Efficacy of Dayabon®, a botanical pesticide, on different life stages of *Myzus persicae* and its biological control agent, *Aphidius matricariae*

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**Abstract:** The green peach aphid, *Myzus persicae* (Sulzer) (Hemiptera: Aphididae), is one of the most important pests in greenhouses and its damages are economically important. The overuse of chemical pesticides has caused resistance in green peach aphid to many common insecticides. *Aphidius matricariae* (Haliday) (Hymenoptera: Braconidae) is an effective biological control agent against aphid populations especially in greenhouse crops. Currently, use of safe and biocompatible botanical pesticides in combination with biological control agents is being recommended. In this study, contact toxicity of Dayabon (SL 10%), a new botanical pesticide, was investigated on different life stages of *M. persicae* at 1000 to 7000 ppm. Also, the toxicity was studied on mummies and adult parasitoids at 2000 to 14000 ppm. The estimated LC$_{50}$ on first, second, third, fourth instar nymphs and adults were 3254, 3387, 4194, 3839 and 3508 ppm, respectively. However, concentrations up to 5000 ppm caused less than 50% mortality in parasitoid mummies. Moreover, the residues of Dayabon did not cause any mortality in *A. matricariae* adults. Based on the standard method of IOBC/WPRS Working Group for side-effects of pesticides on natural enemies of insects, the Dayabon is recognized as safe for *A. matricariae* while it has acceptable mortality on green peach aphid. Therefore, the integration of Dayabon with *A. matricariae* could be recommended in order to achieve better control of *M. persicae* in greenhouse products.

**Keywords:** green peach aphid, insecticide, parasitoid, Dayabon, LC$_{50}$

**Introduction**

Aphids are the most important pests that adversely affect crop yield and quality. There are plenty of agriculturally important species in the subfamily Aphidiinae such as green peach aphid, *Myzus persicae* (Sulzur) (Hemiptera: Aphididae). This species is a destructive pest both in greenhouse and field (Blackman and Eastop, 2008; Van Emden and Harrington, 2017). The *M. persicae* infestation not only weakens the plant, but also transmits more than 100 viral or phytoplasma diseases that end up with the plant death, if efficient control methods are not applied (Van Emden et al., 1969). At present, farmers use a great quantity of chemical insecticides against *M. persicae*. Overuse of insecticides has led to the development of aphid's resistance (Bass et al., 2014) and decrement of the aphid's natural enemies specially parasitoids and predators. Biological control is a major component in the integrated pest management (IPM) program of...
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aphids (van Lenteren and Woets, 1988). There are a large number of reports on the efficacy of aphid natural enemies (Rakhshani et al., 2007, 2012; Talebi et al., 2009).

*Aphidius matricariae* (Haliday) (Hymenoptera: Braconidae) is an effective biological control agent against aphid populations especially in greenhouse crops that is produced by a number of commercial companies around the world (Zamani et al., 2006; Tahriri et al., 2007).

This polyphagous parasitoid species probably originated from northern India or Pakistan but it is now found in various parts of the world such as, North and South America, Australia and Europe. Also, *A. matricariae* was reported from different parts of Iran such as Tehran, Khuzestan, Hamedan, Fars, Kurdistan and Mazandaran. It has been reported that *A. matricariae* has more than 50 aphid species as its hosts (Farahani et al., 2016), however, *M. persicae* has been known as one of the preferred hosts (Tazerouni et al., 2016).

To achieve a successful IPM program with the *A. matricariae*, it is necessary to integrate the parasitoid with safe chemical control method in particular, compatible or botanical pesticides (Van Lenteren and Woets, 1988; Rezaei et al., 2014).

Currently, use of safe and biocompatible or botanical pesticides in combination with biological control methods are very noticeable (Ndakidemi et al., 2016). The pesticides and beneficial organisms working group (WPRS) of International Organization for Biological Control (IOBC) has published the standard methods for testing the side-effects of pesticides on natural enemies of insects and mites in laboratory, semi-field and field conditions (Hassan et al., 1985). Also, they have described a laboratory method to evaluate the side effect of pesticides on *Diaeretiella rapae* McIntosh (Aphididae: Hymenoptera), a parasitoid of *Brevicoryne brassicae* (L.). Particularly, Polgar (1988) tested 82 pesticides on *A. matricariae*, using a unique glass plate method. *Aphidius matricariae* shows different levels of sensitivity to various kinds of pesticides. In addition, in the literature, some reports have been published about the side effects of chemical and botanical pesticides on different species of the genus *Aphidius* (Longley, 1999; Bostanian et al., 2005; D’Ávila et al., 2018). However, little is known about the side effects of Dayabon on *A. matricariae*. Dayabon® is a botanical based pesticide consisting of castor oil and salts of fatty acids manufactured by Daya Nanotechnologists Company (Tehran, Iran).

