vitrata* and *Clavigralla tomentosicollison* Cowpea. Archives of Phytopathology and Plant Protection, 40: 246-251.
- Perez-Mendoza, J. and Aguilera-Pena, M. 2004. Development, reproduction and control of the Indian meal shin stored seed garlic in Mexico. Journal of Stored Products Research, 40: 409-421.
- Prowse, G. M., Galloway, T. S. and Foggo, A. 2006. Insecticidal activity of garlic juice in two dipteran pests. Agricural and Forest Entomology, 80: 1-6.
- Qi, B., Gordon, G. and Gimme, W. 2001. Effects of Neem-fed prey on the predacious insects *Harmonia conformis* (Boisduval)(Coleoptera: Coccinellidae) and *Mallada signatus* (Schneider) (Neuroptera: Chrysopidae). Biological Control, 22: 185-190.
- Rahman, G. K. M. M. and Motoyama, N. 2000. Repellent effect of garlic against stored product pests. Journal of Pesticide Science, 25: 247-252.
- Ratti, C., Araya-Farias, M., Mendez-Lagunas, L. and Makhlouf, J. 2007. Drying of garlic and its effect on Allicin retention. Drying Technology, 25: 349-356.
- Rizvi, S. A. H., Hussain, Sh., Rehman, S. U., Jaffar, S. and Rehman, M. F. U. 2016. Efficacy of ecofriendly botanical extracts of Ginger (*Zingiber officinale*), Garlic (*Allium* sativum) and Tobacco (*Nicotiana tabacum* L) for the control of cabbage looper (*Trichoplusia* binotalis) under agro ecological conditions of Peshawar, Pakistan. Journal of Entomology and Zoology Studies, 4: 88-90.
- Robertson, J. L., Russell, R. M., Preisler, H. K. and Savin, N. E. 2007. Bioassays with Arthropods. CRC Press, Boca Raton.
- Sadeghi, A., Smaqqhe, G., Broeders, S., Hernalsteens, J. P., De Greve, H., Peumans,

W. J. and Van Damme, E. J. 2008. Ectopically expressed leaf and bulb lectins from garlic protect transgenic tobacco plants against Cotton leafworm (*Spodoptera littoralis*). Transgenic Research, 17: 9-18.

- Saeed, N., Mori, N., Battisti, A. and Ashraf, M. 2016. Effect of *Brassica napus*, *Medicago* sativa, *Trifolium alexandrinum* and *Allium* sativum strips on the population dynamics of Sitobean avenae and predators in wheat ecosystem.Journal of Entomology and Zoology Studies, 4: 178-182.
- Singh, V. K. and Singh, D. K. 1996. Enzyme inhibition by allicin, the molluscicidal agent of *Allium sativum* L.(garlic). Phytotherapy Research, 10: 383-386.
- SPSS 15.0. 2012. Command Syntax Reference, Chicago, Illinois: SPSS Inc.
- Tillman, P. G. and Mullinix, J. B. G. 2004. Comparison of susceptibility of pest *Euschistus servus* and predator *Podisus maculiventris* (Heteroptera: Pentatomidae) to selected insecticides. Journal of Economic Entomology, 97: 800-806.
- Tukey, J. W. 1953. The problem of multiple comparisons. Unpublished manuscript. Princeton University.
- Upadhyay, S. K. and Singh, P. K. 2012. Receptors of garlic (*Allium sativum*) lectins and their role in insecticidal action. Protein Journal, 31: 439-446.
- Upadhyay, S. K., Singh, S., Chandrashekar, K., Tuli, R. and Singh, P. K. 2012. Compatibility of garlic (*Allium sativum* L.) leaf agglutinin and Cry1Ac δ-endotoxin for gene pyramiding. Applied Microbiology and Biotechnology, 93: 2365-2375.
- Vassiliou, V. A. 2011. Botanical insecticides in controlling Kelly's citrus thrips (Thysanoptera: Thripidae) on organic grapefruits. Journal of Economic Entomology, 104: 1979-1985.
- Yousaf, Z., Umer, A., Younas, A., Khan, F. and Wang, Y. 2012. Allelopathic plants: 24. Genus *Allium* L. Allelopathy Journal, 29: 1-12.

سمّیت ترکیبات سیر روی سن شکارگر (Podisus maculiventris (Hemiptera: Pentatomidae) در مقایسه با دو میزبان آن

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چکیده: سمیت گیاه سیر بر روی گروهی از آفات کشاورزی تأیید شده است. هدف از این مطالعه، بررسی حساسیت سن شکارگر (Say) *Podisus maculiventris* (Say) به عصاره گیاه سیر در مقایسه با دو آفت کرم آرد، (Zeller) *Ephestia kuehniella و سوسک کلرادو سیبزمینی، Leptinotarsa decemlineata* (Say) بوده است. در در محاسبه شده برای کرم آرد در حدود ۸/۰۲ درصد برآورد شده است. نتایج حاصله گویای اثرات تأخیری ترکیبات سمّی بر تمامی مراحل رشد و نموی و پارامترهای تولیدمثلی سوسک کلرادو بوده است. در نقطه مقابل، بسیاری از پارامترهای بیولوژیکی سن آفات کش سوسک کلرادو بوده است. در نقطه مقابل، بسیاری از پارامترهای بیولوژیکی سن *ا*معنوان یک آفتکش سرز پیشنهاد میکند که میتواند به عنوان یک جایگزین مناسب در برنامههای مدیریتی آفات مدنظر قرار گیرد.

واژگان کلیدی:Allium sativum عوامل کنترل بیولوژیک، آفتکشهای گیاهی، Ephestia kuehniella، Leptinotarsa decemlineata