Imidacloprid Resistance Status and Role of Detoxification Enzymes in *Bemisia tabaci* (Hemiptera: Aleyrodidae) Populations from Iran

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**ABSTRACT**

Neonicotinoid pesticides such as imidacloprid and thiacloprid are agonists of nicotinic Acetylcholine Receptors (nAChRs). This chemical group is commonly used in controlling sucking pests such as cotton whitefly, *B. tabaci*, one of the most serious and destructive pests of agricultural crops worldwide. Bioassays were performed using a leaf dip method and Ahvaz population with the lowest LC₅₀ value (24.40 mg ai L⁻¹) was considered as the susceptible population. LC₅₀ values of Karaj, Isfahan, Gorgan and Minab populations were estimated as 189.81, 136.91, 106.95, 141.09, and 68.31 mg ai L⁻¹ respectively. Low Resistance Ratios (RR) to imidacloprid were observed in the tested populations (RR values< 10). The piperonylbutoxide (PBO) and TriPhenyl Phosphate (TPP) showed the highest synergistic ratios of 1.99 and 2.42 in the population of Kashan, respectively, but DiEthyl Maleate (DEM) did not show a high synergistic ratio. The activity of cytochrome P450-dependent monooxygenase (P450s), CarboxylEsterase (CarEs) and Dlutathione S-Transferases (GST) were measured. There was an increase in the activity of P450s up to 3-fold in the Gorgan population and CarE activity in Kashan population up to 2-fold in comparison to the susceptible population. Based on the results, P450s and CarEs are possibly the enzyme systems responsible for imidacloprid resistance in the tested populations of *B. tabaci*.

Keywords: Bioassays, Cotton whitefly, Monooxygenases, Neonicotinoid, Synergism.

**INTRODUCTION**

Neonicotinoid pesticides are important in pest management because of their high effectiveness against a wide range of pests in the world and have been registered in more than 120 countries (Bass et al., 2015). Their discovery has been considered as a turning point in research for new insecticides (Nauen and Denholm, 2005). The rates of application and toxicity of neonicotinoids are lower than those of previous insecticides (Tomizawa and Casida, 2003). The ionic channels of nicotinic Acetylcholine Receptors (nAChRs) that are placed in the central nervous system of insects are the target of neonicotinoids (Casida, 2010; Crossthwaite et al., 2017). The first neonicotinoid insecticide released was imidacloprid, in 1991 (Karunker et al., 2008). Imidacloprid was first registered in Iran for controlling tobacco aphids in 1996 (Meschi, 2007). Resistance development is a major risk to the agricultural efficiency of
commercial insecticides (Rauch and Nauen, 2003). Most reported cases of neonicotinoid resistance by 2016 belong to *Bemisia tabaci* (Gennadius), *Nilaparvata lugens* (Stål), *Myzus persicae* (Sulzer), and *Aphis gossypii* (Glover), and imidacloprid has the greatest share to the resistance of neonicotinoids (APRD, 2016; Bass et al., 2015).

The cotton whitefly, *Bemisia tabaci* (Hemiptera: Aleyrodidae) is an important polyphagous pest which has developed resistance to various insecticides worldwide (Gravalos et al., 2015; Oliveira et al., 2001). This pest damages more than 500 host plant species of 60 families (Mound and Halsey, 1978). The cotton whitefly directly damages host plants by feeding and indirectly by transmission of viruses and excretion of honeydew (Brown et al., 1995; Byrne and Bellows Jr, 1991). *B. tabaci* is a species complex with at least 34 biotypes that based on the molecular criteria are distinct (Cuthbertson and Vanninen, 2015). The biotypes B (Middle East–Asia Minor1, MEAM1) and Q (Mediterranean, MED) have worldwide distribution and have been studied more extensively (Barbosa et al., 2015; Horowitz et al., 2005).