The effect of Dayabon on elm leaf beetles, *Xanthogaleruca luteola* (Muller) (Chrysomelidae: Coleoptera) was investigated by Vahabi Mashhour et al. (2016). They indicated the possibility of practical use of Dayabon in management of *X. luteola* in urban landscape. Dayabon has a suitable mortality when used in greenhouses to control two spotted spider mite, *Tetranychus urticae* Koch (Acari: Tetranychidae) without any deleterious effects on the predatory mite, *Amblyseius swirskii* (Athias-Henriot) (Acari: Phytoseiidae) (Mortazavi et al., 2016). The toxicity of Dayabon has also been reported in a number of aphid species such as *Brevicoryne brassicae* L. (Rezaian et al., 2015), *Aphis fabae* Scopoli (Amini Jam, 2017) and *Myzus nicotianae* Blackman (Rezaei et al., 2017b).

Due to the deleterious effects of chemical pesticides on non-target organisms, beneficial insects and the environment, the use of botanical pesticides would be a safe and suitable method for pest control. In this study, the contact toxicity of Dayabon was evaluated on different life stages of *M. persicae*. Moreover, the side effects of Dayabon were investigated on potential parasitoid of green peach aphid, *A. matricariae*.

Materials and Methods

Plant and insect rearing protocols

Chinese cabbage, *Brassica pekinensis* cv. Hero, as a host plant, was grown in plastic pots (10 cm diameter) without application of any fertilizer or pesticides under greenhouse condition at 25 ± 5 °C, 65 ± 5% RH and L: D 16:8 h. Then, laboratory cultures of *M. persicae* were maintained on 5-leaf stage in ventilated cage (50 × 50 × 50cm) and in a constant environmental condition at 25 ± 1 °C, 70 ± 5%
RH and L:D 16:8 h. Then cultures of *A. matricariae* were maintained on *M. persicae* in conditions as mentioned above. Also, a cotton ball containing aqueous honey solution (40%) was placed in each rearing cage to feed the adult parasitoids and was renewed every 48 h. The rearing method was adopted from Zamani et al. (2006). Population of *A. matricariae* and *M. persicae* were first collected from greenhouses of Varamin County (35° 18’ N, 51° 44’ E, 969 m), located in Tehran province.

**Experimental design**

In this study, contact toxicity of Dayabon (SL, castor oil 10%) was investigated on different life stages (1st, 2nd, 3rd, 4th instar nymphs and adult) of *M. persicae*. In order to achieve the uniform aphids in age, apterous females from their stock cultures were transferred individually onto leaf discs of the host plant, placed in translucent ventilated plastic containers (11 × 10 × 4 cm), to produce offsprings for 24 h. Then, the newly produced nymphs were maintained at standard environmental conditions (25 ± 2°C; 70 ± 5% RH; 16:8, L: D h) to achieve desired life stages. The bioassay was designed to determine both LC50 and LC90 values of 24 h post treatments. Based on the preliminary experiments to cause 20 and 80 percent mortality, toxicity tests were conducted at 1000, 2000, 3000, 4000, 5000, 6000 and 7000 ppm. The lethal effect of Dayabon was tested by dipping the established aphids on leaf discs (5 cm diameter) for 3 seconds in the pesticide (Rezaei et al., 2017a).

Deleterious effects of Dayabon on the parasitoid wasp, *A. matricariae*, was studied based on the standard methods to test the side-effects of pesticides on natural enemies of insects developed by the IOBC/WPRS Working Group, Pesticides and Beneficial Organisms (Hassan et al., 1985) with some modifications. The methods used in this study are much more rigorous than the IOBC methods. The methods developed by the IOBC/WPRS have been accepted by the EU for use in the registration of pesticides. The toxicity tests on parasitoid were conducted by two methods. In order to obtain parasitoid mummies and adults, 400 individuals of aphids, established on the host plant, were exposed to 10 mated females of *A. matricariae* (< 1 day) for 24 h. Then, the parasitized aphids were fed on the host plants until parasitoid mummies emerged. The mummies (<1 day) were collected and used in the first part of experiment. Then, some mummies were maintained under standard environmental conditions until adult parasitoids were emerged. The newly emerged adults (< 1 day) were used in the second part of experiment. At first, parasitoid mummies (< 1 day) were dipped into aqueous solution of Dayabon at concentrations ranging from 2000 to 14000 ppm for 3 seconds. Then, mummies were checked daily for adult emergence. The experiment was replicated five times per concentration and each replication contained 30 mummies of the parasitoid. In the second experiment, the tubes (1.5 cm diameter and 10 cm high) were treated by Dayabon solution at 2000, 3000, 4000, 5000 ppm. After drying the tubes for less than 2 h, five adults (< 1 day) were introduced into each tube. A cotton ball of honey solution (40%) was placed in the tubes in order to feed the adult parasitoids. Then, the number of dead parasitoid wasps was recorded 24 h after treatment. This experiment was replicated 10 times per concentration and each replication contained five adult parasitoids. All experiments were performed at 25 ± 2°C; 70 ± 5% RH; LD 16:8 h. In addition, the control was treated with water only.

