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Toxicity of imidacloprid to developmental stages of *Rhynchophorus ferrugineus* (Curculionidae: Coleoptera): Laboratory and field tests

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Abstract

The toxicity of imidacloprid was evaluated against various developmental stages of the red palm weevil (RPW), *Rhynchophorus ferrugineus* Olivier. Based on topical, oral, and contact toxicity bioassays, imidacloprid was very effective in controlling various stages of the RPW. Mortality increased with exposure time and dose. The qualitative chemical analysis, using the TLC technique, detected the imidacloprid residues in leaf base and gomar parts; while the quantitative analysis, using the UV spectroscopy analysis, confirmed and quantified residues in all plant parts. The imidacloprid-formulated compound gave excellent control, in the semi-field and field experiments, when applied with soil-drench-irrigation. The development of treatment strategies for the inclusion of imidacloprid in RPW integrated management programs would be worth considering.

1. Introduction

The red palm weevil (RPW), *Rhynchophorous ferrugineus* Olivier, is an economically important, tissue-boring pest of date palm in many parts of the world. Originating in southern Asia and Melanesia, where it is a serious pest of coconuts, this weevil has been advancing westwards very rapidly since the mid 1980s (Gomez and Ferry, 1999). It reached the Kingdom of Saudi Arabia, United Arab Emirates, and Oman in 1985 (Abozuhairah et al., 1996; El-Ezaby, 1997), Savaran region of Iran in 1996 (Faghih, 1996), Sharquiya region of Egypt in 1992 (Cox, 1993), southern of Spain in 1994 (Barranco et al., 1996), and Israel, Jordan, Palestine and the occupied territories in 1999 (Kehat, 1999).

The RPW is a concealed tissue borer and all of its life stages are found inside the palm tree. Damage symptoms are indicated by the presence of tunnels in the trunk, oozing of thick yellow to brown fluid from the tree, the appearance of chewed up plant tissue in and around openings in the trunk, the presence of a fermented odor from the fluid inside infested tunnels in the trunk, and/or breaking of the trunk or toppling of the crown (Kaakeh et al., 2001a).

Imidacloprid possess excellent systemic properties and is effective against a broad range of pests on cotton, tobacco, and vegetable crops (Woodford, 1992; Bayer Corporation, 1999a, b; Hernandez et al., 1999; Leal, 2001), turfgrass ornamental plant products (Bayer Corporation, 2000), in indoor and outdoor cockroach control products (Rospischil et al., 1999), in termite control products (Bayer Corporation, 1999c), and for the treatment of cats and dogs against fleas (Bayer Corporation, 1996). To date, there is no published research on the use of imidacloprid-formulated systemic insecticides for the control of the RPW.

The objectives of this study were to determine the toxicity of imidacloprid, the active ingredient of the systemic insecticide Confidor SI 200 g/l, for controlling various stages of the RPW. The specific objectives were to determine (1) the topical toxicity, (2) the oral or feeding toxicity, (3) the contact toxicity, (4) the relative efficacy of imidacloprid to control weevils in young date palm trees in simulated field conditions (i.e., semi-field study), (5) the fate of imidacloprid in young date palm

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trees, through qualitative or quantitative chemical analysis of its residues, and (6) the relative efficacy of imidacloprid-formulated Confidor to reduce weevil populations in the field, and the lower the incidence of attack by the RPW.

2. Materials and methods

2.1. Test insects

The culture of the RPW was maintained on sugarcane stems in the rearing room in the Department of Aridland Agriculture, College of Food Systems, UAE University. The room was maintained at 25±2 °C and 60–70% RH. The photoperiod was approximately 12:12 L:D.

2.2. Topical toxicity bioassay

2.2.1. Toxicity to RPW using diluted solutions of imidacloprid-formulated confidor

The toxicity of imidacloprid was determined by topically spraying these concentration of the SL 200 formulation diluted in water (1.5, 2.5, and 3.5 ml/l) on adults, cocoons, and eggs, using a hand-held sprayer. Each dose rate (and the control) was replicated three times (8 insects per stage per replicate or $n = 24$). Immediately after the spraying, adults were removed from the treated area (plastic rectangular arena of 25 × 15 × 5 cm), placed in jars (15 cm height and 10 cm diameter), and provided with a cotton wicks saturated with a 50% sugar solution. Approximately 2.5–3.0 ml of diluted solution was used for treatment. The amount of spray landed on each adult was not known. Newly laid eggs (< 1d old, $n = 24$) were kept on the treated surface (filter paper in Petri dish of 2 cm height and 15 cm diameter). The numbers of moribund or dead adults, and the number of hatched eggs were recorded for up to 14 d after treatment. Cocoons were not treated topically but dipped in diluted solutions for 5, 15, 30 s, and for 3 min. Treated cocoons were placed in jars, and observed for emergence of adults for up to 14 d.

