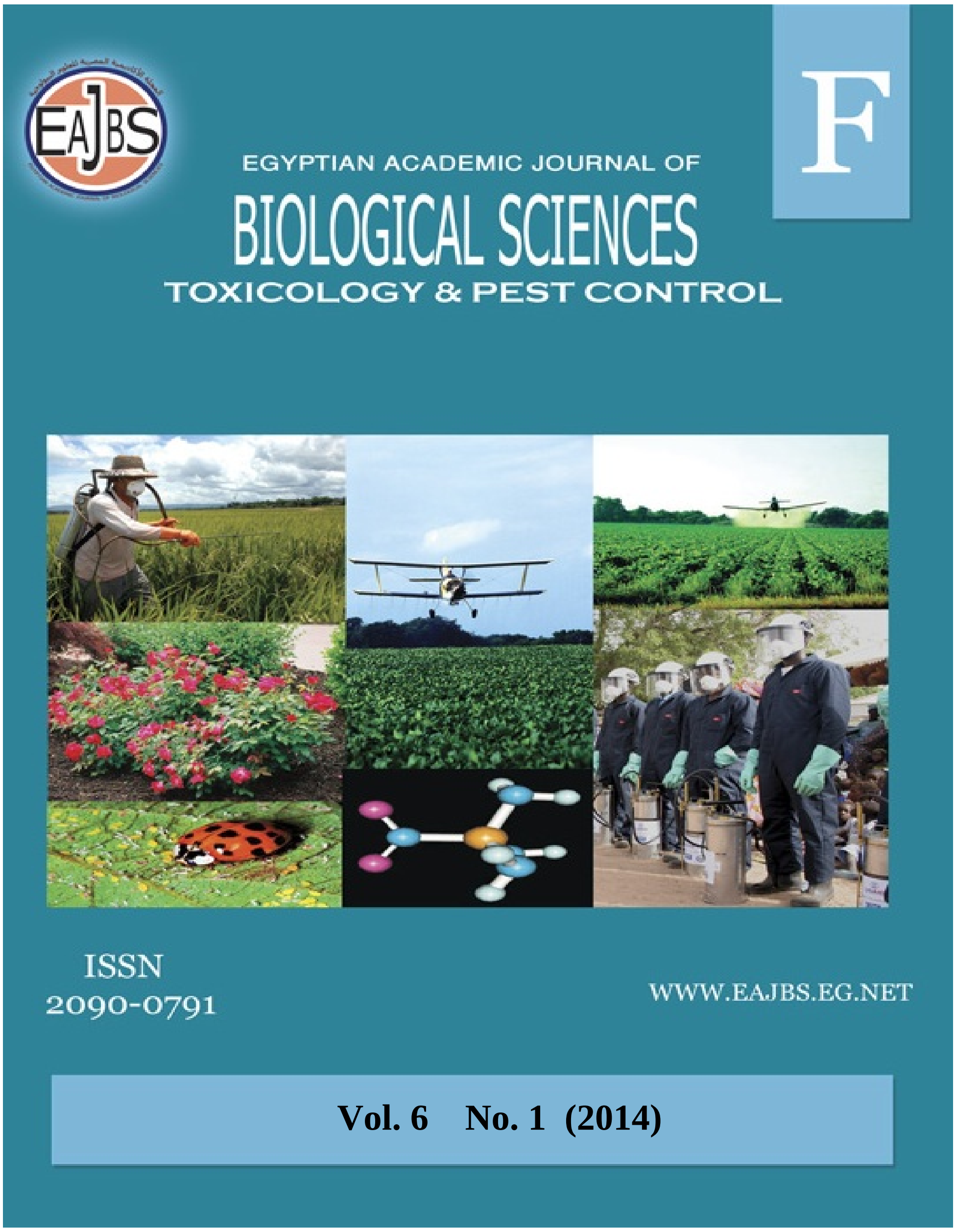

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Drenching Efficacy of Imidacloprid and Thiamethoxam against Dubas Bug, *Ommatissus lybicus* (Hem: Tropiduchidae)

