Bait-Free Attract and Kill Technology (Hook™ RPW) to Suppress Red Palm Weevil, Rhynchophorus Ferrugineus (Coleoptera: Curculionidae) in Date Palm *

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BAIT-FREE ATTRACT AND KILL TECHNOLOGY (HOOK™ RPW) TO SUPPRESS RED PALM WEEVIL, RHYNCHOPHORUS FERRUGINEUS (COLEOPTERA: CURCULIONIDAE) IN DATE PALM*

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Abstract

The red palm weevil (RPW), *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae), is a lethal pest of date palm, *Phoenix dactylifera* L, and several other palm species worldwide. Pheromone (Ferrugineol) traps have been used to monitor and mass trap RPW in area-wide integrated pest management programs (IPM). However, these conventional food baited pheromone traps (FBPTs) have to be periodically serviced (change of food bait and insecticide solution) which is labor intensive. A bait-free method to 'attract and kill' RPW adults, Hook™ RPW, has been recently developed for weevil control in date palm. We tested this formulation against FBPTs for controlling RPW in a date plantation in Al-Hassa, Saudi Arabia. Weevil captures were not significantly different in the Hook RPW- and FBPT-treated plots, indicating that both equally sustained trapping efficiency during the test period of 3 mo. Using Hook RPW in and around heavily infested plantations could substantially reduce the cost of an area-wide IPM program due to elimination of trap servicing associated with FBPTs. Additionally, Hook RPW demonstrated the same level of attractiveness with or without the presence of food bait, suggesting that the formulation may be applied directly to non-susceptible date palm trees without the risk of bait-lure synergy which could potentially incite damage to healthy trees.

Key Words: Bait-Free Attract and Kill Technology (Hook™ RPW), Specialized Pheromone and Lure Application Technology (SPLAT™), Food Baited Pheromone Traps (FBPT), *Phoenix dactylifera*

Resumen

El picudo rojo de la palma (PRP), *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae), es una plaga letal de la palmera datilera (*Phoenix dactylifera* L.) y varias especies de palma en todo el mundo. Se han utilizado trampas de feromonas (Ferrugineol) para monitorear y capturar de forma masiva PRP en todo las áreas de programas de manejo integrado de plagas (MIP). Sin embargo, estas trampas convencionales con cebo de feromonas (TCCF) tienen que ser reaprovisionadas periódicamente (cambio de cebo y solución de insecticida), que es una labor intensiva. Hook™ RPW, un método sin cebo para "atraer y matar" adultos de PRP que utiliza la Tecnologia Especializada de Feromonas y Aplicación de Señuelos (SPLAT™) fue recientemente desarrollado para el control de picudos en palmera datilera. Probamos Hook RPW [=PRP] en relación de las TCCF para controlar PRP en una plantacion de palmeras datileras en Al-Hassa, Arabia Saudita. Nuestro estudio revela que el número de picudos capturados en parcelas tratadas con SPLAT y en las TCCF no fueron significativamente diferentes, lo que indica que ambos sostuvieron igualmente la eficiencia de atrapar los PRP durante el período de prueba de tres meses. Utilizando Hook RPW en y alrededor de plantaciones altamente infestadas puede reducir sustancialmente el costo de un programa de MIP para el PRP en todo el área debido a la eliminación del reaprovisionamiento de las trampas asociadas con las TCCF. Además, Hook RPW demonstró el mismo nivel de atración con o sin la presencia de cebo, lo que sugiere que la formulación puede ser aplicada directamente sobre árboles de palmeras datileras no susceptibles sin el riesgo de sinergía del cebo-señuelo que potencialmente podria causar daño a los árboles sanos.