**Statistical analysis**

Data obtained from dose-response bioassays were subjected to probit analysis in order to estimate LC50 and LC90 values (lethal concentration for 50 and 90% mortality, respectively) (Finney, 1971). Relative median potency (RMP) test was used to compare the significant differences of LC50s between treatments. Also, one-way ANOVA was used to test the effect of different concentrations of Dayabon on the mortality of *A. matricariae*. Then, post hoc pairwise comparisons between concentrations were performed using Tukey’s honestly significant difference (HSD) tests at *P*
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**Results**

The lethal concentration to cause 50% mortality (LC$_{50}$) and their 95% confidence limits on first, second, third and fourth instars, and adult aphids were 3254 (2835-3646), 3387 (2943-3791), 4194 (3980-4393), 3839 (3575-4080) and 3508 (3157-3840) ppm, respectively (Table 1). Moreover, LC$_{50}$ value of Dayabon on parasitoid mummies was 7595.4 (6709.5-8843.4) ppm. Using relative median potency test, it was found that the 3$^{rd}$ instar aphid (4194 ppm) was significantly more tolerant than the other instars and adult aphids. Other instars and adult aphids were not significantly different to each other (Table 2). However, mummies was significantly more tolerant than the most tolerant aphid stage (3$^{rd}$ instar nymph) (Table 2). Probit lines also exhibited a distinct distance between aphid stages and mummies (Fig. 1). The toxicity values of Dayabon on 1-day-old parasitoid mummies are shown in Fig. 2. The minimum and maximum percent mortality of *A. matricariae* was observed at 2000 (14%) and 14000 (73.33%) ppm, respectively (Fig. 2). However, 24h after exposure to Dayabon residue, no adult mortality was observed at ranges from 2000 to 5000 ppm. This means that all adult parasitoids stayed alive.

**Table 1** The LC$_{50}$ and LC$_{90}$ values of Dayabon on different life stages of the green peach aphid, *Myzus persicae* and *Aphidius matricariae*.

<table>
<thead>
<tr>
<th>Species</th>
<th>Stage</th>
<th>n$^1$</th>
<th>$\chi^2$ (df)</th>
<th>$P$-value</th>
<th>Slope ± SE</th>
<th>LC$_{50}$ (ppm) (95% confidence limits)</th>
<th>LC$_{90}$ (ppm) (95% confidence limits)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Myzus persicae</em></td>
<td>1$^{st}$ instar nymph</td>
<td>228</td>
<td>1.839 (5)</td>
<td>0.871</td>
<td>1.60 ± 0.23</td>
<td>3254.1 (2834.7-3645.5)</td>
<td>5866.5 (5291.5-6719.2)</td>
</tr>
<tr>
<td></td>
<td>2$^{nd}$ instar nymph</td>
<td>250</td>
<td>0.650 (5)</td>
<td>0.986</td>
<td>1.52 ± 0.22</td>
<td>3387.3 (2943.1-3791.0)</td>
<td>4194.1 (2642.7-3979.8)</td>
</tr>
<tr>
<td></td>
<td>3$^{rd}$ instar nymph</td>
<td>933</td>
<td>1.704 (5)</td>
<td>0.888</td>
<td>1.95 ± 0.15</td>
<td>4194.1 (2934.1-3791.0)</td>
<td>6956.7 (6242.7-7307.4)</td>
</tr>
<tr>
<td></td>
<td>4$^{th}$ instar nymph</td>
<td>625</td>
<td>0.578 (5)</td>
<td>0.989</td>
<td>1.83 ± 0.17</td>
<td>3838.7 (3979.8-4392.7)</td>
<td>6530.5 (6639.7-7348.6)</td>
</tr>
<tr>
<td></td>
<td>Adult</td>
<td>322</td>
<td>0.909 (5)</td>
<td>0.970</td>
<td>1.62 ± 0.21</td>
<td>3580.0 (3156.9-3840.1)</td>
<td>6279.3 (5722.7-7100.5)</td>
</tr>
<tr>
<td>*Aphidius</td>
<td>Mummies</td>
<td>750</td>
<td>2.488 (3)</td>
<td>0.477</td>
<td>2.10 ± 0.18</td>
<td>7595.4 (6709.5-8843.4)</td>
<td>30868.6 (23087.0-46143.4)</td>
</tr>
<tr>
<td>matricariae</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$^1$ The number of tested insects.