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ABSTRACT

Dubas bug, *Ommatissus lybicus,* is one of the key pests of date palms in Iran. Chemical control is the most conventional control method of this dangerous pest. The aim of this investigation was to compare efficacy, advantages and disadvantages of drenching, and foliage spraying of chemical control. The study was conducted in a Randomized Complete Block Design with 10 treatments and 3 replications (trees) in a completely infested date palm grove. Treatments included imidacloprid SC350 (Confidor®) and thiamethoxam WG250 (Actara®) by foliar spraying (4 g/tree) and by drenching method (10, 20, 80, and 100 g/tree), diazinon EC600 (40 ml/tree) as recommended insecticide by foliar spraying and then the check (without treatment). The nymph population and number of honeydew drops were recorded one day before and 7, 14, and 120 days after treatment. Insecticide residue of date palm and cost-benefit ratio were calculated. The results showed that all foliage application treatments had more efficacy compared to drenching treatments at 1 and 2 weeks after spraying but at 120 days after drenching, thiamethoxam (80 g/L) and imidacloprid (100 g/L) had 100% efficacy, while the efficacies of thiamethoxam, imidacloprid, and diazinon foliar spraying was zero. The residue of date fruit treated by high doses of drenching was not detectable. The highest cost-benefit ratio belongs to imidacloprid foliage spraying (24.86) followed by imidacloprid drenching (15.67). The lowest ratio belongs to thiamethoxam drenching (3.12). Comparison of different concentrations of neonicotinoid drenching revealed that high concentration of thiamethoxam and imidacloprid was more than two times effective.

INTRODUCTION

There are about 90 million date palms cultivated in the Northern latitudes (between 10° and 30°). They produce more than 50,370,000 tons of dates, annually, most of which belong to the Middle East and North of Africa (Zohary *et al.*, 2012).

Iran produces more than one million tons per year. There are more than 400 cultivars of date palm in Iran, cultivated in 272,103 ha (Center for Communications, 2013).

Dubas bug, *Ommatissus lybicus*, (Hem.: Tropiduchidae) is the most important hemipteran pest of date palm. It feeds from plant sap and excretes honeydew on the leave. Dubas bug causes direct damage to date palms by feeding. Its indirect damage is due to reduction of the respiration and photosynthesis, resulting in reduction of yield quality and quantity, tree weakness, and death. Infestation levels of Dubas bug are classified as low (< 10 eggs or nymphs per leaf), moderate (10-15 eggs or nymphs per leaf), and high (>15 eggs or nymphs per leaf) (Hussein, 1963; Blow, 2007). Heavy infestation by Dubas bug resulted in a 400,000$ loss in Egypt in 1935 (Al-Shamsi, 2003). High infestation by Dubas bug destroyed 12 million palms in Morocco during two decades, and decreased its production to zero (Wilson, 1987).

Dubas bug has two generations per year. Female oviposits in the veins of date palm leaves. Dubas nymphs undergo 5 instars. It has two diapauses, aestivation, and hibernation, taking place in the egg stage of each generation (Gharib, 1966; Hussein and Ali 1996).

The conventional control method against this pest in infested palm groves of Iran is spraying with insecticides. An appropriate application time is when 40% of eggs are hatched, which is done mostly through ground application (Askari and Bagheri, 2005). However, ground application cannot completely cover the canopy of date palm, because the height of some trees can reach up to 6 m or more, and the current spraying apparatus in Iran cannot cover this canopy. Moreover, exodrift (i.e., drift by wind) and endodrift (i.e., run off) are in high volumes, and the spraying personnel are subjected to high risk of poisoning (Matthews, 1999; Blow, 2007). Therefore, to decrease the mentioned problems, it may be appropriate to apply systemic insecticides against sucking pests, via drenching method and through the irrigation system. In this method, the insecticide solution is poured on the soil (under the canopy) and is taken up by the roots. The insecticide is translocated through the plant, reaches the leaves and finally kills the pest (Buss, 2009).

Thiamethoxam and imidacloprid are neonicotinoid insecticides, and are effective on sucking pests. Due to their polar chemical structure and high solubility in water, they are good candidates for drenching method (Felsot *et al*., 1998.)

The objectives of this study were (1) to compare foliage spraying with drenching method against Dubas bug, (2) to determine insecticides efficacy, (3) to determine the optimal concentration for drenching method, and (4) to determine residue of insecticides in date fruits at harvesting time in drenching method.