The red palm weevil (RPW), *Rhynchophorus ferrugineus* (Coleoptera: Curculionidae), is an internal tissue borer reported to infest 26 palm species worldwide in diverse agro-ecosystems (Malumphy & Moran 2009). The latest report of an RPW invasion occurred in late 2010 in Laguna Beach, California, USA (CDFA 2011) where it was found infesting *Phoenix canariensis* hort. ex. Chabaud. Palms in the early stages of attack are difficult to detect but can be cured with insecticide (stem injection). Palms in the later stages of attack often harbor several overlapping life stages of the pest with extensive tissue damage due to feeding by grubs, and have to be eradicated (Faleiro 2006). RPW is originally from South Asia where it is a major pest of coconut, *Cocos nucifera*. In the Mediterranean basin RPW has become a key pest of *P. canariensis* which is extremely sensitive to its attack (Dembilio et al. 2009). In the Gulf region of the Middle East RPW has been designated as a category-I pest of date palm, *Phoenix dactylifera* L., by the Food and Agriculture Organization of the United Nations, where economic losses due to eradication of severely infested palms between 1 and 5 percent infestation is estimated to range from US$5.18 million to US$25.92 million, respectively (Anonymous 2004; El-Sabea et al. 2009). Since the mid nineteen eighties the spread of RPW has been rapid mainly through infested planting material shipped for farming and landscape gardening. Currently RPW is reportedly present on all continents (with the exception of Antarctica).

The RPW male produced aggregation pheromone, Ferrugineol (4-methyl-5-nonanol), was identified and first synthesized in the early nineteen nineties (Hallett et al. 1993) and since then, pheromone technology has been incorporated in the management strategy against RPW to monitor and mass trap adult weevils in several countries (Faleiro 2006). Addition of 4-methyl-5-nonanone in small amounts to Ferrugineol significantly enhances weevil captures when dispensed in the field through food baited traps (Abozuhairah et al. 1996). RPW adult captures in pheromone traps are female dominant (male: female ratio of 1:2). Trapped female weevils are young, gravid and fertile (Abraham et al. 2001; Faleiro et al. 2003) which increases the likelihood that mass trapping will suppress RPW field populations.

Conventionally, RPW pheromone is dispensed in the field as lures in bucket traps containing food bait mixed with water and laced with a non-repellent insecticide to kill captured weevils. Dates and sugarcane are among the best food baits recommended for use in RPW pheromone traps. Trapping efficiency is reduced if the food baits are not changed every 7 to 15 d (Faleiro 2006). In area-wide programs RPW has been mass trapped at varying trap densities ranging from one to 10 traps per hectare (Oehlschlager 1994; Soroker et al. 2005; Faleiro et al. 2011). Frequent servicing (change of food bait and insecticide solution) of RPW-food baited pheromone traps (FBPTs) becomes cumbersome and costly, especially at a higher trap density where traps have to be set deep inside the plantation without access to motor-able roads. In this context, trap-free management of RPW adults is desirable.

One of the technologies available for trap-free management of RPW involves the use of a biologically inert matrix for the release of semiochemicals (such as synthetic pheromones), pesticides and products that are volatile or labile compounds which require an appropriate delivery and dispensing system to modulate their release in a manner that offers the best insect attraction in the time period desired. Specialized Pheromone and Lure Application Technology (SPLAT™, ISCA Technologies, Inc., Riverside, CA, USA) is a widely used method that has been effective in mating disruption and attract and kill programs for many insect pests (http://www.iscatech.com/exec/SPLAT.htm). Hook™ RPW is a SPLAT-based formulation that has recently been developed for the red palm weevil. Hook RPW is a food bait-free 'attract and kill' formulation containing Ferrugineol (15%) and the insecticide cypermethrin (5%) in an amorphous and flowable paste. The formulation can be applied mechanically or manually through a variety of methods, the simplest of which is via disposable plastic syringes and caulking guns. The aim of this study was to assess the efficacy of Hook RPW technology compared to that of the standard mass trapping program for controlling red palm weevil in date plantations in Al-Hassa, Saudi Arabia.