*B. tabaci* has developed resistance to different groups of insecticides including carbamates, organophosphates, pyrethroids, Insect Growth Regulators (IGRs), Ketoenols (Bielza et al., 2018), and neonicotinoids (Byrne et al., 2003; Houndete et al., 2010; Nauen et al., 2015; Roditakis et al., 2009). The first case of neonicotinoid resistance was reported against imidacloprid in 1996 in Spanish populations of *B. tabaci*. Imidacloprid resistance in *B. tabaci* has been suggested to be associated with increased detoxification by cytochrome P450 monoxygenases (Karunker et al., 2008; Rauch and Nauen, 2003).

Few studies have investigated neonicotinoid resistance in Iranian pest populations. Nazemi and Khajehali (2016) assessed imidacloprid resistance in *Thrips tabaci* populations collected from Iranian onion fields and found different levels of resistance in most populations. Basij et al. (2017) reported development of resistance to neonicotinoids (imidacloprid and acetamiprid) in *B. tabaci* populations from Iran.

Iranian growers have been facing many problems in controlling *B. tabaci*. The aim of this study was to evaluate the resistance status to imidacloprid in several cotton whitefly populations. Additionally, to study the metabolic mechanism of resistance, we aimed to investigate the activity of cytochrome P450-dependent monoxygenase (P450s), CarboxyLesterase (CarEs) and Glutathione S-Transferases (GST) *in vitro* as well as *in vivo* using different synergists.

**MATERIALS AND METHODS**

**Insects**

The various *B. tabaci* populations were collected from Isfahan, Karaj, Kashan, Ahvaz, Minab, and Gorgan in 2017-2018 (Figure 1). The populations had been exposed to frequent application of insecticides such as neonicotinoids, organophosphates, pyrethroids, and Insect Growth Regulators (IGRs) in protected or open field crops, except for the population of Ahvaz that was reared in the laboratory without selection pressure for two years. The collected populations were transferred to the cotton landrace, *Gossypium hirsutum*, inside separate net-covered cages, and reared under greenhouse conditions: photoperiod (16:8 h), temperature (27±2°C) and humidity (65±2%). To keep whitefly populations, the plants in the cages were replaced every 3 weeks with new ones.

**Insecticides and Synergists**

Imidacloprid SC 35% (Golsam, Gorgan, Iran), Piperonyl Butoxide (PBO, Sigma-Aldrich, Bornem, Belgium), TriPhenyl Phosphate (TPP, Merck, Darmstadt, Germany) and DiEthyl Maleate (DEM,
Sigma-Aldrich, Bornem, Belgium) were used.

**Bioassays**

Bioassays were performed using the leaf-dip method (Feng *et al*., 2010; Rauch and Nauen, 2003). Leaf discs of 3-4 cm in diameter were made from cotton leaves. The discs were dipped in various concentrations of imidacloprid (1 to 1,000 mg active ingredient per liter) for 10 seconds and dried on air. Leaf discs were put with their adaxial surface downwards onto a bed of agar (10 g L⁻¹) in Petri dishes. Each treatment had four replicates. Distilled water was considered as the control treatment. The mixed (male and female) adult whiteflies (2 days old) were collected from the rearing cages by aspirator and, after CO₂ anesthesia, 20 adults were transferred to each Petri dish. Each Petri dish was sealed with parafilm. The dishes were kept at 27±2°C, 65±2% RH under 16:8 (Light: Dark) photoperiod. The mortality of the insects was recorded after 48 hours.

**Effect of Synergists on the Insecticide Resistance**

To measure the effect of inhibition of detoxifying enzymes on imidacloprid resistance, three synergists PBO, TPP, and DEM were used in combination with the
insecticide. Three populations of Ahvaz (as a reference population), Kashan and Minab with different levels of imidacloprid resistance were tested. Stock solutions (10,000 mg L\(^{-1}\)) of PBO, TPP, and DEM were prepared in acetone and subsequently diluted with water. To determine the highest concentration with less than 10% mortality, different concentrations of synergists were tested. The toxicity test method was similar to the leaf-dip bioassay described above. After pre-exposure for five hours to 200 mg L\(^{-1}\) of either PBO, TPP or DEM, adults were transferred to imidacloprid treated leaf discs.