MATERIALS AND METHODS

The experiment was conducted in Bam (Kerman Province, Iran) on 7 May 2012 (32.5 ºC and 17.5% RH). The study was conducted in a Randomized Complete Block Design with 10 treatments (Table 1) and 3 replications (trees) in a completely infested date palm grove (‘Mazafati’ cultivar, 25-30 years old). The control (without any treatment) was included in the treatment numbers mentioned above. A motorized hydraulic sprayer with a standard cone nozzle was used. In spraying method, 60 ± 2 L/tree of solution was applied and 40 L/tree solution was applied in the drenching method. The drenching was applied before irrigation. At spraying time, the majority of the population was in the second and third nymphal instars. The second nymphal instar is 1.75-2.25 mm long. It is white with two grey lines along the dorsal side of the body. The third instar is 2-2.5 mm long. Its wing buds cover the first and a part of the second abdominal segment (Hussein, 1963).

Sampling Method

Four fronds from North, South, East, and West sides of each replication were chosen. The number of nymphs in four leaflets/frond was counted one day before treatment as well as three and seven days after treatment. Numbers of honeydew droplets, as a feeding index, were recorded one day before treatment, and also 3, 7, and 14 days after treatment. For this purpose, transparent glass plates (12×12 cm^2) were used. Each glass was divided into 64 frames of 1.5×1.5 cm^2. The plates were placed on the soil surface under canopy of the trees for 12 hours (19:00 to 07:00 as per local time). Four plates per tree were used. Number of honeydew droplets was counted in three randomly chosen frames/glass plates.

Insecticide Residue of Date Palm

Different parts of leaves and clusters at four directions were sampled from high concentration of drenching treatments at harvest time. Each fruit sample was about 1 kg. Imidacloprid and thiamethoxam were extracted with solid phase extraction (SPE) technique and were analyzed with HPLC in the samples (Placke and Weber, 1998).

Cost-Benefit Ratio Calculation

Cost-benefit ratio is calculated from equation (1) (Ponnusamy, 2003):

$$\frac{\text{Treated benefit (\$) - Untreated benefit (\$)}}{\text{Cost of Protection (\$)}} \quad [1]$$

Cost of protection was calculated. Cost of protection ($) is sum of insecticide cost ($), spray cost ($) (labour cost + sprayer rent cost), and possibility of re-spraying ($).

Statistical Analysis

The efficacy percentage of treatments was calculated using Henderson and Tilton (1955) formula. Analysis of variances was done in SAS (Ver. 9.1) (Proc GLM). Comparison among treatment means was done with Tukey's test.

RESULTS

The results showed that four months after drenching, thiamethoxam (80 g/tree) and imidacloprid (100 g/tree) had 100% efficacy, while efficacies of thiamethoxam, imidacloprid, and diazinon foliar spraying was zero. On the other hand, 1 and 2 weeks after treatment, spraying was more effective compared to drenching method. Moreover, foliar spraying with neonicotinoid insecticides was effective more than two times compared conventional insecticide (diazinon).

Comparison different concentrations of neonicotinoids in drenching method showed that efficacy of high concentration of thiamethoxam and imidacloprid was two times more than low concentrations.

Analysis of efficacy of treatments based on nymph density per leaflets revealed that there was a difference among treatments on 7 ($F_{8,16}$ = 6.27, P < 0.0009), 14 ($F_{8,16}$ = 18.55, P < 0.0001), and 120 ($F_{8,16}$ = 101.11, P < 0.0001) days after treatment. Mean (±SE) efficacy of treatments is shown in Table 1.

Table 1: Mean (±SE) percentage of efficacy of insecticides, based on nymphs and honeydew number of Dubas bug, *Ommatissus lybicus,* on different days after treatment.