Materials and Methods

Study Site

Experiments were conducted in RPW infested date plantations in Al-Guaibah village in Al-Hassa, Saudi Arabia (25°19'60"N latitude and 49°37'60"E longitude) for 3 mo from 29 Mar to 28 Jun, 2011 to coincide with peak weevil activity in the region (El-Garhy 1996). Date palm groves were planted with Saudi Arabia's premier cultivar 'Khalas'. Palms in the test sites were 3 m tall and approximately ten years old, planted at a density of about 150 palms per hectare. Palms in Experiment - I were irrigated at fort-nightly intervals through drip lines, while palms in Experiment - II were flood irrigated through open channels at weekly intervals.

The entire oasis of Al-Hassa with an estimated 3 million palms is currently under an area-wide

RPW integrated pest management (IPM) program operated by the Ministry of Agriculture, Kingdom of Saudi Arabia. The main components of this program include mass trapping of adult weevils using FBPTs along with periodic inspection of palms to detect infestations, and regular preventive and need-based curative insecticidal treatments, in addition to eradication of severely infested palms, as recommended by Abraham et. al. (1998). The test plantation used for this study was under a mass trapping program with conventional FBPTs set at a trap density of one trap per hectare placed at the periphery of palm blocks along motor-able roads, to facilitate easy servicing of these traps. Traps were serviced (change of food bait and insecticide solution) at weekly intervals followed by inspection of palms to detect infestations around FBPTs capturing weevils. During this study a total of 59 infestations were detected in the entire plantation (2.81%), of which 28 severely infested palms were eradicated. The plantation was sprayed before the trial during Mar 2011 with 0.2% Fenitrothion 50 EC (Hortak 50 EC), which is formulated in Saudi Arabia by the Arabian Company for Chemical Products, Riyadh.

Experiment - I

Within a 14 hectare date plantation we identified a 2-hectare block of about 300 date palms and marked out a 100 × 40 m (0.4 ha) plot with ~60 palms where Hook RPW was applied as one-hundred 3 g dollops (equivalent to 112 g of Ferrugineol and 37 g of cypermethrin per hectare). Although it is recommended that Hook RPW dollops be applied directly to the bark of the tree, for the purposes of measuring the number of weevils attracted to and killed by contacting the material, in this study dollops were placed individually at the bottom of a 5 L bucket, with 25 buckets positioned in each of four 100 m rows. Rows receiving dollops were spaced 10 m apart and separated by 5 rows of date palms. Dollop to dollop distance within a row was maintained at 4 m.

The 5 L buckets were specially fabricated with 12 windows (3 cm diam; 8 just below the bucket rim and 4 on the lid) to facilitate easy entry of the adult weevils into the bucket, and to record absolute counts of the weevils captured. Weevil captures were compared in the Hook RPW-treated block with weevils captured in a typical mass trapping regime consisting of 2 conventional FBPTs (200 g of dates as food bait in 1 L of water laced with 0.01% Carbofuran 10G plus pheromone (Ferrolure+ 700 mg) in a 5 L 4-window bucket trap) that were located approximately 60 m on either side of the Hook RPW-treated plot. Weekly observations on weevils captured in each bucket were recorded during the experimental period of 13 wk.

Experiment - II

In order to assess the extent of bait-lure synergy associated with Hook RPW, if any, we carried out a second trial consisting of 3 treatments: i) Hook RPW dollop (3 g) in a 5 L 12-window bucket trap as mentioned above without food bait, ii) food bait (200 g dates) in 1 L water laced with 0.01% Carbofuran 10G plus pheromone (Ferrolure+ 700 mg) in a 5 L 4-window bucket trap (FBPT), and iii) food bait (200 g dates) in 1 L water laced with 0.01% Carbofuran 10G plus Hook RPW dollop (3 g) hung from the lid of a 5 L 4-window bucket trap in a plastic container.