**Total Carboxylesterase Activity**

Total CarEs activity was measured by using 1-naphthyl acetate (Sigma-Aldrich, USA) as substrate (Van Asperen, 1962). From each population, 50 adults were homogenized in 300 μL of ice-cold sodium phosphate buffer (0.2 M, pH 7, containing 0.1% of Triton X-100). The homogenates were centrifuged at 12,000×g and 4°C for 15 minutes. The supernatant was used as the source of the enzyme extract. Thirty μL of supernatant was added to 200 μL phosphate buffer (0.1M, pH 7.0) and 200 μL of the substrate (64 mM in acetone). Then, 120 μL fast blue RR (1.6 mg mL\(^{-1}\) in distilled water) was added to the reaction mixture, and the released naphthol was continuously measured using spectrophotometer (UNICO, Dayton, USA) at 450 nm for 20 minutes. Experiments were performed in three replications. Using different concentrations of naphthol as the reaction product, the standard curve of absorbance was obtained.

**Glutathione S-Transferase (GST) Activity**

GST was measured by using 1-Chloro-2,4-DinitroBenzene (CDNB) (Sigma-Aldrich, USA) and Reduced Glutathione (GSH) (Sigma-Aldrich, USA) as substrate (Habig et al., 1974). About 50 adults were homogenized in 300 μL of ice-cold sodium phosphate buffer (0.2M, pH 7). Total volume of reaction included, 30 μL supernatant (12,000×g, 15 min), 200 μL of CDNB (1.2 mM) and 200 μL of GSH (3 mg mL\(^{-1}\) in distilled water). The change in absorbance was determined continuously for 5 minutes at 340 nm using the spectrophotometer (UNICO, Dayton, USA) with at least four replicates for each population. The absorbance changes in minutes were calculated using an absorption coefficient of 9.6 mM cm\(^{-1}\). Results were reported in terms of the amount of CDNB congestion per minute per mg protein.

**Cytochrome P450-Dependent Monooxygenase Activity**

Cytochrome P450 activity was estimated by measuring heme peroxidase activity similarly to Brogdon (1997). The total reaction volume per vial was 650 μL, consisting of 40 μL of enzyme solution, 160 μL of 0.625 M potassium phosphate buffer (pH 7.2), 400 μL of TMBZ (Sigma-Aldrich, USA) solution and 50 μL of hydrogen peroxide (3%). Vials were incubated at room temperature for 2 hours before reading at 450 nm as the endpoint in the spectrophotometer (UNICO, Dayton, USA). A standard curve for heme peroxidase activity was provided using different concentrations of cytochrome C from horse heart (Merck, Germany). Monooxygenase levels were expressed as equivalent units of cytochrome P450 mg\(^{-1}\) protein using the standard curve of cytochrome C.

In the enzymes assay, the total protein content of the enzyme samples was measured according to the Bradford (1976). The standard curve was plotted using the BSA (Merck, Germany) solution.

**Data Analysis**

LC\(_{50}\) values and their 95% confidence limits, resistance ratios, and synergistic...
RESULTS

Toxicity and Resistance

Imidacloprid bioassay results for the different populations are shown in Table 1. In this study, using the leaf-dip method, the population of Ahvaz with an LC$_{50}$ value of 24.40 mg active ingredient per Liter (mg ai L$^{-1}$) and the Karaj population with an LC$_{50}$ value of 189.81 mg ai L$^{-1}$ presented the lowest and highest LC$_{50}$ values, respectively. The highest and the lowest Resistance Ratios (RRs) obtained were 7.79- and 2.80-fold for the populations of Karaj and Minab, respectively.

Effect of Synergists

The results of the effect of three different synergists in combination with imidacloprid in Ahvaz population as a susceptible strain showed no significant decrease in LC$_{50}$ (Table 2). The oxidase inhibitor PBO and the esterase inhibitor TPP, in Kashan population showed 1.99- and 2.42-fold synergism, respectively. Synergism ratio was not significantly higher in Minab population than in Ahvaz population based on their confidence limits.