2.2.2. Toxicity to RPW using technical grade imidacloprid

The topical toxicity of Confidor to RPW adults was also assayed using the technical grade imidacloprid with an Automatic Micro-applicator (Burkard Scientific PAX 100, UK.). Imidacloprid was dissolved in spectrophotometric grade acetone and applied topically in 20 µm droplets to the intercoxal spaces of the ventral mesothorax of the adults and to the ventral thorax area of the larvae. Only one droplet per adult was applied. A series of imidacloprid concentrations (100, 300, 500, and 1000 ppm) were assayed. After treatment, adults were placed in jars and provided with cotton wick saturated with a 50% honey solution for feeding. Larvae were placed in sugarcane stems for feeding. Each concentration (and the control) was replicated three times (6 insects per stage per replicate; $n = 18$). Mortality was recorded at 18, 36, 48, and 72 h following treatment.

2.3. Oral (feeding) toxicity bioassay

Adults were provided with cotton wicks saturated with a series of water-diluted solutions of the imidacloprid. Sugarcane stem pieces (25 cm long) were vertically cut and dipped in the diluted concentrations (0.5, 1, 1.5, 2, 4, 6, 10, and 20 ppm) and provided to larvae as food. Cocoons were also dipped in the same series of diluted concentrations of imidacloprid for 3 min, and then placed in clean glass jars. Cocoons were checked for adult emergence for up to 114 h after treatment. Each concentration (and the control) was replicated three times (6 insects per stage per replicate; $n = 18$). Mortality was observed at 18, 24, 48, 72, 90, and 114 h following treatment for each developmental stage.

2.4. Contact toxicity bioassay

Adults were allowed to contact a surface sprayed, using a handheld sprayer, with imidacloprid at a dose rate of 1.5, 2.5, and 3.5 ml/l of water for 2 and 5 min. Each application rate (and control) was replicated three times (8 adults per replicate; $n = 24$) for each exposure time. Adults were removed from the treated surface and placed in clean jars and provided with cotton wicks saturated with a sugar solution. Daily observations were made to record the number of adults that showed any reversible knockdown effect and also to determine the number of dead individuals.

2.5. Semi-field experiment

Nine 3-year-old young date palm trees (50 cm trunk diameter and 1.5 m high) were selected, and placed in large plastic containers (70 cm height and 60 cm diameter). Trees were placed in a shed constructed outside the laboratory to simulate field conditions. The trunk of each tree was infested with four larvae, by making four holes (2 cm deep) around the trunk using the drill to aid the larvae in boring inside the trunk. Treatments were conducted 1 week after infestation, through soil drench-irrigation around the trunk of the trees. Each tree was irrigated with 41 of a diluted solution of imidacloprid-formulated Confidor at a rate of 2.5 ml/l of water. Additional three trees were irrigated with water and kept as controls. Trees were cut 10, 20, and 30 d after treatment (three trees at each time period).

2.6. Chemical residue analysis

Two residue chemical analyses were conducted on the palm trees used in the semi-field experiment. The first analysis was a qualitative chemical analysis using the thin layer chromatography (TLC) technique. The second analysis comprised the quantitative chemical analysis where the high-performance liquid chromatography (HPLC) was used to quantify the amount of imidacloprid residues present in each part of the palm tree.

Five plant parts were collected from each tree cut at 10 and 20 d after treatment. Samples were taken from the following parts: (1) pinnae (leaflets or pinnate leaves, or rigid, sharp pointed, and parallel-ribbed segments), (2) rachis (leaf midrib or central leaf axis, where pinnae are folded into the rachis), (3) lead base, (4) gomar (center of trunk below the terminal bud), and (5) roots. Plant parts were replicated three times (i.e., from three trees), with three samples from each part.

2.6.1. Extraction of residues

Extracts, from each plant part, were prepared using 300 gm from each plant sample per tree. Samples were stored deep frozen between sampling (cutting the desired plant samples) and extraction process. Soaking was used after blending the samples with solvent. Solid parts in each sample were then removed by filtration through a porcelain suction filter. The filtrated extracts were partitioned with other solvents (dimethylether, *n*-hexan, chloroform and acetonitril). The separatory funnels were left over night for separation of extracts into organic and aqueous layers. The final partition of the organic layer was cleaned-up (phase I) using a Florisil column, the extracts were further cleaned-up (phase II) using another Florisil column. The rotary evaporation technique was used to concentrate the extracts as 20 ml of each extract.