The study site was divided into 7 blocks, with all 3 treatments assigned to each block, resulting in 7 replicates per treatment. Data on the number of RPW captured per trap for each treatment was recorded once per wk for 3 wk. In order to counter possible position biased effects due to the aggregated nature of RPW distributions (Faleiro et al. 2002) the treatments within each block were rotated from one position to another at weekly intervals so as to give every treatment equal opportunity at each position. Within each block the treatments were spaced 15 m apart while a distance of 25 m was maintained between the blocks. Observations were recorded on weevil captures for 3 wk.

Data Analysis

For the first experiment, data on the total number of weevils captured (killed) per wk in each treatment plot was converted into weevils captured and killed per hectare per wk in order to homogenize the measurement scale between the two treatments. Weekly weevil captures per hectare per treatment was analyzed using a non-parametric Mann-Whitney test to determine the significance of treatment (Hook RPW versus FBPTs) on capture rates. For the second experiment, data on the mean number of weevils captured per wk per trap for each of the 3 treatments was analyzed using a non-parametric Kruskal-Wallis test. For all statistical tests, alpha was equal to 0.05.

Results and Discussion

Hook RPW vs. FBPTs

Results presented in Figure 1 show the weekly weevil captures per hectare in the Hook RPW-treated plot and the conventional FBPT. Both treatments resulted in similar rates of weevils captured over the course of the study with 2.47 weevils / ha / wk in the Hook RPW treatment and 3.46 weevils / ha / wk in the FBPTs. The results of the Mann-Whitney test were not significant (Fig. 1), indicating that Hook RPW and mass trapping with FBPTs exerted the same level of

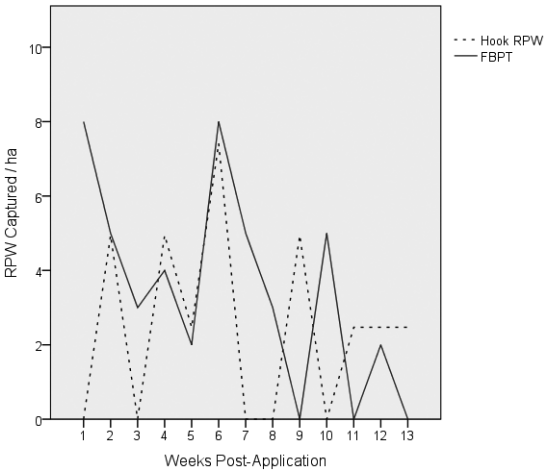

Fig. 1. Weekly red palm weevil captures on a per ha basis in date palms treated with Hook RPW or food-baited pheromone traps (FBPT) in Al-Hassa, Saudi Arabia (Mar-Jun 2011). Hook RPW was applied once at the beginning of the study. FBPTs were serviced weekly (change of food bait and insecticide solution) for the duration of the study. The effect of treatment on weevils captured per ha per wk was not significant ($U = 62.5$, $P = 0.251$).

control of the red palm weevil as measured by the number of weevils attracted and killed per unit area. During the course of this study, infestation levels in the entire test plantation were 2.81% (Personal communication: Directorate of Agriculture, Al Hassa, Saudi Arabia). A recent report from Saudi Arabia showed that in plantations with low weevil activity and less than 1% infested palms, a trap density of one trap per hectare is sufficient to control infestations. In plantations where infestation levels are above 1%, ten traps per hectare resulted in the best weevil capture rates. However, depending on the resources available, the pest could be effectively mass trapped using 4 to 7 traps per hectare with the conventional FBPTs (Faleiro et al. 2011). In this context, and given the results of our study, Hook RPW could replace FBPTs in RPW IPM programs, thus eliminating the labor and costs associated with the weekly renewing of the water and food baits in FBPT-based programs. Using Hook RPW would be especially advantageous when controlling RPW in severely infested plantations where it is currently recommended that FBPTs be used at higher densities. Weevils attracted to and killed by Hook RPW point sources were predominantly female, as observed in FBPTs; however, this aspect needs further investigation.