Enzyme Activity Assays

The comparison of the average activity of CarEs showed a significant difference between the populations of Gorgan, Kashan, and Minab (F$_{2,8}$= 571.31; P= 0.0001). Kashan population had the highest activity (1,366.52 nmol mg$^{-1}$ min$^{-1}$) of CarEs. There was also a significant difference in P450s (F$_{3,11}$= 11.72; P= 0.0027) between all tested populations. The populations of Gorgan and Ahvaz showed the highest and lowest P450 activity, respectively.

The average of the GST activity in Minab and Kashan populations was almost twice the population of Gorgan. However, Gorgan, Kashan, and Minab populations did not show a significant difference in the GST activity assay (F$_{2,8}$= 4.35; P= 0.0680). Correlations between the LC$_{50}$ values of the tested populations and the activity of detoxification enzymes are shown in Figure 2. A positive correlation was observed only between P450 monooxygenase activity and LC$_{50}$ values.

Table 1. Log-dose probit-mortality data for populations of B. tabaci in response to imidacloprid.$^a$

<table>
<thead>
<tr>
<th>Population</th>
<th>n</th>
<th>LC$_{50}$ mg ai L$^{-1}$ (95% CI)</th>
<th>LC$_{90}$ mg ai L$^{-1}$ (95% CI)</th>
<th>Slope±SE</th>
<th>$\chi^2$ (df)</th>
<th>RR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ahvaz</td>
<td>145</td>
<td>24.40 (15.94-34.34)</td>
<td>180.02 (101.94-584.12)</td>
<td>1.48±0.29</td>
<td>1.08(2)</td>
<td>1</td>
</tr>
<tr>
<td>Isfahan</td>
<td>381</td>
<td>136.91 (108.51-189.28)</td>
<td>743.89 (439.10-1866.13)</td>
<td>1.74±0.25</td>
<td>1.10(4)</td>
<td>5.61</td>
</tr>
<tr>
<td>Karaj</td>
<td>310</td>
<td>189.81 (151.32-251.96)</td>
<td>952.47 (583.24-2351.64)</td>
<td>1.83±0.29</td>
<td>1.25(3)</td>
<td>7.79</td>
</tr>
<tr>
<td>Kashan</td>
<td>447</td>
<td>106.95 (87.27-129.44)</td>
<td>597.82 (432.20-954.91)</td>
<td>1.72±0.18</td>
<td>0.83(4)</td>
<td>4.39</td>
</tr>
<tr>
<td>Gorgan</td>
<td>242</td>
<td>141.09 (81.25-212.07)</td>
<td>1119.82 (586.55-4041.15)</td>
<td>1.13±0.20</td>
<td>1.32(3)</td>
<td>5.79</td>
</tr>
<tr>
<td>Minab</td>
<td>357</td>
<td>68.31 (43.91-92.49)</td>
<td>1901.94 (995.24-6526.95)</td>
<td>1.06±0.19</td>
<td>0.42(4)</td>
<td>2.80</td>
</tr>
</tbody>
</table>

$^a$ n: Number of B. tabaci tested; Resistance Ratio (RR)= LC$_{50}$ of any population/LC$_{50}$ of Ahvaz, 95% CI: Confidence limits.
Table 2. Synergistic effect of PBO, TPP, and DEM on imidacloprid resistance in *B. tabaci* populations.

