EFFICACY OF FIVE INSECTICIDES AGAINST *ORIBIUS INIMICUS* MARSHALL AND *O. DESTRUCTOR* MARSHALL (COLEOPTERA: CURCULIONIDAE)

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ABSTRACT

Oribius inimicus *and* O. destructor *are serious horticultural pests of the Highlands region of Papua New Guinea. Adult weevils feed externally on all non-woody parts of a wide range of agricultural and amenity plants. No insecticides currently registered for use in PNG have been formally tested against these insects. In this study we used laboratory bioassays to evaluate the efficacy of five insecticides (Karate® [Lambda-cyhalothrin], Malathion, Chlopyrifos, Target® [Primiphos-Methyl Permethrin] and Orthene® [Acephate]), all of which are commercially available and commonly used by Highlands' farmers. Follow-up laboratory and field trials of the two most promising chemicals tested efficacy at one-quarter, one-half and 1 x manufacturers' label dilution rates. Of the insecticides tested, Karate®, Target® and Chlophyrifos were found to be the most effective in terms of both total knockdown and time to knockdown. In laboratory bioassays, 100% mortality was reached within 20 minutes for these chemicals when insecticide was applied topically to individuals. In field studies, plots treated with Karate® yielded a significantly greater weight and number of fruit than plots treated with Target®, but different dosage rates (one-quarter, one-half or full manufacturers' recommended concentrations) within insecticide type did not alter yield. We recommend Karate® as the chemical of preference for Highlands' growers for* Oribius *control because of its significantly lower cost and better field control.*

Keywords. *Grey weevils, pest management, efficacy, Papua New Guinea*

INTRODUCTION

Weevils of the genus *Oribius* (Marshall) (Coleoptera: Curculionidae) are abundant throughout Papua New Guinea (PNG) and West Papua, Indonesia. Belonging to a group of closely related, small flightless weevils known regionally as "grey weevils" (which also includes, for example, the genera *Apirocalus* Pascoe and *Hypotactus* Marshall [Moxon 1992]), *Oribius* spp are restricted to the island of New Guinea (Thomas & Verloop 1962) and the northern tip of Cape York, Australia (Zimmerman 1991). While the genus is considered to contain over 50 species (Marshall 1956), only eight of these are recognised as pestiferous in PNG (authors' unpublished data): no pest species are known to occur outside the island of New Guinea.

In common with other grey weevils, *Oribius* species are flightless and the adults walk onto their host plants: larvae are soil dwelling and pupation occurs in the soil. Adults are the damaging stage, feeding on growing tips, soft shoots, green stems, flower buds and developing fruit of their host plants (Thistleton 1984). In the Highlands region of PNG, a very wide range of agricultural crops are attacked, from leafy greens through to introduced orchard trees, such as apples and oranges, and field crops such as coffee (Marshall 1957, 1959; Szent-Ivany 1959; Szent-Ivany & Stevens 1966; Greve & Ismay 1983; Thistleton 1984; Waterhouse 1997). *Oribius* spp are also recorded as forestry pests (Gray & Wylie 1974) and they are an abundant component of the PNG rainforest insect fauna (Novotny *et al.* 2002). Feeding by oribius weevils causes significant loss of growth, yield decline, downgrade of crop marketability and, in severe cases, tree and seedling mortality.

Although recognised as important pests since at least the 1950's, there has been very little formal

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study of the ecology or management of oribius weevils (references cited herein cover the available literature). Currently, there is little control of *Oribius* species within Papua New Guinea's agricultural sector, despite crop yields increasing 100-200% when weevils are managed (authors' unpublished data). While some farmers do try to manage oribius using insecticides, the efficacy of the different chemicals available and their most efficient and cost effective application rates have not been evaluated. Because of the highly significant yield gains which can be made when weevils are managed, it is imperative that research be undertaken which supplies easily implemented recommendations for weevil control. This paper represents the outcome of some of this research, on laboratory and field evaluation of five, locally available insecticides. We deliberately chose locally available chemicals as previous pest management research in PNG had demonstrated that trialling non-available chemicals (for example those registered in Australia but not sold in PNG) led to significant grower dissatisfaction when they could not immediately implement the benefits of trials in which they had participated or observed. Studies were conducted on two pest *Oribius* species, *O. inimicus* Marshall and *O. destructor* Marshall, which occur sympatrically in the Highlands' cropping districts.

MATERIALS AND METHODS

Study Site

Both laboratory and field trials were conducted at the [PNG] National Agricultural Research Institute (NARI) Main Highlands Program, Aiyura Valley (6°20'23" S 145°54'18"E), via Kainantu, Eastern Highlands Province, PNG. Laboratory trials were conducted under ambient conditions: mean temperature and relative humidity were 20.5°C and 90.0% respectively.