**Table 2** Comparison of LC$_{50}$ values between different stages of green peach aphid, *Myzus persicae*, by relative median potency (RMP).

<table>
<thead>
<tr>
<th>Stage (A / B)</th>
<th>RMP (LC$<em>{50}$A / LC$</em>{50}$B)</th>
<th>95% confidence limits</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Lower</td>
<td>Upper</td>
</tr>
<tr>
<td>Adult/1$^{st}$ instar</td>
<td>1.078</td>
<td>0.888</td>
<td>1.449</td>
</tr>
<tr>
<td>Adult/2$^{nd}$ instar</td>
<td>1.036</td>
<td>0.918</td>
<td>1.292</td>
</tr>
<tr>
<td>Adult/3$^{rd}$ instar</td>
<td>0.836</td>
<td>0.658</td>
<td>1.022</td>
</tr>
<tr>
<td>Adult/4$^{th}$ instar</td>
<td>0.914</td>
<td>0.735</td>
<td>1.170</td>
</tr>
<tr>
<td>4$^{th}$/1$^{st}$ instar</td>
<td>1.180</td>
<td>0.926</td>
<td>1.611</td>
</tr>
<tr>
<td>4$^{th}$/2$^{nd}$ instar</td>
<td>1.133</td>
<td>0.907</td>
<td>1.494</td>
</tr>
<tr>
<td>4$^{th}$/3$^{rd}$ instar</td>
<td>0.915</td>
<td>0.738</td>
<td>1.074</td>
</tr>
<tr>
<td>3$^{rd}$/1$^{st}$ instar</td>
<td>1.289</td>
<td>1.055</td>
<td>1.783</td>
</tr>
<tr>
<td>3$^{rd}$/2$^{nd}$ instar</td>
<td>1.238</td>
<td>1.032</td>
<td>1.650</td>
</tr>
<tr>
<td>3$^{rd}$/3$^{rd}$ instar</td>
<td>1.041</td>
<td>0.861</td>
<td>1.251</td>
</tr>
<tr>
<td>Mummy/3$^{rd}$ instar</td>
<td>1.811</td>
<td>1.368</td>
<td>2.980</td>
</tr>
</tbody>
</table>

* and ns indicate significant and non-significant differences between two groups based on lower and upper 95% confidence limits.
Figure 1 Lines of probit mortality of Dayabon on different stages of green peach aphid *Myzus persicae* and parasitoid wasp mummies *Aphidius matricariae*.
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Discussion

Our results obviously show that Dayabon can be considered as an effective pesticide against green peach aphid, M. persicae (Table 1). Dayabon is a new botanical pesticide which is safe for human and other mammals. Generally, the Dayabon is registered as an acaricide in particular, for the control of two-spotted spider mite, T. urticae in greenhouse crops (Mortazavi et al., 2016). However, this is the first experiment reporting the toxicity of Dayabon on M. persicae. The LC50 of Dayabon varied for different aphid life stages. In this regard, the first and second instar as well as adults were more tolerant than the third instar nymphs. The high susceptibility of adult stage could be as a result of more coverage of insecticide on insect body surface. Additionally, susceptibility of the first and second instars could be attributed to small body size facilitating coverage of the body. This finding is in agreement with Vahabi Mashhour et al. (2016) who showed the adult stage of X. luteola is more susceptible than the third instar larvae to Dayabon.

The effects of a number of essential oils and botanical pesticides have been documented on M. persicae (Hori, 1998; Pavela, 2009; Nzanza and Mashela, 2012). For instance, the toxicity and synergistic effect of fermented plant extracts of neem leaf and wild garlic has been reported on M. persicae (Nzanza and Mashela, 2012). Also, the seed extracts of Melia azedarach L. (Meliaceae) has insecticidal effects on M. persicae (Salari et al., 2012). Compared to other botanical compounds, Dayabon has a suitable mortality effect on M. persicae at a reasonable concentration. Moreover, Dayabon is recognized as safe for some greenhouse natural enemies (Mortazavi et al., 2016).

