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Toxicity of Pesticides to Adult *Diaprepes abbreviatus* L. (Coleoptera: Curculionidae)[1]

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Abstract The purpose of this study was to determine the toxicity of selected pesticides to adult *Diaprepes abbreviatus* L. Because pesticides applied directly to this weevil were generally ineffective, they were exposed to field rates of pesticide-treated bouquets of fully-expanded, mature citrus leaves. Of the 28 compounds tested at field rates, 14 were effective with 85% or greater mortality within 72 h for male and female *Diaprepes* beetles. With field rates, 100% mortality was achieved within 72 h with Avaunt™, Baythroid™, Furadan™, Fury™, Lannate™, and Supracide™ for males and females. At a field rate, only Supracide was effective producing 100% mortality within 24 h after exposure. Field rates of Avaunt, Baythroid, Capture, Furdan, Fury, Lannate, and Supracide produced 100% mortality of males and females in 72 h. The field rates of Sevin™ and Carzol™, currently used for *D. abbreviatus*, produced mortality levels of about 95% after 72 h. Comparative LC_{50} showed that toxicity was in the order Baythroid = Fury = Capture = Pounce = Asana > Avaunt = Furadan > Lannate > Supracide > Danitol > Vydate = Sevin = Carzol = Guthion > Imidan = Lorsban.

Key Words pesticides, root weevil, adult mortality

Diaprepes root weevil, *Diaprepes abbreviatus* L., is a polyphagous feeder (Fennah 1942) whose most economically important Florida host is *Citrus* spp. (Simpson et al. 1996), the most valuable Florida agronomic crop with a 1999-2000 estimated 337,061 ha and an annual value of $9.13 billion (Hodges et al. 2001). This important economic pest of citrus is difficult to manage (Hall et al. 2001). Since its discovery in 1964, *D. abbreviatus* has spread to 21 counties and currently infests approximately 66,420 ha (Anonymous 1997). Adult and larval stages feed on leaves, roots, or fruit of many agronomic and native host plants in Florida and several island nations of the Caribbean (Fennah 1942, Woodruff 1968, Simpson et al. 1996). In the United States, important agricultural host plants include citrus, corn, cotton, potatoes, tobacco, sugar cane, and soybeans (Jones 1915, Simpson et al. 1996). *Diaprepes abbreviatus* has now been detected in California and Minnesota on ornamental plants, and in Texas on citrus. (S. E. Simpson, FDACS, pers. comm.).

In citrus, male and female adult weevils feed on young leaves. Eggs are glued in a mass between two, generally mature, leaves. After emerging from the egg, the larvae drop to the ground and feed on the roots. Adults emerge from the soil 6 mo to 2 yr later (Griffith 1975). Larval feeding may take a citrus planting out of economic

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production within 5 yr of the first female oviposition in the planting. Bifenthrin (Talstar®) is required in nursery potting soil to control *Diaprepes* larvae if a state inspector finds any *D. abbreviatus* life stage in the nursery (McCoy et al. 1995, Simpson and McCoy 1996).

Diaprepes abbreviatus has proven difficult to control in commercial citrus (McCoy and Simpson 1994). In Florida, adults can emerge from the soil at any time during the year, but there is often a strong emergence peak associated with early spring rains, continuing high emergence through the summer, a secondary emergence peak in the fall, and low emergence during the drier winter months (Nigg et al. 2001c, 2002, 2003, Futch 2002, McCoy et al. 2003, 2004). However, the precise pattern of emergence can vary considerably and often unpredictably for different locations and years (Nigg et al. 2001c, 2003, Futch 2002, McCoy et al. 2003, 2004). Females oviposit and neonate larvae hatch and enter the soil whenever adults are present, but this activity ceases with the onset of the cooler winter months when adults, egg masses, and hatching neonates are generally not detectable within groves (Nigg et al. 2003, McCoy et al. 2003). The prolonged emergence, egg-laying, and egg-hatching periods for this weevil, combined with the longevity and high fecundity of the adults (Nigg et al. 2004), contribute to control difficulties.

Previous work indicated that fewer larvae entering the soil after adult oviposition would be a viable management goal for *D. abbreviatus* (Nigg et al. 1999a,b, 2001a,b). There is a high correlation of the number of adults present and the number of larvae entering the soil, suggesting that adult control with pesticides would reduce larval numbers (Nigg et al. 2003). The purpose of this study was to determine the laboratory toxicity of pesticides to adult *D. abbreviatus* for ultimate field validation.

Materials and Methods

Adult *D. abbreviatus* were obtained from the rearing facility at the Florida Dept. Agr. and Consumer Services, Dept. of Plant Industry, Gainesville, FL. Due to genetic and age variation in field-collected weevils, laboratory-reared weevils were used for this study (Bas et al. 2000). Weevils were shipped in individual rearing containers as newly-emerged virgin adults and were held for 6 to 13 d as individual pairs in a 950-mL plastic container with a screen top. One oviposition strip, a bouquet of immature citrus foliage and a cotton dental wick containing 1% sucrose were provided. The citrus foliage and dental wick were replaced Monday, Wednesday, Friday each week. Oviposition strips were checked daily for eggs. Only females which oviposited were included in mortality tests.

Topical treatment. Formulated pesticides obtained commercially were used for this study (Table 1). The field rates of these pesticides listed in Table 2 are the highest United States label rate for any crop. Initial topical tests were conducted with a Potter tower (Burkard Mfg. Co., Ltd., Rickmansworth, Herts, England). To avoid mating, which would block treatment of females, males and females were treated separately in Potter tower tests. Ten males or ten females were placed in a 9 × 25 mm plastic Petri dish with a 0.3 × 0.3 cm screen top. The screen-topped Petri dish was placed at the bottom of a Potter tower. One mL of the 1167 L/ha rate of each chemical was delivered at 9.66×10^4 Pa. The one mL volume was chosen as the volume evenly covering a 9-mm diam. water sensitive paper (Teejet Spraying Systems Co., Wheaton, IL). Weevils were removed immediately after treatment to a 960-mL plastic container. Each container was supplied with a dental wick wetted with 1% sucrose solution. Dead weevils were counted and removed at 24, 48, and 72 h after treatment. Weevils were scored as dead when no movement occurred after probing with a needle probe. There were three replicates of each treatment, that is, three containers with 10 males and 10 females each. Mortality was calculated as percent mortality.

Topical treatment also was performed with a 50-μl glass syringe driven by a manual apparatus delivering 1/50 of the syringe every push of the button. A 1 μl drop of pesticide in acetone was delivered either to the dorsal thorax or ventral abdomen. Controls received acetone only. There were three containers containing 5 males and 5 females per dose. After treatment weevils were placed in a 960-mL plastic container with a bouquet of immature citrus leaves and a 3.0 cm dental wick wetted with 1% sucrose. Fifty males and 50 females were weighed to produce an average weight for dose calculation.