Insects and Laboratory Trials

Adult *Oribius inimicus* and *O. destructor* were bulk collected from various host plants around the Aiyura valley in the week preceding their use in laboratory trials. Insects were held in an outdoor insectary containing a mix of known host plants until used. Insects used in trials were thus of unknown age and maturity, although they could be, and were, sexed.

Five insecticides were used for the trials: Karate® [Lambda-cyhalothrin, 25g/L active ingredient], Malathion [500g/L active ingredient], Chlopyrifos [500g/L active ingredient], Target® [Pirimiphos-Methyl/Permethrin, 5 + 95g/L permethrin pirimiphos-methyl] and Orthene® [Acephate, 75%w/v active ingredient]. Insecticides were chosen based on their ready availability for Highlands' growers, rather than any preconceptions about preferred mode of action, etc. For each insecticide three treatments and a control were applied which manipulated the insecticide's application mode:

(i) Filter paper dipped into the insecticide and then allowed to air dry before being added as a lining to a petri dish;
(ii) Insecticide misted onto weevils until droplets appeared (topical application);
(iii) Host plant (Thickhead, *Crassocephalum crepidioides*) leaf material immersed in insecticide dilution, allowed to air dry, and then placed with weevils into a petri dish.
(iv) Control – Water sprayed on individuals.

The basic replicate, 10 for each treatment, consisted of a 90mm diameter disposable petri dish, lined with filter paper, containing five male and five female weevils. Recordings of weevil morbidity were made at 5, 15, 30, 60, 360 and 1440 minutes after exposure, and then as required once every 24 hours until 100% mortality was reached. Treatments were abandoned after 336 hours. Insecticides were applied at a rate equivalent to manufacturers' label instructions for general horticultural use. These were: Karate® 0.9ml/L water; Malathion 2.5ml/L water; Chlopyrifos 4ml/L water; Target® 5ml/L water; Orthene® 0.24g/L water.

The three most efficacious insecticides were then further tested at lower concentrations (one-quarter and one-half of full dosage) using the most effective application methods. Each insecticide was tested using the same protocols as for the initial trials.

Field Trials

Based on lab results, two of the three most efficacious insecticides (Karate® and Target®, see results) were subsequently field validated at full (Karate®, 1ml/L; Target® 5ml/L), one-half and one-quarter concentrations. Three replicate field plots were planted on-station for each of the two insecticides tested. Each replicate plot consisting of 80 capsicum plants, separated into four quadrants, each quadrant of which was treated with the same insecticide at the three concentrations and a control (no insecticide application). Capsicums were chosen as they are readily available and commonly grown in the Highlands, have a rapid growth rate and are known hosts of *Oribius* (authors' unpublished data).

Trials were planted at Aiyura on 19.04.2005 and fruits were progressively harvested and weighed as they reached maturity (last harvest date 29.07.2005), in line with normal local farming practice. Insecticide application was conducted on a "as need" basis (based on observations from full concentration plots): this resulted in three sprays being applied on 23.05.2005, 22.06.2005 and 29.07.2005. On completion of the crop cycle, cumulative weights, the total number of fruits harvested and the total number of damaged fruits were calculated for each insecticide/concentration replicate.

Cost/benefit of control

A simple cost/benefit analysis was undertaken on the results obtained from the field trial. Costings were based on average local market value of capsicum for 2004-2005 (Kina 3.52/kg) and average local store costs of insecticides (Karate® K29.03/L, Target® K72.30/200ml, Wetting agent - Holimpas K16.00/5L). Labour costs were not included as we were targeting individual grower gardens where owner-farmers carry out all work. For the same reason we kept the results of the analysis at a small plot size, as against, for example, converting it to a per hectare figure, as horticultural crops in the Highlands are very rarely grown in large, contiguous fields.

RESULTS

Laboratory Results

Combining the different insecticides, application method significantly affected efficacy ($F=33.434$, $df = 2$, $p < 0.001$), with topical application of insecticide being the most effective exposure technique: this overall result was consistent regardless of the insecticide or *Oribius* species tested (Table 1). Independent of exposure type, Chlophyrifos, Target® and Karate® were significantly more effective than the other two chemicals against both *O. inimicus* and *O. destructor* ($F_{inimicus} = 31.376$, $df = 4$, $p < 0.001$; $F_{destructor} = 24.886$, $df = 4$, $p < 0.001$). While the different *Oribius* species responded slightly differently to the different insecticides, with the most obvious difference being the much greater efficacy of malathion against *O. inimicus* than *O. destructor*, there was a generally consistent pattern in the response of both species to the different insecticides (Table 1).