2.6.2. Qualitative analysis of residues

Fluorescent plant samples were used to determine the presence or absence of residues in the samples, using TLC technique. The spotting technique was applied using a micropipet of each extract compared with the parent compound "Imidacloprid". The solvent system benzyne:chloroform (3:7) was used as a elution solvent system. The TLC plates were placed under a lamp set in order to see the defined spots for each sample.

2.6.3. Quantitative analysis of residues

The UV spectroscopy analysis was used to quantify the parent compound. A wavelength of 280 nm was measured by the Spectroscopy Laboratory of the Central Laboratory Unit in United Arab Emirates University.

2.7. Field study

Eight highly-infested date palm trees (5–6 year-old; 4–5 m high) were randomely selected from a palm plantation. The large trees were then treated with imidacloprid at the manufacturer's recommended rate of 20 ml per 4 l of water per tree (soil drench-irrigation around the trunk of the trees). Highly-infested trees were those trees showing serious symptoms such as oozing of thick yellow to brown fluid from the tree, the appearance of chewed up plant tissue in and around openings in the trunk, and the presence of a fermented odor from the fluid inside infested tunnels in the trunk. Three weeks after treatment, each tree was cleaned from the chewed up plant tissue, and checked for the number of live and dead larvae and adults, the presence or absence of new cocoons, and the presence or absence of new tunnels inside the trunk. All live larvae, cocoons, and adults, collected from inside the trunk, were taken back to the laboratory and placed in clean containers to check for late mortality. Adults were provided with cotton wicks saturated with 50% sugar solutions for feeding, while larvae were provided with freshly cut sugarcane stem pieces for feeding.

2.8. Statistical analysis

MSTAT Program (Michigan State University) was used to carry out the statistical analysis. Data for each time period, in all bioassays, were analyzed for a randomized complete block design (RCBD) according to procedure outlined by Steel and Torrie (1980). Differences in each factor were evaluated by analysis of variance (ANOVA). When F values were significant ($P<0.05$), means were compared using the least significance difference test (LSD) for all aspects of this study. Data for all factors (X) were transformed to square root scale of ($X+0.5$) to stabilize variances before analysis. Means of non-transformed data are presented.

3. Results

3.1. Topical toxicity bioassay

3.1.1. Toxicity to RPW using diluted solutions of imidacloprid-formulated confidor

Significant differences ($P<0.05$) in average total mortality of adults were observed (Table 1). Total mortality (100%) of adults was recorded 11.5, 8.8, and 6.1 d after application at the rates of 1.5, 2.5, and 3.5 ml/l, respectively (Table 1). Slight reversible knockdown of a few adults was observed 4, 2, and 1 d after application at the three rates, respectively. Similar reversible knockdown results were also observed in other insects (Kaakeh et al., 1997).

Significant differences ($P<0.05$) in average total mortality of cocoons were recorded when cocoons were dipped for 5 and 10 s at the rates of 1.5 and 2.5 ml/l. At the rate of 3.5 ml/l, total mortality was recorded 3.2 d after treatment when dipped in a solution for up to 30 s. Cocoons dipped for 3 min in solutions at high concentrations died within 3 d. Adults that emerged from few cocoons died after 2 d.

Topically applying the higher rate resulted in a reduced percentage of hatched eggs. All larvae from hatched eggs, previously treated at the rate of 1.5 and 2.5 ml/l, died within 6 d of treatment. Larvae died after 4 d of egg hatching when treated at a rate of 3.5 ml/l. Significant differences ($P<0.05$) in the percentages of hatched eggs were found; these percentages were 76.7%, 33.3%, and 10.0% at the three rates, respectively.

3.1.2. *Toxicity to RPW using a technical grade imidacloprid*

Larval and adults mortalities significantly ($P<0.05$) increased with increasing concentrations at each time after treatment (Table 2). At 1000 ppm, a total mortality was recorded 18 and 48 h after treatment for adults and larvae, respectively. Adults were more sensitive to imidacloprid than larvae at all concentrations.