<table>
<thead>
<tr>
<th>Population</th>
<th>Synergist</th>
<th>LC$_{50}$ mg ai L$^{-1}$ (95% CI)</th>
<th>Slope±SE</th>
<th>SR$^a$ (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ahvaz</td>
<td>Imidacloprid</td>
<td>24.40 (15.94-34.34)</td>
<td>1.48±0.29</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>+PBO</td>
<td>22.98 (12.97-34.56)</td>
<td>1.46±0.38</td>
<td>1.06 (0.58-1.93)</td>
</tr>
<tr>
<td></td>
<td>+TPP</td>
<td>24.77 (15.22-36.15)</td>
<td>1.58±0.42</td>
<td>0.98 (0.56-1.74)</td>
</tr>
<tr>
<td></td>
<td>+DEM</td>
<td>27.96 (17.99-43.38)</td>
<td>1.56±0.42</td>
<td>0.87 (0.49-1.55)</td>
</tr>
<tr>
<td>Kashan</td>
<td>Imidacloprid</td>
<td>106.95 (87.27-129.44)</td>
<td>1.72±0.18</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>+PBO</td>
<td>53.71 (31.70-74.24)</td>
<td>1.66±0.31</td>
<td>1.99 (1.29-3.09)</td>
</tr>
<tr>
<td></td>
<td>+TPP</td>
<td>44.16 (33.80-54.32)</td>
<td>3.25±0.58</td>
<td>2.42 (1.80-3.27)</td>
</tr>
<tr>
<td></td>
<td>+DEM</td>
<td>83.13 (59.07-135.73)</td>
<td>2.33±0.64</td>
<td>1.29 (0.86-1.92)</td>
</tr>
<tr>
<td>Minab</td>
<td>Imidacloprid</td>
<td>68.31 (43.91-92.49)</td>
<td>1.06±0.19</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>+PBO</td>
<td>55.38 (26.82-78.66)</td>
<td>1.67±0.38</td>
<td>1.23 (0.69-2.20)</td>
</tr>
<tr>
<td></td>
<td>+TPP</td>
<td>52.67 (15.81-93.53)</td>
<td>0.92±0.27</td>
<td>1.30 (0.6-2.83)</td>
</tr>
<tr>
<td></td>
<td>+DEM</td>
<td>58.32 (23.80-102.87)</td>
<td>0.97±0.27</td>
<td>1.17 (0.58-2.37)</td>
</tr>
</tbody>
</table>

$^a$ Synergistic Ratio (SR)= LC$_{50}$ of pretreatment population/LC$_{50}$ of population without pretreatment.

Table 3. Enzyme activities (mean±SE) in different populations of *B. tabaci*.

<table>
<thead>
<tr>
<th>Population</th>
<th>CarE activity (nmol mg$^{-1}$ min$^{-1}$)</th>
<th>Ratio$^A$</th>
<th>GST activity (nmol mg$^{-1}$ min$^{-1}$)</th>
<th>Ratio$^A$</th>
<th>P450s activity (Unit mg$^{-1}$)</th>
<th>Ratio$^B$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ahvaz</td>
<td>-</td>
<td>-</td>
<td>3.67±0.25 c</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minab</td>
<td>514.75±10.05 b$^c$</td>
<td>1</td>
<td>534.44±115.76 a</td>
<td>1</td>
<td>5.98±1.23 bc</td>
<td>1.63</td>
</tr>
<tr>
<td>Kashan</td>
<td>1366.50±40.10 a</td>
<td>2.65</td>
<td>521.95±24.48 a</td>
<td>0.98</td>
<td>8.99±0.91 ab</td>
<td>2.45</td>
</tr>
<tr>
<td>Gorgan</td>
<td>274.40±4.56 c</td>
<td>0.53</td>
<td>242.37±69.37 a</td>
<td>0.45</td>
<td>11.21±1.15 a</td>
<td>3.05</td>
</tr>
</tbody>
</table>

$^A$ The same letters indicate no significant difference using Tukey test, $P<0.05$.

$^B$ Ratio= Activity of any population/Minab activity, $^c$ Ratio= Activity of any population/ Ahvaz activity.

![Figure 2](image)

Figure 2. Correlation between the LC$_{50}$ values of the populations and activity of detoxification enzymes. Pearson’s r: -0.87 (a), 0.99 (b) and -0.17 (c).