Treatment	Dosage (g/tree*)	Application	Efficacy based on nymph numbers (± SE) (days after treatment)			Efficacy based on honeydew numbers (± SE) (days after treatment)		
			+7	+14	+120	+7	+14	+120
imidacloprid SC350 (Confidor®)	100	drenching	25.51±6.58BC**	52.89±9.02BC	100 A	13.17 ±6.48BC	42.20±8.83BC	100 A
imidacloprid SC350 (Confidor®)	20	drenching	14.87 ± 2.44C	27.26±10.44CD	52.06 ± 5.42B	4.72 ± 2.36C	17.09±10.22CD	29.88±8.98B
imidacloprid SC350 (Confidor®)	10	drenching	10.02 ± 4.56C	16.23 ± 2.87D	42.23±9.24BC	2.31 ± 1.64C	9.35 ± 3.84D	17.81±2.51BC
imidacloprid SC350 (Confidor®)	4	foliage spraying	53.55±2.57AB	92.03 ± 2.58A	0 D	40.79 ± 2.53AB	87.37 ±2.53A	0 C
thiamethoxam WG250 (Actara®)	80	drenching	31.07 ± 8.89BC	50.74 ±13.91C	100 A	15.69 ± 8.75BC	37.15±13.62C	99.89±0.11A
thiamethoxam WG250 (Actara®)	20	drenching	30.06±10.07BC	35.28±3.73CD	31.80±2.58CD	16.72 ± 9.88BC	22.99±3.65CD	17.81±2.50BC
thiamethoxam WG250 (Actara®)	10	drenching	23.37 ± 5.03BC	18.92 ± 3.00CD	22.44 ± 5.22D	11.06 ± 4.96BC	6.97 ± 2.94CD	9.19 ± 4.59C
thiamethoxam WG250 (Actara®)	4	foliage spraying	70.13 ± 2.57A	88.99±5.23AB	0 D	56.14 ± 2.53A	75.59±5.12AB	0 C
diazinon EC600 (Basudin®)	40	Foliage spraying	32.53±14.66BC	20.36 ± 6.38CD	0 D	19.15±14.40BC	10.28 ± 6.30CD	0 C

*In spraying method, 60±2 L/tree of solution was applied and 40 L/tree solution was applied in the drenching method.
**Means followed by same letter (s) in each column are not significantly different based on Tukey test (α = 0.01).

Analysis of efficacy of treatments based on feeding index showed that there was difference among treatments on 7 ($F_{8,16} = 6.28$, $P < 0.0009$), 14 ($F_{8,16} = 18.58$, $P < 0.0001$), and 120 ($F_{8,16} = 121.52$, $P < 0.0001$) days after treatment. Diazinon had the same efficiency as low dosage of thiamethoxam (Table 1).

Maximum number of honeydew droplets was observed in control on 7 and 14 days after treatment, while it was observed in control and foliage spraying of imidacloprid, thiamethoxam and diazinon on 120 days after application (Table 2).

Table 2: Mean (±SE) number of honeydew droplets of Dubas bug, *Ommatissus lybicus*, per 1.5 cm^2 (during 4 h), on different days after treatment.

Treatment	Dosage (g/tree*)	Application	Number of honeydew droplets (± SE) (days after treatment)		
			+7	+14	+120
imidacloprid SC350 (Confidor®)	100	drenching	13.20±0.99ABC**	7.63±1.17BCD	0 B
imidacloprid SC350 (Confidor®)	20	drenching	15.06 ±0.93AB	10.94 ±1.35AB	3.4 ± 0.30B
imidacloprid SC350 (Confidor®)	10	drenching	15.22 ±1.42AB	13.17 ±2.52AB	4.07 ± 0.52B
imidacloprid SC350 (Confidor®)	4	foliage spraying	9 ± 0.39BC	1.66 ± 0.33D	19.63 ± 2.95A
thiamethoxam WG250 (Actara®)	80	drenching	12.82±1.33ABC	8.30 ± 1.80BC	0.0067±0.0067B
thiamethoxam WG250 (Actara®)	20	drenching	12.74±1.57ABC	10.17 ±0.48AB	4.77 ± 0.14B
thiamethoxam WG250 (Actara®)	10	drenching	13.52 ±0.75AB	12.28 ±0.39AB	5.33 ± 0.33B
thiamethoxam WG250 (Actara®)	4	foliage spraying	6.67 ± 0.38C	3.22 ± 0.67CD	17.79 ± 0.91A
diazinon EC600 (Basudin®)	40	foliage spraying	13 ± 2.71ABC	12.11 ±1.06AB	16.22 ± 3.63A
control	-	-	17.24 ± 1.5 A	16.33 ± 0.96A	20.45 ± 1.53A