Contact/oral treatment. Pesticides were applied as the label field rate (Table 3) to bouquets of fully-expanded, mature citrus leaves. Each bouquet contained 8 to 10 mature leaves inserted through a slit in the plastic top of a 30-mL plastic cup (Solo Cup Co., Urbana, IL, Lid No. PL1). Applications were made with a handheld trigger pump sprayer just to runoff, bouquets were allowed to dry (about 1 h) before being placed in a 960-mL plastic container. In addition to the bouquet, weevils were provided with 3.0 cm dental wick wetted with 1% sucrose solution. Weevils were scored as alive, dead (no movement on probing with a needle), or down (movement of any body part) at 24, 48, and 72 h. Dead weevils were removed at each time period. Each experiment was terminated at 72 h after treatment. There were 5 males and 5 females per container and three containers for each treatment to avoid crowding of weevils. The total percent mortality for the three containers, i.e., percent dead of 15 total males or 15 total females, was one replication. Each treatment was replicated three times, with only one replicate of any treatment per week. Each treatment set included three containers of 5 males and 5 females on untreated leaves as controls.

Although these weevils preferentially consume immature leaves, feeding occurred on the mature leaves in these experiments and, consequently, feeding was assessed as: 0 = none, 1 = very light, 2 = light, 3 = light medium, 4 = medium, 5 = medium heavy, 6 = heavy, and 7 = very heavy. Feeding means were compared by ANOVA followed by Tukey's HSD test, $P = 0.05$ (SAS Institute 1999-2001).

An LC_{50} for selected pesticides was produced using the bouquet method just described. LC_{50s} were calculated with PROCPROBIT (SAS Institute 1999-2001) to fit a nonlinear regression with a forced 100% survival at time zero with 95% confidence intervals. Only replicates with less than 10% mortality in controls were used in these calculations.

Results and Discussion

There was generally 1 to 10% mortality when weevils were treated topically with field rates with a Potter tower. An exception was zeta-cypermethrin (Fury, FMC Corp, Philadelphia, PA) which produced 100% mortality with the Potter tower. Consequently, the Potter tower method of treatment was not used further. We postulated that the low mortality produced with the Potter tower was due to pesticide applied to the back; that the higher mortality with bouquets was related to pesticide penetration through the abdomen but we could not confirm this supposition by application of pesticide to either thorax or abdomen (Table 2). Methidathion (Supracide, Gowan Co,

Table 1. Common and chemical name and the chemical formulation of compounds used in this study

Trade name	Formulation	Active ingredient	Percent A.I.	Chemical name	Chemical class
Admire	2F	Imidacloprid	21.4	1-[(6-chloro-3-pyridinyl) methyl]-N-nitro-2-imadazolidinimine	Chloronicotynyl
Agrimek	0.15EC	Abamectin	1.9	A mixture of avermectins containing primarily Avermectin B1a and B1b	Glycoside
Asana	XL	Esfenvalerate	8.4	[(S)-cyano (3-phenoxyphenyl) methyl (S)-4-chloro-alpha-(1-methylethyl) benzeneacetate]	Pyrethroid
Assail 70 WP	70 WP	Acetamiprid	70	(E)-N[1]-[(6-chloro-3pyridyl) methyl]-N[2]cyano-N[1]-methylacetamidine	Nicotinoid
Avaunt	WG	Indoxacarb	30	Methyl (S)-N-[7-chloro-2,3,4a,5-tetrahydro-4a-(methoxycarbonyl) indeno[1,2-e][1,3,4] oxadiazin-2-ylcarbonyl]-4'-(trifluoromethoxy) carbanilate methyl(S)-7-chloro-2,3,4a,5-tetrahydro-2 [methoxycarbonyl (4-trifluromethoxyphenyl) carbamoyl] indeno[1,2-e] [1,3,4] oxadiazine-4a-carboxylate	Oxadiazine
Baythroid 2	2 EC	Cyfluthrin	25	Cyano (4-fluor-3-phenoxyphenyl) methyl-3-(2,2-dichloroethenyl)-2,2-dimethyl-cyclopropanecarboxylate	Pyrethroid
Capture*	2EC	Bifenthrin	25	(2 methyl [1,1'-biphenyl]-3 yl) methyl 3-(2-chloro-3,3,3-trifluoro-1-propenyl)-2,2-dimethyl-cyclopropanecarboxylate	Pyrethroid
Carzol	SP	Formetanate HCl	92	N,N-dimethyl-N' [3-[[(methylamino) cabonyl] oxy] phenyl] Methanimidamide monohydrochloride	Carbamate
Danitol*	2.4EC	Fenpropathrin	30.9	[alpha-cyano-3-phenoxybenzyl 2,2,3,3-tetramethyl-cyclopropanecarboxylate	Pyrethroid
Diamond	0.83EC		10	1-[3-chloro-4-(1,1,2-trifluoro-2-trifluoro-methoxyethoxy) phenyl]-3-(2,6-diflurobenzoyl) urea	Insect Growth Regulator
Ethion	4M	Ethion	46.5	O,O,O'O'-tetraethyl S,S"-methylene bisphosphorodithioate	Organophosphate
EXP 61685	EC	RPA 107382	10	Not available	Phenyl Pyrazole
Furadan	4F	Carbofuran	44	2,3-dihydro-2,2-dimethyl-7-benzofuranylmethylcarbamate	Carbamate
Fury	1.5EC	Zeta-cypermethrin	18.1	S-cyano (3-phenoxyphenyl)methyl (±) cis/trans 3-(2,2-dichloroethenyl)-2,2-dimethylcyclopropane carboxylate	Pyrethroid

Table 1. Continued.