**DISCUSSION**

Over-use of insecticides often leads to the fast development of pest resistance to a wide range of pesticides, especially in developing countries. On the other hand, the most dangerous pesticides are used in these countries (Wilson and Otsuki, 2002) and in case of pest resistance, sometimes higher doses of pesticides are applied. Thus, it is important to determine which chemical compounds can be effective against local populations of key pests. In recent years, neonicotinoid insecticides have been considered to protect a wide range of pests on different plants. Diversity in the
formulations and application methods seems to have resulted in increasing neonicotinoid applications (Jeschke et al., 2010; Takacs et al., 2017).

In this study, resistance to imidacloprid was evaluated in several *B. tabaci* populations. Ahvaz population was considered as the reference population with the lowest LC$_{50}$ value. Other collected populations had frequently been sprayed by farmers, often more than four times a year, but the Ahvaz population had not been treated with insecticides for 2 years. Based on the results, none of the tested whitefly populations showed a high resistance ratio to imidacloprid. Probably, the reference population of this research had been exposed to insecticide treatments and was not fully susceptible to imidacloprid. In most studies, a susceptible laboratory strain has been used in RR calculation. In this study, the LC$_{50}$ of reference population was relatively high (24.40 mg ai L$^{-1}$) compared with that of susceptible populations used in other studies and tested with similar bioassays (Gorman et al., 2010; Jones et al., 2011; Nauen et al., 2002). A study in Greece showed that the LC$_{50}$ values of a reference population of *Trialeurodes vaporariorum* against imidacloprid and thiacloprid were 94.4 and 100.6 mg L$^{-1}$, respectively. Also, high resistance levels to imidacloprid were not found and RR values ranged from 1.5 to 4.4, which was very close to our results (Pappas et al., 2013). The results of a study in Turkey indicated moderate to high levels of resistance to neonicotinoids in field populations of *B. tabaci*. The resistance ratios exhibited a different range when different susceptible populations were considered as the reference population (up to 30-fold based on Lab1, and 300-fold based on Lab2) (Sahin and Ikten, 2017).

Previous studies on the resistance dynamic had shown that imidacloprid resistance was not stable and declined with decreasing selection pressure (Wen et al., 2009). Considering the highest slope of probit-mortality line in Karaj population, it can be concluded that this population has relatively high homogeneity.

The LC$_{50}$ of Ahvaz population did not significantly change after pre-treatment with PBO, TPP, and DEM synergists. This population was the population most susceptible to imidacloprid compared to other populations. In the Kashan population, the LC$_{50}$ value was significantly decreased after application of either PBO or TPP synergists, based on non-overlapping 95% confidence limits of LC$_{50}$ values. Many studies have proved the role of cytochrome P450-dependent monoxygenases in reducing the toxicity of neonicotinoids through synergistic tests (Feng et al., 2010; Rauch and Nauen, 2003) and increasing the expression of involved genes (Yang et al., 2013). Carboxylesterases also play an important role in the detoxification of organophosphates, carbamates, and pyrethroid insecticides (Sogorb and Vilanova, 2002; Wheelock et al., 2005). In the population of Kashan, TPP had a higher synergistic effect, probably reflecting a more prominent role of CarEs. Previous studies on neonicotinoids resistance in *B. tabaci* populations from Cyprus showed a moderate correlation between imidacloprid resistance and carboxylesterase activity (Vassiliou et al., 2011). Based on in vivo assays, the involvement of several enzymes to detoxify imidacloprid in Kashan population is possibly associated with application of neonicotinoids along with other insecticides in controlling *B. tabaci* during the growing season of the host plant. In this population, the synergistic ratio of DEM was 1.29-fold, with no significant difference compared to Ahvaz population. Thus, possibly GSTs do not play a significant role in decreasing the toxicity of neonicotinoids in this population. The effect of PBO, TPP, and DEM synergists in reducing the LC$_{50}$ value in Minab population was not significant. This population was relatively susceptible to imidacloprid with a resistance ratio of 2.80-fold.