*In spraying method, 60±2 L/tree of solution was applied and 40 L/tree solution was applied in the drenching method.
**Means followed by same letter (s) in each column are not significantly different based on Tukey test (α = 0.01)

Residual Test

Chromatogram of imidacloprid standard was shown in two concentrations in Figs. 1 and 2. We did not detect any residue of imidacloprid and thiamethoxam in date fruits and leaves treated by drenching imidacloprid 100 g/tree (Figs. 3 and 4) and thiamethoxam 80 g/tree.

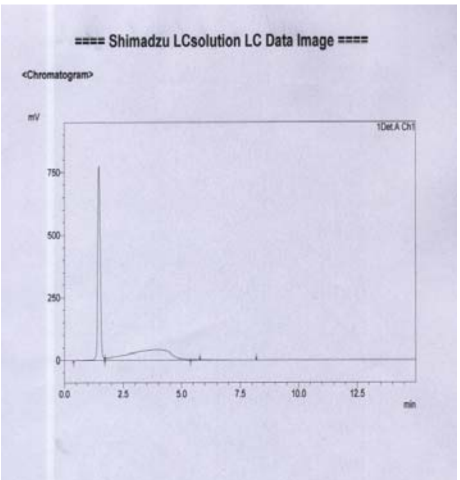

Fig. 1: Chromatogram of imidacloprid standard (1 ppm).

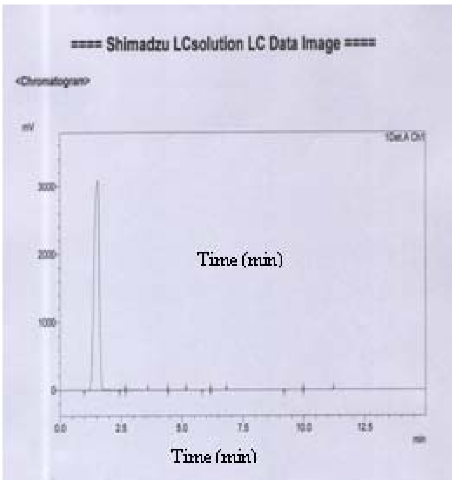

Fig. 2: Chromatogram of imidacloprid standard (5 ppm).

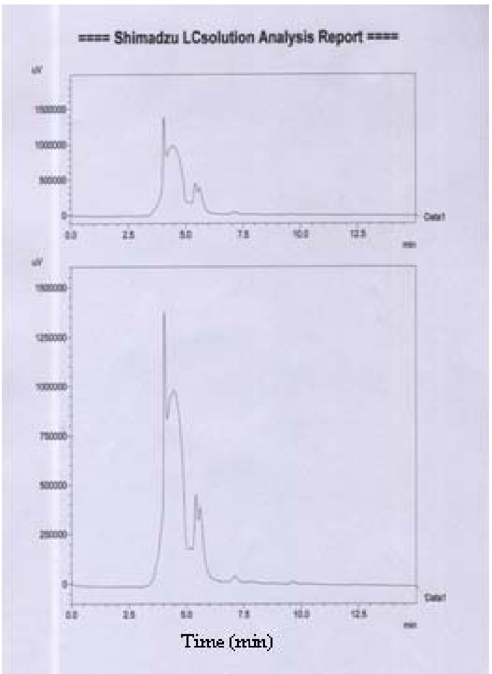

Fig. 3: Chromatogram of date fruit samples treated by drenching imidacloprid 100 g/tree.

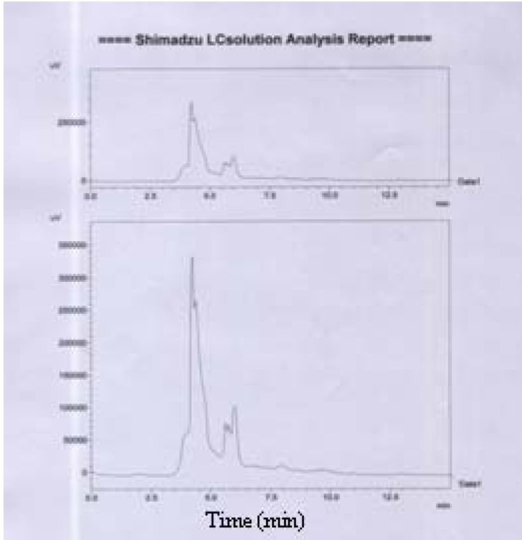

Fig. 4: Chromatogram of date leaves samples treated by drenching imidacloprid 100 g/tree.