Trade name	Formulation	Active ingredient	Percent A.I.	Chemical name	Chemical class
Fury	0.8EC	Zeta-cypermethrin	9.7	S-cyano (3-phenoxyphenyl)methyl (±) cis/trans 3-(2,2-dichloroethenyl)-dimethylcyclopropane carboxylate	Pyrethroid
Guthion*	2L	Azinphos-methyl	27	O,O-dimethyl S-[(4-oxxo-1,2,3-benzotriazin-3-(4H)-yl) methyl] phosphorodithioate	Organophosphate
Imidan	70W	Phosmet	70	N-(mercaptomethyl) pthalimide, S-(O,O-dimethyl phosphorodithioate)	Organophosphate
Lannate	LV	Methomyl	29	Methyl-N-[[(methylamino) carboyl]oxy] ethanimidothioate	Carbamate
Lorsban	4E	Chlorpyrifos	44.9	O,O-diethyl O-(3,5,6-trichloro-2-pyridinyl) phosphorothioate	Organophosphate
Mesa	EC	Milbamectin	1.0	(6R, 25R)-5-O-demethyl-29-deoxy-6,28-epoxy-25-ethylmilbemycin B +(6R, 25R)-5-O-demethyl-28-deoxy-6,28-epoxy-25-methylmilbemycin B	Antibiotic insecticide
Metasystox-R	SC	Oxydemeton-methyl	25	S-[2-ethylsulfinyl)ethyl] O,O-dimethyl phosphorothioate	Organophosphate
NouGuard	EC	Capsaicin and other capsaicinoids	0.64		Repellent
Pounce	3.2EC	Permethrin	38.4	(3-phenoxyphenyl)methyl (±) cis/trans 3-(2,2-dichloroethenyl)-2,2-dimethylcyclopropanecarboxylate	Pyrethroid
Sevin XLR*	EC	Carbaryl	41.2	1-napthyl N-methylcarbamate	Carbamate
Spintor	2SC	Spinosad	22.8	Mixture of Spinosyn A&D	Natural product
Supracide (2E)	2E	Methidathion	24.4	O,O-dimethyl-S-[5-methoxy-2-oxo-1,3,4-thiadiazol-3(2H)-yl-methyl]-dithiophosphate	Organophosphate
Supracide (25W)	25W	Methidathion	25	O,O-dimethyl-S-[5-methoxy-2-oxo-1,3,4-thiadiazol-3(2H)-yl-methyl]-dithiophosphate	Organophosphate
Vydate	L	Oxamyl	24	Methyl-2-(dimethylamino)-N-[[(methylamino)carbonyl]oxy]-2-oxoethanimidothioate	Carbamate

* Registered for use against *D. abbreviatus* (McCoy et al. 2004).

Table 2. Toxicity (72 h) of pesticide formulation applied to the thorax or abdomen of *Diaprepes abbreviatus*

Pesticide	Rate/ha	ppm	Mortality (%) ♂	Mortality (%) ♀
Thorax				
Control	0	0	7	27
imidacloprid (Admire 2F)	0.32 L	72	7	7
imidacloprid (Admire 2F)	2.34 L	428	13	13
methidathion (Supracide 2E)	23.38 L	4880	100	100
oxamyl (Vydate L)	4.68 L	960	7	7
zeta-cypermethrin (Fury 0.8 EC)	0.37 L	31	40	7
Abdomen				
Control	0	0	0	0
imidacloprid (Admire 2F)	0.32 L	72	0	7
imidacloprid (Admire 2F)	2.34 L	428	0	7
methidathion (Supracide 2E)	23.38 L	4880	100	100
oxamyl (Vydate L)	4.68 L	960	13	0
zeta-cypermethrin (Fury 0.8 EC)	0.37 L	31	13	13

Yuma, AZ) produced 100% mortality with topical treatment, but zeta-cypermethrin did not (Table 2).

Mortality due to topical/oral treatments with field rates is reported in Table 3. Those compounds that produced less than 70% mortality in 72 h with the field rate (Table 3) were not used for LC_{50} determinations. Compounds producing low mortality when applied to leaves, and probably not useful for adult *D. abbreviatus* control, were imidacloprid (Admire™, Bayer Crop Science, Research Triangle Park, NC), abamectin (Agrimek™, Novartis™, Greensboro, NC), acetamiprid (Assail™, Cerexagri, King of Prussia, PA), ethion (Ethion™, FMC Corp, Philadelphia, PA), azinphos-methyl (Guthion™, Bayer Crop Science, Research Triangle Park, NC), milbamectin (Mesa™, Gowan, Mesa, AZ), oxydemeton-methyl (Metasystox-R™, Gowan Co, Yuma, AZ), capsaicin (NouGuard™, NTI, Tequesta, FL), and spinosad (Spintor™, Dow Agrosciences, Indianapolis, IN). Imidacloprid is a systemic compound, is usually applied as a soil drench and, in our experience, is toxic to *D. abbreviatus* (Nigg and Simpson, unpubl.). Applied to leaves, this compound was virtually nontoxic to *D. abbreviatus* adults (Table 3). Phosmet (Imidan™, Gowan Co, Yuma, AZ) and oxamyl (Vydate™, Dupont, Wilmington, DE) are also systemic compounds, but produced 80 to 100% mortality. Because feeding occurred with all three compounds (Table 4), we suggest that imidacloprid must be metabolized in the plant to the actual toxicant.

Table 4 presents the feeding estimation data for feeding on the same bouquet of leaves every 24 h over 72 h. These data indicate that most of the feeding in these tests occurred in the first 24 h. Toxic compounds generally had a feeding estimate of 1.0 or less with the exception of indoxacarb (Avaunt™, Dupont, Wilmington, DE), and phosmet (Table 4). Feeding estimates averaging greater than 1.0 occurred with compounds that produced less than 20% mortality in the first 24 h (Tables 3 and 4). Control feeding was generally greater than 5.0, maximum = 7 (Table 4). Feeding, or lack thereof, is usually not monitored in toxicity testing (Hayes 1975, Klassen 1996). The technical term for lack of feeding is anorexia ("lack or loss of the appetite for food" as per Dorland's Illustrated Medical Dictionary [1988]). For compounds that were not toxic, there was no difference between feeding comparing the controls and treatments: abamectin, novaluron (Diamond™, Crompton Corp, Middlebury, CT), ethion, milbamectin, spinosad. An exception to this generalization was capsaicin. For compounds that produced a toxicity of 50% or more, there was a difference in feeding between controls and treatments (Tables 3 and 4). For formetanate HCl (Carzol™, Gowan Co, Yuma, AZ) this feeding difference was dose related, for Imidan it was not.

Formetanate HCl and carbaryl (Sevin™, Bayer Crop Science, Research Triangle Park, NC) currently registered for *D. abbreviatus* adults, had LC_{50}s of 435 ppm and 436 ppm, respectively (Table 5). Based on the LC_{50}, better choices for controlling *D. abbreviatus* adults might be esfenvalerate (Asana™, Dupont, Wilmington, DE), indoxacarb, cyfluthrin (Baythroid™, Bayer Crop Science, Research Triangle Park, NC), bifenthrin (Capture™, FMC Corp, Philadelphia, PA), fenpropathrin (Danitol™, Valent, Walnut Creek, CA), carbofuran (Furadan™, FMC Corp, Philadelphia, PA), zeta-cypermethrin (both formulations), methomyl (Lannate™, Dupont Corp, Wilmington, DE), permethrin (Pounce™, FMC Corp, Philadelphia, PA), and methidathion (both formulations) (Table 5). These compounds represent widely differing chemistries (Table 1), but none is registered for *D. abbreviatus.* Carbofuran and methidathion will probably never be registered for *D. abbreviatus* because they are acetylcholinesterase inhibiting pesticides.