3.2. *Oral (feeding) toxicity bioassay*

Significant differences ($P<0.05$) in the percentage mortality of adults, larvae, and cocoons were observed over the various concentrations for each time after treatment (Table 3). Total mortality of adults was recorded 18 h after feeding at concentrations from 2 to 20 ml/l, and 90 h at the rate of 1.5 ml/l (see footnote of Table 3). Total mortality of larvae was recorded 18 h after feeding at concentrations from 6 to 20 ml/l, and 24 h after feeding at 1.5 to 4 ml/l. Total mortality was recorded 72 and 114 h after feeding at 1.0 and 0.5 ml/l, respectively.

No mortalities of cocoons, 18 and 24 h after treatment, were observed when dipped in solutions at all rates (Table 3). Total mortality of cocoons was

Table 1
Topical toxicity of imidacloprid-formulated Confidor to developmental stages of *R. ferrugineus*

Dose rate (ml/l)	Adults		Av. total mortality of cocoons days after dipping for			Eggs and Larvae	
	First adults showed RK[a] at day	100% mortality days after treatment	5 s	10 s	30 s	% hatched eggs	100% larval mortality days after egg hatching
1.5	4	11.5 a	14.5 a	10.0 a	9.6 a	76.7 a	6
2.5	2	8.8 b	9.5 b	9.6 b	9.2 a	33.3 b	6
3.5	1	6.1 c	5.9 c	6.0 c	3.2 b	10.0 b	4
LSD value		0.731	0.591	0.268	0.486	40.6	

Means within a column followed by the same letter are not significantly different ($P<0.05$) by LSD test. No mortality was recorded in the control treatment.

[a]RK = Reversible knockdown.

Table 2
Topical toxicity of the technical grade imidacloprid against larval and adult stages *R. ferrugineus*

Stage	Conc. (ppm)	% Mortality at times (h) after treatment			
		18	36	48	72
Adults	1000	100.0 a	100.0 a	100.0 a	100.0 a
	500	66.7 b	72.2 b	72.2 b	72.2 b
	300	72.2 b	72.2 b	72.2 b	100.0 a
	100	0 c	38.9 c	72.2 b	94.4 a
	LSD value	10.9	8.9	15.5	12.6
Larvae	1000	72.2 a	72.2 a	100.0 a	100.0 a
	500	0 b	38.9 b	72.2 b	72.2 b
	300	0 b	0 c	0 c	38.9 c
	100	0 b	0 c	0 c	0 d
	LSD value	8.9	10.9	8.9	10.9

Means within a column, for each stage, followed by the same letter are not significantly different ($P<0.05$) by LSD test. No mortality was recorded in the control treatment.

observed 114 h after treatment when dipped in 20 ml/l solution. Lower mortalities were recorded at lower concentrations; adults emerged from cocoons, treated at lower concentrations, showed slow movements and survived for more than a week after emergence.

3.3. Contact toxicity bioassay

Significant differences ($P<0.05$) in the percentages of adults showing reversible knockdown or the percentage of adults dying were observed for both exposure times at different application rates (Table 4). All adults showed a reversible knockdown effect 4.2, 2.2, and 2.1 d after 5 min contact treatment at the rate of 1.5, 2.5, and 3.5 ml/l, respectively. Adults were considered to be moribund (very slow movement and disorientation compared with normal untreated adults). Total mortalities of adults were recorded 8.1, 7.2, and 4.2 d after treatment at the three rates, respectively. At 2 min exposure time, all adults showed reversible knockdown

Table 3
Oral toxicity of imidacloprid to developmental stages of *R. ferrugineus*

Stage	Conc. (ppm)	% Mortality at times (h) after treatment					
		18	24	48	72	90	114
Adults	2	100.0 a	100.0 a	100.0 a	100.0 a	100.0 a	100.0 a
	1.5	72.2 b	72.2 b	73.2 b	73.2 b	100.0 a	100.0 a
	1	38.9 c	38.9 c	38.9 c	73.2 b	73.2 b	72.2 b
	0.5	0 d	0 d	38.9 c	73.2 b	73.2 b	72.2 b
	LSD value	7.8	12.4	11.1	5.5	5.5	5.5
Larvae	6	100.0 a	100.0 a	100.0 a	100.0 a	100.0 a	100.0 a
	4	76.7 b	100.0 a	100.0 a	100.0 a	100.0 a	100.0 a
	2	72.2 bc	100.0 a	100.0 a	100.0 a	100.0 a	100.0 a
	1.5	72.2 c	100.0 a	100.0 a	100.0 a	100.0 a	100.0 a
	1	0 d	0 b	38.9 b	100.0 a	100.0 a	100.0 a
	0.5	0 d	0 b	38.9 b	38.9 b	66.7 b	100.0 a
	LSD value	5.5	11.1	9.6	7.8	0.2	—
Cocoons	20	0	0	44.4 a	44.4 a	72.2 a	100.0 a
	4	0	0	44.4 a	44.4 a	72.2 a	72.2 b
	2	0	0	33.3 a	33.3 a	72.2 a	72.2 b
	1.5	0	0	0 b	0 b	44.4 b	44.4 c
	1	0	0	0 b	0 b	44.4 b	44.4 c
	0.5	0	0	0 b	0 b	38.9 b	38.9 c
	LSD value	—	—	23.7	23.7	5.7	5.7