Regarding the field longevity of Hook RPW, the results of our study (Fig. 1) indicate that the formulation sustained the 'attract and kill' capacity throughout the test period of 13 wk under the hot, arid environmental conditions of Saudi Arabia. It is pertinent to mention that RPW pheromone lures used in the conventional FBPTs are reported to last in the field for 12 to 51 wk depending on the formulation of these lures and weather factors (Faleiro 2006).

Bait-Lure Synergy

Data on the number of weevils captured in baited and non-baited bucket traps used to assess bait-lure synergy indicated that Hook RPW point sources maintained the same level of RPW attraction independent of added food baits (Table 1). Further, the results of the Kruskal-Wallis test were not significant (Table 1), indicating there were no differences in the mean ranks of weevils captured per wk per trap among the Ferrolure+ baited trap and the Hook RPW baited and non-baited traps. It is recommended that Hook RPW be applied at the base of the date palm, directly on the tree bark, which could pose a threat to susceptible palm trees, in spite of the lack of bait-lure synergy observed in this study. RPW is known to preferentially infest young date palms below 20 years of age, those in the age group of 5-15 years being the most susceptible (Abraham et al. 1998). Therefore, it is recommended whenever possible, that dollops be applied to the trunks of older palms and non-host plants to eliminate the possibility of infesting young, susceptible palms.

The combined results of this study suggest that Hook RPW has the potential to become a useful tool for area-wide RPW IPM and eradication programs when applied to trees at a high density of point sources in the target area; however, further field studies about the effects of Hook RPW

TABLE 1. ASSESSMENT OF BAIT-LURE SYNERGY FOR 3 TREATMENTS: I) HOOK RPW DOLLOP (3 G) IN A 5 L 12-WINDOW BUCKET TRAP WITHOUT FOOD BAIT, II) FOOD BAIT (200 G DATES) IN 1 L WATER LACED WITH 0.01% CARBOFURAN 10 G PLUS PHEROMONE (FERROLURE + 700 MG) IN A 5 L FOUR-WINDOW BUCKET TRAP (FBPT), AND III) FOOD BAIT (200 G DATES) IN 1 L WATER LACED WITH 0.01% CARBOFURAN 10 G PLUS HOOK RPW DOLLOP (3 G) HUNG FROM THE LID OF A 5 L FOUR-WINDOW BUCKET TRAP INSIDE A PLASTIC CONTAINER.

Treatment	Mean (SE)	Rank
Hook RPW	0.14 (0.143)	8.79
Hook RPW with Food Bait	0.43 (0.202)	11.36
Ferrolure+ with Food Bait	1.14 (0.595)	12.86

Shown is the mean number of RPW captured per wk per trap for each treatment. The results of a Kruskal-Wallis test were not significant ($\chi^2 = 2.211$, 2 df., $P = 0.331$); the mean ranks of weevils captured per wk per trap were not significantly different among the 3 treatments.

on weevil populations over time and at varying point source densities are warranted. In addition, long-term field studies are needed to determine the levels of weevil infestation in palms treated with the formulation directly, in the absence of bucket traps. The attractiveness of Hook RPW point sources contained in bucket traps, independent of food baits, does have the potential to increase the efficiency of mass trapping programs. Frequent change of food bait and insecticide solutions in FBPTs at a high trap density is labor intensive and costly, especially where traps have to be set deep inside the plantation without access to motor-able roads. In this context, the Hook RPW formulation could be used as a bait-free pheromone to attract and kill RPW adults to traps in and around heavily infested plantations, which may substantially enhance the efficiency of an area-wide RPW IPM program. Furthermore, in addition to the elimination of food baits, the insecticide dose in the Hook RPW formulation (5% cypermethrin) would also eliminate the need to add insecticide solutions to the traps. These factors should be taken into account in an area-wide operation.

Based on these findings, it would be worthwhile to assess in long-term area-wide field trials the impact of Hook RPW in curtailing RPW infestations. These studies should test the long term effectiveness of Hook RPW when deployed in traps, as in this study, and also when applied directly onto the trunk of non-susceptible trees.

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