Table 6 presents the maximum active ingredient concentration tested in this study. If the rate shown in Table 6 is not the field rate, it is a rate higher than the field rate. For this insect, the mortality at this maximum dose is important. *Diaprepes abbreviatus* females may produce as many as 10,000 eggs over their lifetime (Nigg et al. 2004) and, thus, one female potentially can infest a substantial area. Consequently, compounds that resulted in 100% mortality at the field rate or lower would be desirable for *D. abbreviatus.* Compounds in this category are indoxacarb, cyfluthrin, bifenthrin, carbofuran, zeta-cypermethrin, phosmet, methomyl, and methidathion (Tables 3 and 6). However, formetanate HCl and carbaryl, labeled and recommended for *D. abbreviatus,* did not produce 100% mortality even at concentrations higher than field rates (Table 6) and were thus grouped with compounds that produced mortality levels greater than 90%: formetanate HCl, azinphos-methyl, phosmet, carbaryl, and oxamyl (Tables 3 and 6). Compounds that produce less than 100% mortality may prove useful for controlling adult *D. abbreviatus.* These suppositions require field experimentation (Stark et al. 1995). The very high rates of ethion, imidacloprid, abamectin, capsaicin, and spinosad confirm their relative non-toxicity to *D. abbreviatus* (Table 6).

One of the difficulties in assessing pesticides for *D. abbreviatus* is that there is no reliable field method for monitoring adult populations. Adults may be trapped, but trap threshold and efficiency are not known and trapping gives only relative abundance only (Duncan et al. 2001, McCoy et al. 2003). Adults may be collected by beating into an umbrella; this method has been validated only for young citrus trees (Nigg et al. 1999b, 2001c). Larval abundance may be determined and provides a field management assessment method (Nigg et al. 2003). We suggest that the larval abundance method should be used for the field efficacy assessment of adulticides most likely to be registered for *D. abbreviatus:* indoxacarb, cyfluthrin, zeta-cypermethrin, phosmet, and oxamyl, and also for formetanate HCl and carbaryl, currently registered for *D. abbreviatus.*

The effective management of *D. abbreviatus* will likely require an integrated program of persistent adult control and effective biological control for eggs in the canopy.

Table 3. Diaprepes mortality with field rates of presticides applied to leaves

Treatment	Field rate per ha (formulation)	ppm finished spray* (a.i.)	Mortality (%) 24 h ♂	24 h ♀	48 h ♂	48 h ♀	72 h ♂	72 h ♀
imidacloprid (Admire 2F)	0.32 L	72	5 ± 4	2 ± 4	5 ± 4	7 ± 7	24 ± 21	27 ± 14
imidacloprid (Admire 2F)	2.34 L	428	0 ± 0	2 ± 4	0 ± 0	5 ± 4	38 ± 28	47 ± 43
abamectin (Agrimek 0.15EC)	0.73 L	12	7 ± 12	0 ± 0	7 ± 12	2 ± 4	7 ± 12	7 ± 7
esfenvalerate (Asana XL)	0.58 L	42	9 ± 16	13 ± 23	56 ± 48	60 ± 46	89 ± 3	85 ± 17
acetamiprid (Assail 70 WP)	400 g	210	2 ± 4	16 ± 10	2 ± 4	16 ± 15	22 ± 17	31 ± 25
indoxacarb (Avaunt WG)	245 g	66	0 ± 0	0 ± 0	5 ± 4	0 ± 0	93 ± 12	93 ± 0
indoxacarb (Avaunt WG)	421 g	113	2 ± 4	0 ± 0	36 ± 56	33 ± 58	100 ± 0	100 ± 0
cyfluthrin (Baythroid 2)	0.20 L	42	73 ± 35	69 ± 38	82 ± 25	78 ± 24	100 ± 0	100 ± 0
bifenthrin (Capture 2EC**)	0.47 L	100	27 ± 12	33 ± 23	29 ± 10	33 ± 23	100 ± 0	100 ± 0
formetanate HC1 (Carzol SP)	0.58 L	460	36 ± 30	20 ± 12	62 ± 14	42 ± 20	82 ± 25	49 ± 17
formetanate HC1 (Carzol SP)	1.17 L	920	69 ± 10	42 ± 14	87 ± 17	73 ± 17	93 ± 12	95 ± 4
fenpropathrin (Danitol 2.4EC**)	1.17 L	309	2 ± 4	7 ± 0	18 ± 19	26 ± 29	78 ± 22	78 ± 17
novaluron (Diamond)	1.02 L	88	3 ± 5	4 ± 4	3 ± 5	5 ± 6	5 ± 9	9 ± 13
ethione (Ethion 4M)	5.85 L	2325	0 ± 0	0 ± 0	2 ± 4	0 ± 0	2 ± 4	2 ± 4
fipronil analog (EXP 61685 EC)	0.38 L	400	5 ± 4	5 ± 4	22 ± 22	18 ± 14	91 ± 16	82 ± 17
carbofuran (Furadan 4F)	2.34 L	880	80 ± 24	78 ± 33	85 ± 17	87 ± 17	100 ± 0	100 ± 0
zeta-cypermethrin (Fury 0.8EC)	0.18 L	16	13 ± 17	24 ± 27	33 ± 34	31 ± 38	80 ± 7	75 ± 17
zeta-cypermethrin (Fury 0.8EC)	0.29 L	25	5 ± 4	15 ± 4	38 ± 49	40 ± 41	78 ± 20	89 ± 14
zeta-cypermethrin (Fury 0.8EC)	0.37 L	31	67 ± 42	67 ± 37	69 ± 43	69 ± 38	100 ± 0	100 ± 0
zeta-cypermethrin (Fury 1.5EC)	0.37 L	58	44 ± 41	49 ± 34	55 ± 37	62 ± 28	100 ± 0	96 ± 8
azinphos-methyl (Guthion 2L**)	7.02 L	1320	42 ± 40	27 ± 24	51 ± 34	42 ± 25	56 ± 32	56 ± 20
phosmet (Imidan 70W) (non buffered)	2244 g	1400	7 ± 7	13 ± 23	33 ± 18	36 ± 14	78 ± 17	87 ± 23

Table 3. Continued.