The side effects of insecticides have been studied on a number of natural enemies (Longley, 1999; Sterk et al., 1999; Arnó and Gabarra, 2011; Rezaei et al., 2014; D’Ávila et al., 2018). The effect of pesticides on biological control agents should first be evaluated under laboratory condition. The pesticides found to be harmless to biological control agents in laboratory are most likely be harmless in greenhouse conditions (Hassan et al., 1985). In this regard, the members of the IOBC/WPRS working group stated four evaluation categories to classify initial toxicity test on natural enemies in laboratory including, harmless (< 50%), slightly harmful (50-79%), moderately harmful (80-99%) and harmful (> 99%). According to results, the percent mortality of

Figure 2 Impact of Dayabon on the mortality of Aphidius matricariae mummies calculated by number of emerged adult wasps. Vertical bars indicate standard error of mean. Means followed by the same letters are not significantly different (Tukey’s test, P ≤ 0.05).
Dayabon on aphid mummies was no more than 32.66% at 5000 ppm. So, it could be concluded that Dayabon is a harmless botanical pesticide on *A. matricariae*. Besides, no mortality was observed for adult parasitoids exposed to dry residues of Dayabon.

An important issue threatening the successful augmentation of natural enemies is the use of pesticides (Elzen *et al.*, 2003). Thus, many studies have documented the detrimental effects of pesticides on natural enemies (Tedeschi *et al.*, 2001; Urbaneja *et al.*, 2008; Pavela, 2009) in particular the genus *Aphidius* parasitoids (Jansen, 1996; Joseph *et al.*, 2011; D’Ávila *et al.*, 2018). However, when the population of aphids is in outbreak, the parasitoids especially *A. matricariae* cannot succeed to acceptable control of aphids in greenhouse (Jacobson and Croft, 1998). In this case, Dayabon could be used as an ideal botanical pesticide for the control of aphid outbreaks. In addition, according to detrimental effects of pesticides on fertility and fecundity of natural enemies (Arnó and Gabarra, 2011), further research is needed to elucidate the sublethal effects of Dayabon on reproductive performance of *A. matricariae*.

In conclusion, according to the IOBC index, the Dayabon is recognized as safe for *A. matricariae* while it has acceptable mortality on green peach aphid. Therefore, integration of Dayabon with *A. matricariae* could be recommended in order to achieve suitable control of *M. persicae* in greenhouse products. However, further experiments are necessary to elucidate the efficacy of Dayabon in the natural field and greenhouse conditions.

**Acknowledgments**

We thank Mohammad Bashiri for the technical supports.

**References**


تأثیر آفت‌کش گیاهی دایاپون روی مراحل مختلف زیستی شته سبز هلو Myzus persicae و عامل کنترل پیلوژیک آن Aphidius matricariae

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چکیده: شته سبز هلو، Myzus persicae (Sulzer) (Hemiptera: Aphididae) یکی از مهم‌ترین آفات گلخانه‌ای محصول می‌شود که خطرات آن از لحاظ اقتصادی بسیار مهم محسوب می‌شود. عامل بیش از حداکثر پیش‌بینی شده است. زنبور پارازیت‌نما‌ی از عوامل مهم مؤثر کنترل پیلوژیکی این آفت محسوب شده‌اند. این آفت‌کش‌ها به صورت احتمالی به‌صورت ۱۰٪ از تعداد مولفه‌های روی میوه می‌پردازند و حشرات کامل زنبور پارازیت‌نما را می‌دریافت، اما در حالتی که هر روز دایاپون به‌صورت از راه اندازی از آن‌ها استفاده شود، این آفت‌کش‌ها می‌توانند در مدت زمانی کمتر از دو هفته، این آفت‌کش‌ها می‌توانند در مدت زمانی کمتر از دو هفته، در حدود ۵۰ دخصوص به‌صورت دو هفته، همچنین با این‌mania دایاپون هیچگونه مارک‌میکروی در حشرات کامل زنبور پارازیت‌نما در این آفت‌کش‌ها لجست‌گر ندارد. براساس استاندارد آزمایش‌های ارزش‌آمیز این آفت‌کش‌ها (IIBC/WPRS) آفت‌کش‌ها روی دشمنان طبیعی حشرات توسط گروه کاری A. matricariae به‌صورت دو هفته که حشرات کشی خطر شناخته شده، این در حالی است که دایاپون مارک‌میکروی قابل‌قبولی در شته‌های سبز ایجاد نمود. بنابراین کاربرد تلفیقی دایاپون و زنبور پارازیت‌نما در M. persicae می‌تواند برای رسیدن به کنترل مناسب شته‌های سبز هلو از این آفت‌کش‌ها استفاده شود.

واژگان کلیدی: شته سبز هلو، حشره کش، پارازیت‌نما، دایاپون، LC₅₀