Means within a column, for each stage, followed by the same letter are not significantly different ($P<0.05$) by LSD test. Total mortality (100%) of adults and larvae was recorded 18 h after feeding at concentrations from 4 to 20 ppm and from 6 to 20 ppm, respectively. No mortality was recorded in the control treatment.

Table 4
Contact toxicity of imidacloprid to adults of *R. ferrugineus*

Exposure time (min)	Application rate (ml/l)	DAT where adults (%) showed reversible knockdown		DAT where adults (%) recorded as dead[a]	
		50%	100%	50%	100%
2	1.5	3.2 a	9.0 a	10.1 a	18.0 a
	2.5	1.1 b	7.1 b	10.1 a	13.1 b
	3.5	1.1 b	3.2 b	4.1 b	8.1 c
	LSD value	0.248	0.502	0.373	0.406
5	1.5	3.2 a	4.2 a	4.3 a	8.1 a
	2.5	1.1 b	2.2 b	3.2 b	7.2 b
	3.5	1.1 b	2.1 b	2.2 c	4.2 c
	LSD value	0.101	0.248	0.190	0.190

Means within a column, for each exposure time, followed by the same letter are not significantly different ($P<0.05$) by LSD test. No mortality was recorded in the control treatment.

[a]DAT = days after treatment.

9.0, 7.1, and 3.2 d after treatment at the three rates, respectively. Total mortalities of adults were recorded 18.0, 13.1, and 8.1 d after treatment. The results indicated that the longer the exposure time, the higher percentage of mortality.

3.4. Semi-field experiment

The average percentage of mortality of larvae reached 86.1%, 100%, and 94.4% in trees cut 10, 20, and 30 d after treatment (the three cut periods), respectively. Dead larvae in the tunnels were dry, white in color with reddish color around the head and the thorax area. The two live larvae (2 out of 36) were weak (slow movement and disoriented) with a slight reddish color around the head. Live larvae also showed a slight increase in weight after 3–5 weeks of feeding. No mortality of larvae was recorded in the control trees.

3.5. Residue analyses

Significant differences ($P<0.05$) in UV values (i.e., qualitative analysis of residues using the TLC technique) in various plant parts were recorded during each time period (Table 5). Higher UV values of the parent compound, imidacloprid, were detected in the "leaf base", "rachis", and "gomar" samples taken 10 and 20 d after treatments. UV values (ppm) ranged from 0.32 to 1.31 after 10 d of treatment. The range decreased in all samples taken 20 d after treatment (except in pinnae) and is estimated from 0.18 to 0.46 (Table 5).

The results of the quantitative analysis of residues showed that the parent compound was detected and quantified in all plant samples at both times after treatment (Table 5). Significant differences ($P<0.05$) in the amount of imidacloprid were detected in the five plant parts taken from trees cut 10 and 20 d after treatments. The concentrations of imidacloprid, in μg/kg of samples taken 10 d after treatment, ranged from 55.3 to 240.9 (or 0.055–0.240 mg/kg). The range decreased in all the samples taken 20 d after treatment (except in pinnae) and is estimated from 32.1 to 83.6 (or 0.032–0.083 mg/kg) (Table 5). This can be translated into a reduction of 62.4–73.8% in the quantity of the parent compound (except in pinnae) in samples taken 20 d after treatment compared to those taken 10 d after treatment. The samples taken from different parts of the date tree probably contained no residues above the limit of quantification. Information on the limit of detection for the parent compound in date palm trunk, leaf, and roots is not available. But it is definitely much higher than the limit defined for date fruits. Higher concentrations were estimated in the "rachis", "leaf base", and "gomar" samples taken at the first time after treatment.