Treatment	Field rate per ha (formulation)	ppm finished spray* (a.i.)	Mortality (%) 24 h ♂	24 h ♀	48 h ♂	48 h ♀	72 h ♂	72 h ♀
phosmet (Imidan 70W) (buffered 6.0-6.5 pH)	2244 g	1400	38 ± 17	40 ± 36	93 ± 3	71 ± 23	98 ± 4	98 ± 4
methomyl (Lannate LV)	3.51 L	870	84 ± 14	64 ± 27	87 ± 12	69 ± 21	100 ± 0	100 ± 0
chlorpyrifos (Lorsban 4E)	5.85 L	2245	18 ± 16	28 ± 14	42 ± 37	55 ± 4	69 ± 14	78 ± 10
milbamectin (Mesa 1% EC)	2.34 L	20	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
milbamecitn (Mesa 1% EC)	2.92 L	25	0 ± 0	0 ± 0	0 ± 0	0 ± 0	2 ± 4	0 ± 0
oxydemeton-methyl (Metasystox-R SC)	4.68 L	1000	5 ± 4	5 ± 4	18 ± 25	16 ± 15	44 ± 30	60 ± 0
capsaicin (NouGuard 0.64)	undiluted	6400	20 ± 35	16 ± 21	22 ± 39	22 ± 24	33 ± 35	33 ± 24
permethrin (Pounce 3.2EC)	1.17	384	11 ± 10	10 ± 12	13 ± 14	22 ± 20	80 ± 18	98 ± 4
carbaryl (Sevin XLR EC**)	23.39 L	8840	37 ± 26	21 ± 18	64 ± 36	52 ± 31	92 ± 12	96 ± 8
spinosad (Spintor 2SC)	0.73 L	141	0 ± 0	2 ± 4	2 ± 4	9 ± 8	4 ± 8	18 ± 14
methidathion (Supracide 2E)	23.39 L	4880	95 ± 4	91 ± 16	95 ± 4	96 ± 8	100 ± 0	100 ± 0
methidathion (Supracide 25W)	2244 g	500	100 ± 0	100 ± 0	100 ± 0	100 ± 0	100 ± 0	100 ± 0
methidathion (Supracide 25W)	4488 g	1000	100 ± 0	100 ± 0	100 ± 0	100 ± 0	100 ± 0	100 ± 0
oxamyl (Vydate L)	4.68 L	960	40 ± 35	40 ± 18	49 ± 20	53 ± 7	98 ± 4	93 ± 7

* Finished spray is based on 1167 L of water per ha. a.i. = active ingredient. n = 3, one replication was three cages with 5 males and 5 females per cage. Replications were run in different weeks. **Registered for use against *D. abbreviatus* in Florida citrus (McCoy et al. 2004).

Table 4. Diaprepes feeding rate*

Product	Field rate/ha (Test mix) formulation	ppm finished spray	24 h	48 h	72 h
imidacloprid (Admire 2F)	0.32 L (33.8 µL/100 mL)	72	2.6 ± 1.5	2.9 ± 0.6	2.2 ± 0.8 a**
Control			7.0 ± 0.0	6.8 ± 0.3	6.7 ± 0.4 b
imidacloprid (Admire 2F)	2.34 L (200 µL/100 mL)	428	1.0 ± 0.1	0.9 ± 0.2	1.0 ± 0.3 a
Control			6.3 ± 0.7	6.2 ± 0.3	5.8 ± 0.7 b
abamectin (Agrimek 0.15 EC)	0.73 L (62.5 µL/100 mL)	12	5.7 ± 0.5	6.2 ± 1.0	6.0 ± 0.6 a
Control			6.5 ± 0.7	5.9 ± 1.2	6.2 ± 0.9 a
esfenvalerate (Asana XL)	0.58 L (50 µL/100 mL)	42	0.7 ± 0.6	0.4 ± 0.4	0.3 ± 0.4 a
Control			6.0 ± 1.0	6.0 ± 1.0	6.1 ± 1.0 b
acetamiprid (Assail 70 WP)	400 g (0.03 g/100 ml)	210	0.9 ± 0.2	1.0 ± 0.3	1.0 ± 0.2 a
Control			5.0 ± 0.0	5.2 ± 0.5	5.7 ± 0.6 b
indoxacarb (Avaunt WG)	245 g (0.02 g/100 ml)	66	4.3 ± 1.2	4.9 ± 1.0	5.1 ± 1.1 a
Control			5.4 ± 1.3	6.1 ± 0.9	6.3 ± 0.8 a
indoxacarb (Avaunt WG)	421 g (0.4 g/100 ml)	113	3.3 ± 0.9	4.4 ± 0.7	2.5 ± 1.6 a
Control			5.8 ± 0.8	6.3 ± 0.4	6.3 ± 0.6 b
cyfluthrin (Baythroid 2)	0.20 L (21.6 µL/100 mL)	42	0.9 ± 0.7	1.0 ± 0.4	0.9 ± 0.4 a
Control			7.0 ± 0.0	6.8 ± 0.3	6.7 ± 0.4 b
bifenthrin (Capture 2EC)	0.47 L (40 µL/100 mL)	100	0.9 ± 0.2	0.9 ± 0.2	0.9 ± 0.1 ab
Control			5.1 ± 0.2	5.3 ± 0.5	5.6 ± 0.5 b
formetanate HC1 (Carzol SP)	0.58 L (40 µL/100 mL)	460	2.8 ± 2.0	2.7 ± 0.5	2.9 ± 0.8 a
Control			6.3 ± 0.6	6.2 ± 0.3	5.8 ± 0.7 a
formetanate HC1 (Carzol SP)	1.17 L (200 µL/100 mL)	920	1.7 ± 0.7	2.0 ± 0.7	2.0 ± 0.6 a
Control			6.3 ± 0.6	6.2 ± 0.3	5.8 ± 0.7 b
fenpropathrin (Danitol 2.4EC)	1.17 L (100 µL/100 mL)	309	1.2 ± 0.2	1.2 ± 0.2	1.1 ± 0.2 a
Control			4.7 ± 1.2	4.5 ± 1.2	4.8 ± 1.3 b
novaluron (Diamond 0.83) EC	1.02 L (87.5 µL/100 mL)	88	2.7 ± 0.7	3.5 ± 0.4	3.6 ± 0.3 a
Control			2.8 ± 0.8	3.2 ± 0.4	3.6 ± 0.2 a

Table 4. Continued.