Chlophyrifos, Target® and Karate® were further tested at reduced concentrations. For all insecticides combined, concentration had a significant effect on mortality ($F_{inimicus} = 6.489$, $df = 2$, $p < 0.001$; $F_{destructor} = 14.375$, $df = 2$, $p < 0.001$), with full strength applications being significantly more efficacious in seven of the twelve comparisons (Table 2). The efficacy of Chlophyrifos was most affected by a reduction in concentration, with time to 100% mortality for *O. destructor* being 12 times slower at one-quarter manufacturer's recommended dose than at full strength. Excluding this exception, all other reduced rate insecticides still caused 100% mortality within a maximum of 40 minutes, and on average within 22 minutes (Table 2).

Table 1: **Mean time (minutes) to 100% mortality for *Oribius destructor* and *Oribius inimicus*, using five insecticides and three exposure treatments**

Insecticide	*Oribius* spp.	Treatment: Topical	Substrate	To food	Control
Karate®	*O. destructor*	18.5 ± 2.7	330 ±3 0	360 ± 0.00	> 20160
Target®	*O. destructor*	12 ± 1.5	468 ± 108	360 ± 0.00	> 20160
Chlophyrifos	*O. destructor*	14.5 ± 2.2	1440 ± 0.0	1440 ± 0.0	> 20160
Malathion	*O. destructor*	160 ± 54	> 20160	> 20160	> 20160
Orthene®	*O. destructor*	330 ± 30	> 20160	1152 ± 256	> 20160
Karate®	*O. inimicus*	7 ± 1.3	108 ± 42	360 ± 0.00	> 20160
Target®	*O. inimicus*	8 ± 1.5	10092 ± 2915	6288 ± 3029	> 20160
Chlophyrifos	*O. inimicus*	16.5 ± 1.5	900 ± 180	1322 ± 108	> 20160
Malathion	*O. inimicus*	16.5 ± 3.2	15300 ± 2195	17568 ± 1319	> 20160
Orthene®	*O. inimicus*	2052 ± 364	13248 ± 2369	2448 ±5 28	> 20160

(Sample size for each treatment equals 10 replicates of 10 insects each).

Field Results

In the field validation studies for Karate® and Target®, both insecticides led to greater harvest yields than unsprayed control plots. However, insecticide type significantly influenced yield regardless of dosage treatment: plots treated with Karate® had a significantly greater harvestable weight of capsicums ($t = 2.65$, $df = 70$, $p = 0.01$) and number of fruit ($t = 2.286$, $df = 70$, $p = 0.025$) than those treated with Target® (Table 3). There was no significant effect of changing dosage rate within an insecticide. Insecticide type did not effect the number of damaged fruit ($t = 1.637$, $df = 70$, $p = 0.106$), which was high in all treatments (Table 3).

Cost/benefit of control

Results of the cost-benefit analysis showed that treatments to control oribius weevils were highly profitable, with one-quarter strength Karate® control yielding a K66.40 increase in return over not controlling weevils (Table 4).

DISCUSSION

This study indicates that use of selected insecticides, such as Karate® and Target®, can be used to reduce damage and increase productivity in crops that are attacked by oribius weevils. Further, the cost/benefit analysis demonstrated that significant profit is to be gained with only a few spray applications during a cropping cycle. Because of its extra efficacy in the field (Table 3) and lower cost (Table 4), we recommend Karate® as the chemical of choice for *Oribius* control.

Yield benefits were recorded despite a relatively high level of damage still being experienced in

***Table 2*: Mean time (minutes) (± 1 S.E) to 100% mortality for *Oribius destructor* and *O. inimicus* using three insecticides at one-quarter, one-half and full manufacturers' recommended concentration.**

Insecticide	Species	Treatment		
		¼ Concentration	½ Concentration	Full Concentration
Karate	*O. destructor*	40.5 ± 5.5*	18 ± 5.9	18.5 ± 2.7
Target	*O. destructor*	27.5 ± 4.6*	14.5 ± 3.6	12 ± 1.5
Chlophyrifos	*O. destructor*	363 ± 47*	38 ± 3.6*	14.5 ± 2.16
Karate	*O. inimicus*	22.5 ± 2.5*	27 ± 2.0*	7 ± 1.3
Target	*O. inimicus*	14 ± 1.0*	9.0 ± 1.63	8 ± 1.5
Chlophyrifos	*O. inimicus*	14 ± 1.0	15.5 ± 3.45	16.5 ± 1.5

* indicates significant difference at $p<0.05$ from full concentration trial

***Table 3:* Mean (± 1 S.E.) number of undamaged fruit, damaged fruit, and harvestable weight of capsicum fruit grown under different insecticide regimes at Aiyura, Eastern Highlands Province, PNG.**