Cost-Benefit Ratio Calculation

The results of the cost-benefit ratio calculation showed that the highest ratio belongs to imidacloprid spraying (24.86) followed by imidacloprid drenching (15.67). The lowest ratio belongs to thiamethoxam drenching (3.12) (Tables 3 and 4).

Table 3: Comparing insecticides in spraying and drenching methods based on some variables.

	Foliage Spraying			Drenching	
	diazinon EC600	imidacloprid SC350	thiamethoxam WG250	imidacloprid SC350	thiamethoxam WG250
Dosage (g/tree)	40	4	4	100	80
Time (min/ha*)	300	300	300	100	100
Spray cost ($/ha)	50	50	50	10	10
Treated area (ha/ 8 hours)	1.6	1.6	1.6	4.8	4.8
Spray cost ($/8 hours)	240	240	240	48	48
Insecticide cost ($/kg)	10	20	105	20	105
Formulated insecticide (kg/ha)	8	0.4	0.4	10	8
Efficiency after 2 weeks (%)	20	92	88	52	50
Efficiency after 4 months (%)	0	0	0	100	100
Possibility of re-spraying (%)	100	100	100	0	0

*100 date palm trees were considered in each hectare.

Table 4. Calculation of cost-benefit ratio in spraying and drenching methods and untreated plots.

Essential factors in calculation	Foliage Spraying			Drenching		Untreated
	diazinon EC600	imidacloprid SC350	thiamethoxam WG250	imidacloprid SC350	thiamethoxam WG250	
Cost of protection ($/ha)	260	116	184	210	850	-
Income of selling date ($/ha)	6000	6000	6000	6500	6500	3000
Benefit ($/ha)	5740	5884	5816	6290	5650	3000
Cost- benefit ratio	10.54	24.86	15.30	15.67	3.12	-

DISCUSSION

Soil application or drenching is one of the chemical control methods. Using insecticides by drenching and drip irrigation has been developed in the last two decades (Ayars *et al*., 2007; Ghidiu, 2012). This method was effective against sucking pests and some dipterian, lepidopteran, and coleptoran pests attacking herbaceous plants especially vegetables (Palumbo, 1997; Kuhar and Spees, 2002; Ghidiu *et al*., 2009; Kuhar *et al*., 2009). Drenching method was applied mostly against pests of vegetables. Few studies have been conducted on drenching and insectigation against pests of trees. The present study showed that application of neonicotinoids by drenching method could be more effective and safer than conventional foliar application, so that a single drenching of neonicotinoids insecticides could control Dubas bug effectively up to 4 months after treatment. Similar results were reported by Byrne *et al*., (2007) who found that application of four neonicotinoids through drenching method had a good efficacy against the avocado thrips up to 14 weeks.

Another important finding was that the efficacy of insecticides in drenching method had slow increasing trend during 120 days after treatment. This finding supports the idea of slow uptake of imidacloprid into tree through drenching method (Byrne *et al*., 2010). The delayed efficacy of drenching was related to the age of treated date palm that was 25 years old. Uptaking of imidacloprid into plant depends on the plant age and applied concentration of insecticides (Byrne and Toscono, 2006).