Product	Field rate/ha (Test mix) formulation	ppm finished spray	24 h	48 h	72 h
ethion (Ethion 4M)	5.85 L (500 µL/100 mL)	2325	4.2 ± 2.6	5.4 ± 2.0	5.5 ± 1.6 a
Control			5.7 ± 0.5	5.5 ± 0.7	5.8 ± 0.5 a
fipronil analog (EXP 61685 EC)	0.38 L (40 µL/100 mL)	400	2.0 ± 1.5	1.8 ± 0.4	1.4 ± 0.3 a
Control			5.9 ± 1.2	6.1 ± 0.9	6.1 ± 0.6 b
carbofuran (Furadan 4F)	2.34 L (200 µL/100 mL)	880	1.0 ± 0.9	0.8 ± 0.6	0.8 ± 0.7 a
Control			4.7 ± 1.2	5.2 ± 0.8	5.6 ± 0.5 b
zeta-cypermethrin (Fury 0.8EC)	0.18 L (16 µL/100 mL)	16	0.2 ± 0.4	0.2 ± 0.3	0.1 ± 0.2 a
Control			5.7 ± 2.3	5.8 ± 1.2	5.9 ± 0.8 b
zeta-cypermethrin (Fury 0.8EC)	0.29 L (26 µL/100 mL)	25	0.0 ± 0.0	0.1 ± 0.1	0.0 ± 0.0 a
Control			5.2 ± 1.6	5.8 ± 1.0	6.1 ± 0.8 b
zeta-cypermethrin (Fury 0.8EC)	0.37 L (32 µL/100 mL)	31	0.3 ± 0.4	0.4 ± 0.4	0.4 ± 0.4 a
Control			6.2 ± 0.7	6.3 ± 0.6	6.2 ± 0.4 b
zeta-cypermethrin (Fury 1.5EC)	0.37 L (32 µL/100 mL)	58	0.4 ± 0.2	0.3 ± 0.1	0.3 ± 0.2 a
Control			6.0 ± 1.4	6.0 ± 1.4	5.9 ± 1.2 b
azinphos-methyl (Guthion 2L)	7.02 L (600 µL/100 mL)	1320	0.9 ± 1.0	1.6 ± 1.0	2.2 ± 1.4 a
Control			5.5 ± 0.3	5.4 ± 0.6	5.7 ± 0.3 a
phosmet (Imidan 70W) (non-buffered)	2244 g (0.2 g/100 ml)	1400	3.7 ± 1.2	3.9 ± 1.5	3.5 ± 1.8 a
Control			4.8 ± 0.9	5.2 ± 0.7	5.5 ± 0.5 a
phosmet (Imidan 70W) (buffered pH 6.0–6.5)	2244 g (0.2 g/100 mL)	1400	5.7 ± 0.4	4.8 ± 1.6	4.6 ± 1.5 a
Control			7.0 ± 0.0	6.8 ± 0.3	6.7 ± 0.4 a
methomyl (Lannate LV)	3.51 L (300 µL/100 mL)	870	0.6 ± 0.5	0.6 ± 0.5	0.6 ± 0.5 a
Control			5.0 ± 0.6	5.5 ± 0.3	5.7 ± 0.2 b
chlorpyrifos (Lorsban EC)	5.85 L (500 µL/100 mL)	2245	1.4 ± 1.6	2.0 ± 1.7	2.3 ± 1.7 a
Control			4.8 ± 2.0	5.4 ± 1.4	5.6 ± 0.9 b

Table 4. Continued.

Product	Field rate/ha (Test mix) formulation	ppm finished spray	24 h	48 h	72 h
milbamectin (Mesa 1% EC)	2.34 L (200 µL/100 mL)	20	4.8 ± 1.2	5.4 ± 0.6	5.8 ± 0.5 a
Control			4.9 ± 2.0	5.6 ± 1.3	5.9 ± 1.0 a
milbamectin (Mesa 1% EC)	2.92 L (250 µL/100 mL)	25	3.9 ± 0.7	4.8 ± 0.5	5.3 ± 0.6 a
Control			4.9 ± 2.0	5.6 ± 1.3	5.9 ± 1.0 a
oxydemeton-methyl (Metasystox R SC)	4.68 L (400 µL/100 mL)	1000	4.0 ± 0.7	4.3 ± 0.6	4.6 ± 0.4 a
Control			5.5 ± 0.7	5.7 ± 0.4	5.9 ± 0.4 a
capasicin (NouGuard 0.64)	undiluted	6400	0.6 ± 0.5	0.5 ± 0.4	0.6 ± 0.6 a
Control			5.9 ± 0.2	5.9 ± 0.1	6.0 ± 0.3 b
permethrin (Pounce 3.2 EC)	1.17 L (1000 µL/100 mL)	384	1.1 ± 0.3	1.0 ± 0.4	0.9 ± 0.5 a
Control			5.8 ± 2.1	6.3 ± 1.3	6.2 ± 0.9 b
carbaryl (Sevin XLR EC)	23.39 L (200 µL/100 mL)	8240	2.0 ± 1.0	1.5 ± 1.1	1.0 ± 0.8 a
Control			5.1 ± 0.2	5.3 ± 0.5	5.6 ± 0.5 b
spinosad (Spintor 2SC)	0.73 L (62 µL/100 mL)	141	4.3 ± 0.4	4.7 ± 0.7	5.0 ± 0.8 a
Control			4.7 ± 1.2	4.5 ± 1.2	4.7 ± 1.3 a
methidahtion (Supracide 2E)	23.39 L (200 µL/100 mL)	4880	1.0 ± 0.9	1.2 ± 1.1	1.4 ± 1.2 a
Control			6.4 ± 1.0	6.6 ± 0.8	6.5 ± 0.6 b
methidathion (Supracide 25W)	2244 g (0.2 g/100 mL)	500	1.1 ± 1.0	1.1 ± 1.0	1.1 ± 1.0 a
Control			2.8 ± 0.8	3.2 ± 0.4	3.6 ± 0.2 a
methidathion (Supracide 25W)	4488 g (0.4 g/100 mL)	1000	1.0 ± 1.0	1.0 ± 1.0	1.0 ± 1.0 a
Control			2.8 ± 0.8	3.2 ± 0.4	3.6 ± 0.2 a
oxamyl (Vydate L)	4.68 L (400 µL/100 mL)	960	1.0 ± 0.2	1.2 ± 0.2	1.2 ± 0.2 a
Control			5.1 ± 0.5	5.4 ± 0.4	5.5 ± 0.5 b

* 0 = no feeding: 1 = very light; 2 = light, 3 = light medium, 4 = medium, 5 = medium heavy, 6 = heavy, 7 = very heavy.

** Means ± S.D. followed by same letter by compound and rate in the same treatment are not different by ANOVA followed by Tukey's HSD test, $\alpha = 0.05$.