Insecticide	Mean treatment yield (± 1 S.E.)			
	Control	¼ dose	½ dose	Full dose
Karate				
Number undamaged fruit	27.3 ± 5.9a	44.1 ± 10.1b	37.1 ± 8.7b	42.1 ± 11.9b
Number damaged fruit	25.1 ± 5.6a	33.7 ± 7.9b	30.8 ± 7.6b	31.5 ± 9.5b
Fruit weight (Kg)	23.77 ± 4.6a	42.5 ± 9.0b	39 ± 9.3b	39.6 ± 10.1b
Target				
Number undamaged fruit	19.3 ± 4.6	25.0 ± 7.6	28.0 ± 8.1	25.7 ± 6.8
Number damaged fruit	18.4 ± 4.5	22.7 ± 7.0	25.1 ± 7.9	22.8 ± 6.4
Fruit weight (Kg)	16.9 ± 4.5	24.6 ± 7.7	22.2 ± 6.6	25 ± 6.4

Each treatment consisted of three replicated, 20 plant plots.

Table 4: Cost/benefit analysis for control of *Oribius* species on 60 capsicum plants using three insecticide concentration rates for Karate® (active ingredient Lambda-cyhalothrin) and Target® (active ingredient Pirimiphos-Methyl/Permethrin).

Parameter	Treatment			
	Unsprayed	One-quarter manufacturer's recommended rate	One-half manufacturer's recommended rate	Full manufacturer's recommended rate
KARATE®				
Treatment cost	0.00	0.16	0.23	0.38
Market Value (K/kg)	3.52	3.52	3.52	3.52
Productivity (Kg)	23.7	42.6	39.0	39.7
Profit (Kina)	83.42	149.79	137.05	139.36
TARGET®				
Treatment cost	0	3.7	7.31	14.54
Market Value (K/kg)	3.52	3.52	3.52	3.52
Productivity (Kg)	16.7	24.6	22.2	25.0
Profit (Kina)	58.78	82.89	70.83	73.46

Calculations based on the Papua New Guinea Kina (K) and figures are based on local store costs in Eastern Highlands Province, PNG. Profit is based on average local market value and total production for each treatment. Three spray applications were made during trial.

our treatment plots. In a separate trial (authors' unpublished data), fortnightly calendar spraying with Karate® did lead to reduced levels of damage in comparison to unsprayed controls, but did not negate all damage. Along with unpublished observational studies of the weevils, we explain the high level of damage in insecticide treated plots as being caused by: (i) the mobility of the weevils, which walk on and off plants twice daily; and (ii) the cryptic nature of surface feeding damage, which on young fruit may go unnoticed, but which becomes progressively more noticeable as the fruit grows. In this latter case it may imply that the three "as needed" spray applications in our field trials were either insufficient, or badly timed. Given these problems, particularly when garden plots are surrounded by non-treated weed vegetation (as is common in the Highlands), insecticide would need to be applied with a very high frequency to eliminate all damage. We do not endorse such an approach, however, given the well documented negative impacts which follow high level insecticide use.

Although a topical application is recommended (based on lab results), the efficacy of Karate® relative to Target® in the field may be linked to the chemical's persistence and mode of action. Lambda-cyhalothrin is considered to have a half life on the leaf-surface of five days (National Pesticide Telecommunications Network) and, in addition to its direct mortality effects, has a repellency action against insects (Tomlin 1997). This persistence on the substrate and repellency action may help it control weevils which walk onto the plant after application.

The efficacy of Target® and Karate® at reduced concentrations has significant implications for management. Although time to kill was lengthened in the laboratory environment, efficacy at one-quarter and one-half recommended concentrations did not lower yields within field trials. Using insecticides at one-quarter concentration reduces insecticide cost by 75%, a significant benefit in a cash poor society (Benjamin *et al.* 2001), and may make the difference as to whether control is applied or not. The benefits of a lower concentration application may also be magnified as, although reduced concentrations still provide a lethal dose to *Oribius* weevils, the general principles of Integrated Pest Management (IPM) would predict that impacts on potential natural enemies and pollinators may be reduced.

ACKNOWLEDGMENTS

This project was funded by the National Government of Papua New Guinea and the Commonwealth of Australia through Australian Centre for International Agricultural Research (ACIAR) Project CS2/2001/032, *Impact and Management of Oribius weevils in Papua New Guinea*. The project was a joint collaboration between the National Agricultural Research Institute (PNG) and the Queensland University of Technology (Australia). Mr Nelson Simbikin (Coffee Research Institute) is thanked for advice and input in the laboratory trials.

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