Measurement of in vitro activity of detoxifying enzymes showed significant
differences in all tested populations. According to the results, it can be stated that the increase in P450 activity was positively correlated with the increase in LC$_{50}$ values (Pearson’s r: 0.99). A strong correlation between increased resistance and cytochrome P450 level has been reported in B. tabaci populations from India (Vivek et al., 2018). In addition, the highest monooxygenases activity has been observed in B. tabaci populations with the highest resistance ratio (RR= 2060) for the neonicotinoids (Satar et al., 2018). Rauch and Nauen (2003) emphasize that in B. tabaci populations, the metabolism of imidacloprid is under oxidative degradation. The activity of CarEs in the populations of Kashan, Minab, and Gorgan also showed a significant difference. The Kashan population had the highest CarE activity, which was consistent with the results of pretreatment with TPP synergist. As shown in Table 2, the highest decrease in the LC$_{50}$ value occurred after inhibiting the CarEs. The level of CarE activity in the Minab and Gorgan populations were much lower than that of Kashan. Activity of CarEs and GSTs were not measured in Ahvaz population, because of sudden decrease of the populations. Activity of GSTs was not significantly different between Kashan and Minab populations. The estimated in vitro activity of the CarEs and GSTs did not show any correlation with the LC$_{50}$ values. 

In this study, the tested populations showed relatively low levels of resistance to imidacloprid. The synergistic tests and measurements of the activity of detoxification enzymes indicated the role of P450s and CarEs in the development of B. tabaci resistance to imidacloprid. However, further works are needed to provide more solid evidence to demonstrate the role of these enzymes in resistance to imidacloprid. With suitable management actions, the resistance ratio can be kept to a minimum and prevent or delay the development of higher levels of imidacloprid resistance.

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**REFERENCES**


وضعیت مقاومت به ایمیداکلوپرید و نقش آنزیم‌های سیتوسول‌یافته در جمعیت‌های عسلک Bemisia tabaci (Hemiptera: Aleyrodidae) از ایران

چکیده

حشره‌کش‌های نوئیکوتینوئید همانند ایمیداکلوپرید و تیاکلوپرید آگونیست‌گیرنده‌های نیکوتین‌ک استیل‌كلیی (nAChR) می‌باشند. این گروه شیمیایی اغلب جهت کنترل آفات مکنده استفاده می‌شود. نظر عسلک پنیه B. tabaci، آزمایش‌هایی زیست‌سنجی به روش غوطه‌وری برگ انجام شد و جمعیت اهواز با کمترین مقدار LC50 (24/4 میلی گرم بر لیتر) به عنوان جمعیت حساس در نظر گرفته شد. در جمعیت‌های کرج، اصفهان، کاشان، گرگان و میان‌بیابان مقادیر LC50 به ترتیب 189/81، 198/1، 10/6، 48/4 و 68/3 میلی گرم بر لیتر محاسبه شد. نسبت مقاومت پایینی به حشره‌کش ایمیداکلوپرید در جمعیت‌های مورد آزمایش عسلک پنیه مانند بهترین نشان می‌دهد (نسبت‌های مقاومت> 10 برابر).

سیرزیست‌های پیروول بوتوکسی‌سید (PBO) و تری فیل فسفات (TPP) (یا بیشتر نسبت سینتیزی فیل) در جمعیت کاشان به ترتیب 1/09 و 1/24 برای نشان داده‌اند. آزمایش‌های نشان داد که تعیین نقش آنزیم‌های سیتوسول‌یافته، فعالیت آنزیم مونوکسیئن‌زهای واپسی به سیتوکروم P450، کربوکسی‌استرازها و گلواترات‌سربست‌ها اندازه‌گیری شد. نسبت جمعیت حساس، افزایش 3 برابری فعالیت سیتوکروم P450 در جمعیت گرگان و افزایش 2 برابری فعالیت، کربوکسی‌استرازها در جمعیت کاشان وجود داشت. بر اساس نتایج به نظر می‌رسد مونوکسیئن‌زهای واپسی به سیتوکروم P450 و کربوکسی‌استرازها آنزیم‌های مستقل در ایجاد مقاومت به نوئیکوتینوئیدها در جمعیت‌های B. tabaci آزمایش شده در این تحقیق می‌باشد.