Table 5. Pesticide LC_{50} by sex for *Diaprepes abbreviatus*

Treatment	Males		Females	
	LC_{50} ppm A.I.	95% Fiducial limits	LC_{50} ppm A.I.	95% Fiducial limits
imidacloprid (Admire 2F, 21.4%)	*	*	*	*
abamectin (Agrimek 0.15 EC, 2.0%)	*	*	*	*
esfenvalerate (Asana XL, 0.66 lb/gal)	20	−32 to 39	20	−9 to 37
acetamiprid (Assail 70 WP, 70%)	*	*	*	*
indoxacarb (Avaunt WG, 30%)	40	27 to 51	70	50 to 92
cyfluthrin (Baythroid 2, 25%)	11	**	11	**
bifenthrin (Capture 2 EC, 25.1%)	15	−12 to 27	20	13 to 26
formetanate HCl (Carzol SP, 92%)	435	**	515	−660 to 1238
fenpropathrin (Danitol 2.4 EC, 30.9%)	120	**	160	130 to 188
ethion (Ethion 4M, 46.5%)	*	*	*	*
fipronil analog (EXP 61685 EC, 10%)	90	−37 to 131	119	**
carbofuran (Furadan 4F, 44.0%)	46	37 to 57	64	57 to 79
zeta-cypermethrin (Fury 1.5 EC, 18.1%)	20	4 to 39	23	17 to 30
zeta-cypermethrin (Fury 0.8 EC, 9.7%)	15	4 to 54	11	8 to 14
azinphos-methyl (Guthion 2L, 22.2%)	472	374 to 602	811	570 to 1133
phosmet (Imidan 70 W (buffered pH 6.0), 70%)	618	445 to 774	563	374 to 728
methomyl (Lannate LV, 29%)	62	**	91	46 to 132
chlorpyrifos (Lorsban 4E, 44.9%)	1005	653 to 1355	675	175 to 1056
milbamectin (Mesa EC, 1%)	*	*	*	*
oxydemeton-methyl (Metasystox R SC, 25%)	*	*	*	*
permethrin (Pounce 3.2 EC, 38.4%)	19	13 to 26	21	14 to 30
carbaryl (Sevin XLR EC, 44.1%)	436	220 to 642	488	240 to 728
spinosad (Spintor 2SC, 22.8%)	*	*	*	*
methidathion (Supracide 2E, 24.4%)	103	74 to 135	119	90 to 154
methidathion (Supracide 25W, 25%)	89	71 to 112	95	75 to 125
oxamyl (Vydate L, 24%)	216	−354 to 521	289	166 to 399

* Excessive application rate (with respect to labeling) with insufficient mortality, prohibitive to LC_{50} analysis.
** Large chi-square prohibits calculation of fiducial limits.

Table 6. *Diaprepes abbreviatus* mortality with highest pesticide rate tested (ppm)

Treatment	ppm	Mean 72 h mortality (%)	
		♂	♀
imidacloprid (Admire 2F, 24.4%)	2,400†	47 ± 41	37 ± 32
abamectin (Agrimek 0.15EC, 1.9%)	500†	7 ± 10	3 ± 8
esfenvalerate (Asana XL, 8.4%)	50**	80 ± 26	84 ± 22
acetamiprid (Assail 70WP, 70%)	300†	53 ± 31	40 ± 20
indoxacarb (Avaunt WG, 30%)	600*	100 ± 0	100 ± 0
cyfluthrin (Baythroid 2, 25%)	42*	100 ± 0	100 ± 0
bifenthrin (Capture 2EC, 25.1%)	100*	100 ± 0	100 ± 0
formetanate HC1 (Carzol SP, 92%)	2,000**	96 ± 9	98 ± 7
fenpropathrin (Danitol 2.4EC, 30.9%)	500**	91 ± 11	69 ± 9
novaluron (Diamond, 10%)	88*	5 ± 9	9 ± 13
ethion (Ethion 4M, 46.5%)	16,000†	13 ± 24	10 ± 17
fipronil analog (EXP 61685, 10%)	500**	98 ± 7	73 ± 33
carbofuran (Furadan 4F, 44%)	880*	100 ± 0	100 ± 0
zeta-cypermethrin (Fury 1.5EC, 17.6%)	58*	96 ± 9	98 ± 7
zeta-cypermethrin (Fury 0.8EC, 9.7%)	30**	82 ± 19	93 ± 14
azinphos-methyl (Guthion 2L, 22%)	2,000**	98 ± 7	89 ± 18
phosmet (Imidan 70W (buffered pH 6.0), 70%)	1,600**	96 ± 9	98 ± 7
methomyl (Lannate LV, 29%)	870*	100 ± 0	100 ± 0
chlorpyrifos (Lorsban 4E, 44.9%)	4,000**	98 ± 7	100 ± 0
milbamectin (Mesa EC, 1%)	25*	2 ± 4	0 ± 0
oxydemeton-methyl (Metasystox R SC, 25%)	1,000*	44 ± 30	60 ± 0
capsaicin (Nouguard, 0.64%)	6,400*	33 ± 35	33 ± 24
permethrin (Pounce 3.2EC, 38.4)	150*	98 ± 7	100 ± 0
carbaryl (Sevin XLR EC, 44.1%)	8,840*	92 ± 12	96 ± 8
spinosad (Spintor 2SC, 22.8%)	141*	4 ± 8	18 ± 14
methidathion (Supracide 2E, 24.4%)	4,880*	100 ± 0	100 ± 0
methidathion (Supracide 25W, 25%)	1,000*	100 ± 0	100 ± 0
oxamyl (Vydate L, 24%)	960*	98 ± 4	93 ± 100

* Field rate.
** Used for probit analyses.
† LC_{50} attempt.

and larvae in the soil (where no registered chemical controls are currently available). The laboratory data we present here will provide a basis for future field assessment and for temporary management recommendations.

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References Cited

Anonymous. 1997. *Diaprepes* Task Force Minutes. July 17, 1997. University of Florida, Lake Alfred, FL. 11 pp.

Bas, B., Z. Dalkilic, T. L. Peever, H. N. Nigg, S. E. Simpson, F. P. Gmitter and R. C. Adair. 2000. Genetic relationships among Florida *Diaprepes abbreviatus* (Coleoptera: Curculionidae) populations. Ann. Entomol. Soc. Amer. 93: 459-467.

Dorland's Illustrated Medical Dictionary. 1988. W. B. Saunders Company, Philadelphia, PA. P. 93.

Duncan, L. W., C. W. McCoy, P. A. Stansly, J. H. Graham and R. F. Mizell. 2001. Estimating the relative abundance of adult citrus root weevils (Coleoptera: Curculionidae) with modified Tedders traps. Environ. Entomol. 30: 939-946.