3.6. Field study

At 25 d after treatment, all adults were found immediately under the surface fiber sheeth. Deterioration of tissues inside, and the basal area of the trunk, were noticed. The percentage mortality of larvae reached 61.9% (range: 40.0–100.0%) 25 d after treatments (Table 6). All

Table 5
UV Spectroscopy analysis and measurement of the parent compound imidacloprid in date palm plant samples (semi-field experiment)

Plant part	UV value (ppm)		μg/kg		
	10 DAT[a]	20 DAT[a]	10 DAT[a]	20 DAT[a]	% reduction in concentration
Pinnae	0.32 e	0.38 c	55.3 e	69.2 c	+25.1
Rachis	1.21 b	0.46 a	222.1 b	83.6 a	−62.4
Leaf base	1.31 a	0.33 d	240.9 a	63.1 d	−73.8
Gomar	1.11 c	0.41 b	203.2 c	74.3 b	−63.4
Roots	0.51 d	0.18 e	93.9 d	32.1 e	−65.8
LSD value	0.006	0.006	1.504	0.795	

Means within a column followed by the same letter are not significantly different ($P<0.05$) by LSD test.
[a]DAT = Days after treatment.

Table 6
Control of developmental stages of *R. ferrugineus* in the field

Stage	Total	No. of Live	No. of Dead	% Mortality	% Mortality of collected live stage within 48 h in the laboratory
Larvae	63	24	39	61.9	100
Adults	54	31	23	42.6	100

Only one dead cocoon was found.

collected live larvae died within 48 h in the laboratory. Live larvae were white in color with a reddish or brown color around the head and the thorax area. Most larvae were weak, disoriented, with a slow movement. No movement of mandibles was noticed in most larvae. Live larvae showed a sign of non-feeding status (shrinking sign around in the thorax area and a change in color of the abdomen). Most larvae were of 3rd to 5th instars (out of 5 major instars in the UAE).

Percent mortality of adults reached 42.6% (range: 33.3–75%) 25 d after treatment (Table 6). The few live adults collected from the trunk were weak, disoriented, with a low movement. All collected live adults died within 48 h in the laboratory. Only one dead cocoon was found in one infested tree. This indicates that no larvae reached the pre-pupal stage and started to construct new cocoons.

Combined percentage of mortality of larvae and adults of *R. ferrugineus* reached 54.4% (range: 35.0–83.3) 25 d after treatments in the date palm trees heavily infested with various stages of *R. ferrugineus*. Data on mortality of various stages could be higher if palm trees were cut at a later date (at least 1 month). This is because all the collected live larvae and adults were weak, disoriented in their movement, and died within 48 h in the laboratory (i.e., 100% mortality). Only one new tunnel was found. This indicates that no feeding occur in the trunk, in addition to the color changing and shrinking of the thorax area.

4. Discussion

The development of a successful integrated pest management strategy against the RPW, in the UAE and the surrounding Gulf states, can readily take up on the extensive research work already conducted on palm weevils. These include surveillance, pheromone lures, and cultural control (Kaakeh et al., 2001b; Azam et al., 2001; Khalifa et al., 2001). Recently, efforts have also examined the potential of developing and using biopesticides (based on nematodes, fungi, viruses, and bacteria) to control RPW (FAO, 1996; Hanounik, 1998; Deadman et al., 2001). However, effective methods for managing the RPW have been difficult to develop due to the concealed nature of the larvae. Insecticides are applied in a range of preventative and curative procedures designed to limit and contain the spread of an infestation (Murphy and Briscoe, 1999). Methods employed have ranged from dusting and spraying of the leaf axils after pruning, soaking of the tree trunk, direct injection of chemicals into the trunk of date palm, and sealing inside the tree a slow release fumigant such as Phostoxin tablets (aluminum phosphide) (Abraham et al., 1975, 1998; Rao and Reddy, 1980; El-Ezaby, 1997; Murthuraman, 1984; Azam and Razvi, 2001; Kaakeh et al., 2001b). The method of soil drench-irrigation around the trunk of the trees, employed in this study, was another procedure and was found to give effective field control. Also, the ineffectiveness of many of the currently used insecticides in recent years, especially the application of organophosphate and carbamate insecticides, has lead to a need to develop new novel systemic insecticides to control the RPW. Some of the currently used insecticides in the United Arab Emirates are carbosulfan, phenthoate + dimethoate, and pirimiphos-ethyl. Based on all the laboratory, semi-field, and field tests in this study, imidacloprid gave excellent control when applied with as soil drench-irrigation. The development of treatment strategies for the inclusion of imidacloprid in RPW integrated management programs would be worth considering.

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