The results of this study strongly indicated low efficacy of conventional spray (diazinon), and high efficacy of imidacloprid and thiamethoxam up to 14 days after spraying. However, 120 days after spraying efficacy of neonicotinoids was zero (Table 1). A possible explanation for this result might be degradation of residues on the foliage due to photolysis (Scholz and Fritz, 1998). Moza *et al*., (1998) reported that 90% of imidacloprid can be photolyzed in 4 hours. The half-life of imidacloprid has reported to be 43-144 min. The difference of half-lives depends on the kind of imidacloprid formulation and diluter (i.e., water) (Wamhoff and Schneider, 1999). Another possible reason for low efficacy of diazinon, applied through conventional spraying, is four decades of its application against Dubas bug. Diazinon is a broad spectrum insecticide, with high vapor pressure, which destroys non-target organisms and natural enemies. Due to frequent and prolonged use of this insecticide against Dubas bug, and based on reports regarding insecticide-resistance biotypes of insects (*Chilo suppressalis* (Walker) (Lepidoptera: Crambidae) (Zibaee *et al*., 2009); *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) (Zhao *et al*., 1994); and *Drosophila melanogaster* (Diptera: Drosophilidae) (Pyke *et al*., 2004)), resistance to diazinon in *O. lybicus* would be expected. Due to weak contact efficacy of neonicotinoids, they were more effective in the second week compared to the first week after application, in the conventional spraying method. Their lethal effect is related to their systemic property.

In some studies, imidacloprid and thiamethoxam were not effective against Dubas bug through drenching method (Askari and Bagheri, 2005; Heidari, 2007). It seems that in these studies, the amount of applied insecticides into the palm tree was similar to what is applied into vegetables. The rate of insecticides should be applied according to size and weight of the tree. For example, if the average weight of a 25-year-old palm tree is around 4 tons, then 70% of it (i.e., 3,000 liters) would be water. If 20 grams (5 ai g) of neonicotinoid per tree is applied, assuming 50% (2.5 ai g) absorption, the desired concentration in plant tissue will be 0.89 mg/ L. This rate is 2.86 mg/ L in tomato. This comparison completely demonstrated why low dosage of neonicotinoid is not efficient (Table 5).

It is recommended to apply neonicotinoid insecticides by drenching against Dubas bug because of rapid photolysis of neonicotinoid on the foliage. The results showed that drenching has long lasting efficacy against Dubas bug, and the unfavorable weather conditions could not restrict timing of application. Furthermore, it can save duration of application and reduce labor requirement and material.

Table 5: Comparing neonicotinoid active ingredient per plant and neonicotinoid concentration in tissue of plant between annual plant and perennial plant.

plant	Total weight (kg)	Water in living tissue (L)	Neonicotinoid (ai) (g/plant)	Neonicotinoid concentration in tissue of plant (mg/L)
Tomato (before flowering)	5	3.5	0.01*	2.86
Date palm (Mazafati, 25 years old)	4000	2800	2.5	0.89

*(Santos *et al*., 2013)

Also, drenching method reduces tractor and equipment traffic in the field and it does not cause soil compaction (Ghidiu, 2012 and Granberry *et al*., 2012). In drenching method, the residue of imidacloprid in date fruit was not detectable. In tomato fruit, insecticide residue by spraying was more than drenching (Juraske *et al*., 2009). Treatment by drenching minimizes worker and consumer exposure to pesticides in terms of both physical contact and exposure time. Insecticide usage by drenching rectifies exodrift and endodrift problems. The optimized drenching could prevent leaching of insecticides into the environment (Juraske *et al*., 2009).

A comparison of the cost-benefit ratio in different treatments revealed that thiamethoxam drenching is not economically justified due to its high price and therefore high cost of protection. The cost-benefit ratio of diazinon is 10.54; however, due to high applied doses, the risk of adverse environmental effects, and high resistance probability, it is not recommended and it should be applied alternately with other insecticides every few years. Spraying thiamethoxam is not recommended due to high price and high rate of photolysis. The cost-benefit ratio of conventional spraying method is higher than drenching method; however, the efficacy of insecticides in drenching method is longer compared to efficacy in conventional spraying method. Therefore, were commend imidacloprid application through drenching method, and in cases where soil conditions are not suitable, imidacloprid spraying is recommended.

Insecticide drenching can be a new method of chemical control of *O. lybicus*, if a study on optimal dosage of insecticides is completed. The optimized dosage of insecticides increases the cost-benefit ratio and reduces environmental pollutions too. Effective drenching depends on the kind of soil, water, and insecticide formulations. These indices will determine area which is appropriate for drenching or spraying. It is necessary to do more research on timing of drenching based on date palm tree physiology and developmental stages of Dubas bug, due to delayed efficacy in drenching method.

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