Fennah, R. G. 1942. The citrus pest's investigation in the Windward and Leeward Islands, British West Indies 1937-1942. Agr. Advisory Dept., Imp. Coll. Tropical Agr. Trinidad, British West Indies. pp. 1-67.

Futch, S. H. 2002. Where the root weevils are. Citrus Ind. 83: 13-15.

Griffith, R. J. 1975. The West Indian sugarcane rootstalk borer weevil in Florida. Proc. Florida State Hort. Soc. 88: 87-90.

Hall, D. G., J. Peña, R. Franqui, R. Nguyen, P. Stansly, C. McCoy, S. L. Lapointe, R. C. Adair and B. Bullock. 2001. Status of biological control by egg parasitoids of *Diaprepes abbreviatus* (Coleoptera: Curculionidae) in citrus in Florida and Puerto Rico. BioControl 46: 61-70.

Hayes, W. J. 1975. Toxicology of Pesticides, Williams & Williams, Baltimore, MD. 580 pp.

Hodges, A., E. Philippakos, D. Mulkey, T. Spreen and R. Muraro. 2001. Economic impact of Florida's citrus industry, 1999-2000. Economic Information Report 01-2, University of Florida, IFAS, Food and Resource Economics Department, Gainesville.

Jones, T. H. 1915. The sugarcane weevil rootborer (*Diaprepes* Spengleri Linn.) Insular Expt. Sta. (Rio Piedras, Puerto Rico) Bull. 14: 1-9, 11.

Klassen, C. D. (ed). 1996. Casarett and Doull's Toxicology. The Basic Science of Poisons 5th ed. McGraw-Hill, NY. 1111 pp.

McCoy, C. W. and S. E. Simpson. 1994. Past and current IPM strategies to combat the spread of *Diaprepes abbreviatus* in Florida citrus. Proc. 30th Caribbean Food Crops Soc., July 31-Aug. 5, St. Thomas, USVI. 30: 247-256.

McCoy, C. W., E. D. Quintela, S. E. Simpson and J. Fojtik. 1995. Effect of surface applied and soil-incorporated insecticides for the control of neonate larvae of *Diaprepes abbreviatus* in container-grown citrus. Proc. Florida State Hort. Soc. 108: 130-136.

McCoy, C. W., R. J. Stuart and H. N. Nigg. 2003. Seasonal life stage abundance of *Diaprepes abbreviatus* in irrigated and non-irrigated citrus plantings in central Florida. Florida Entomol. 86: 34-42.

McCoy, C. W., S. H. Futch, J. H. Graham, L. W. Duncan and H. N. Nigg. 2004. 2004 Florida citrus pest management guide: Citrus root weevils, Pp. 53-57. *In* L. W. Timmer (ed.), 2004 Florida Citrus Pest Management Guide, University of Florida, IFAS Extension, Lake Alfred, FL, 146 pp.

Nigg, H. N., S. E. Simpson, L. E. Ramos, A. T. Tomerlin and N. W. Cuyler. 1999a. Fipronil for *Diaprepes abbreviatus* (Coleoptera: Curculionidae) larval control in container-grown citrus. Proc. Florida State Hort. Soc. 112: 77-79.

Nigg, H. N., S. E. Simpson, L. E. Ramos, and N. W. Cuyler. 1999b. Assessment of monitoring techniques for *Diaprepes abbreviatus* (L.) (Coleoptera: Curculionidae) Proc. Florida State Hort. Soc. 112: 73-77.

Nigg, H. N., S. E. Simpson, H. E. Anderson and L. K. Yang. 2001a. Fipronil toxicity to *Diaprepes abbreviatus* L. (Coleoptera: Curculionidae) larvae. Proc. Florida State Hort. Soc. 114: 52-56.

Nigg, H. N., S. E. Simpson, N. E. El-Gholl and F. G. Gmitter, Jr. 2001b. Response of citrus rootstock seedlings to *Diaprepes abbreviatus* L. (Coleoptera: Curculionidae) larval feeding. Proc. Florida State Hort. Soc. 114: 57-64.

Nigg, H. N., S. E. Simpson, L. E. Ramos, T. Tomerlin, J. M. Harrison and N. W. Cuyler. 2001c. Distribution and movement of adult *Diaprepes abbreviatus* (Coleoptera: Curculionidae) in a Florida citrus grove. Florida Entomol. 84: 641-651.

Nigg, H. N., S. E. Simpson, D. G. Hall, L. E. Ramos, S. U. Rehman, B. Bas and N. Cuyler. 2002. Sampling methods as abundance indices for adult *Diaprepes abbreviatus* (Coleoptera: Curculionidae) in citrus. J. Econ. Entomol. 95: 856-861.

Nigg, H. N., S. E. Simpson, R. J. Stuart, L. W. Duncan, C. W. McCoy and F. G. Gmitter, Jr. 2003. Abundance of *Diaprepes abbreviatus* (L.) (Coleoptera:Curculionidae) neonates falling to the soil under tree canopies in Florida citrus groves. J. Econ. Entomol. 96: 835-843.

Nigg, H. N., S. E. Simpson, R. J. Stuart, L. K. Yang, R. C. Adair, B. Bas, S. Ur-Rehman, N. W. Cuyler and J. I. Barnes. 2004. Reproductive potential of Florida populations of *Diaprepes abbreviatus* (Coleoptera: Curculionidae). J. Entomol. Sci. 39: 251-266.

SAS Institute, Inc. 1999-2001. SAS/STAT Software: Changes and Enhancements through release 8.2 SAS Inst., Inc., Cary, NC.

Simpson, S. E. and C. W. McCoy. 1996. Control of *Diaprepes* root weevil with bifenthrin and other pesticides. Proc. 1996 Annu. Jpn. Beetle Rev., McMinnville, Tenn., Jan. 24-25, 1996. 5 pp.

Simpson, S. E., H. N. Nigg, N. C. Coile and R. A. Adair. 1996b. *Diaprepes abbreviatus* (Coleoptera: Curculionidae): Host plant associations. Environ. Entomol. 25:333-349.

Stark, J. D., P. C. Jepson and D. F. Mayer. 1995. Limitations to use of topical toxicity data for predictions of pesticide side effects in the field. J. Econ. Entomol. 85: 1081-1088.

Woodruff, R. E. 1968. The present status of a West Indian weevil *Diaprepes abbreviatus* (L.) in Florida (Coleoptera: Curculionidae). Entomology Circular 77. Florida Dept. Agric., Div. Plant Ind. 3 pp.