Chemical Control of Male Pre-pupae and Adult Females of *Margarodes prieskaensis* (Jakubski) (Coccoidea : Margarodidae) on Grapevines

C.A. de Klerk

ARC Infruitec-Nietvoorbij, Private Bag X5026, 7599 Stellenbosch, South Africa
E-mail address: annette8@telkomsa.net

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Various contact, fumigant and systemic pesticides were evaluated over three years in a field trial for the control of male pre-pupae and adult females of *Margarodes prieskaensis* on grapevines. Cadusafos at 25 mL/m² gave excellent control of male pre-pupae. Pre-pupae, as well as adult females, were effectively controlled by dichloropropene at 15 mL/m², as well as by thiamethoxam at 2.4 mL/m² and 2.0 mL/m² and imidacloprid at 15 mL/m², 3.0 mL/m² and 1.5 mL/m². Contact and fumigant applications were made during March and April (beginning of leafdrop), and systemics during January (one month after harvest). Chlorpyrifos, furfural, fenamiphos, carbofuran and terbufos were found to be ineffective for the control of *M. prieskaensis*.

INTRODUCTION

Numerous species of the genus *Margarodes* (ground pearls) occur on a wide range of host plants throughout most of the world (Ben-Dov, 2005). Grapevine-infesting species, however, have only been reported from North and South America and from South Africa (De Klerk, 1985). Ten species of *Margarodes* occur in South Africa, five of which infest vine roots in most of the vine-growing areas of South Africa. All vine-infesting species are of economic importance, and vines could even be killed within four years after planting in infested soil (De Klerk, 1985).

Margarodes prieskaensis is one of the main vine-infesting species and occurs in all the vine-growing areas along the Orange River in the Northern Cape (De Klerk, 1985). This is the only species in South Africa in which males and females congregate above ground for mating. According to Du Toit (1975) and De Klerk and Vermeulen (2007), the life cycle of *M. prieskaensis* on vines is as follows: The nymphs that feed on the roots are enclosed in a hard, pearl-like cyst and are present throughout the year. During April, male pre-pupae develop from the cysts and burrow up through the soil where they moult and pupate 20 mm to 30 mm beneath the soil surface. The pupae moult into winged male adults and appear above the ground from June to August. From the beginning of June, adult females emerge from the mature cysts and burrow directly to the soil surface. After mating, the males die and the females burrow down into the soil to deposit their eggs in the vicinity of the roots. After hatching, the nymph inserts its stylets into a suitable root for feeding and starts secreting layers of hard wax to form the cyst. One generation is completed each year.

In field trials conducted in the Orange River irrigation area between 1982 and 1985, various pesticides were evaluated. Hexachlorobutadiene at a rate of 12 mL/m² gave excellent control of pre-pupae, as well as of females (De Klerk, 1987). Because of great variations in the cyst population, no effect on the cysts could be determined. This product, however, is a chlorinated hydrocarbon and could not be registered in South Africa. Dichloropropene, aldicarb, fenamiphos, carbofuran and oxamyl were found to be ineffective for the control of *M. prieskaensis*.

Since the pest is rapidly becoming more serious in the area and no pesticide is presently registered for its control, a field trial was conducted over three years to evaluate different contact, fumigant and systemic products. According to Teixeira *et al*. (2002), good control of *Eurhizococcus brasiliensis* was achieved with neonicotinoid insecticides, imidacloprid and thiamethoxam in field trials with young grapevines. As this species is also a grapevine-infesting species in Brazil, with females and males congregating on the soil surface for mating, these two products were included in the trial.

MATERIAL AND METHODS

The trial was conducted near Pofadder (29,127324º S; 19,396333º E) along the Orange River in the Northern Cape, in a heavily infested Sultanina (Thompson Seedless) vineyard grafted onto Ramsey, with vine spacing 3.0 m x 1.8 m and trained on a gable trellising system. The vines were 12 years old and micro-irrigated. Infested vines were identified during August 2005 by the presence of adult females on the soil surface. These vines were grouped into five randomised blocks of 75 vines each for treatments in the first year, as well as for future treatments. Future treatments depended mostly on results obtained from the previous year. Each treatment was applied randomly in each of the five blocks. Each replicate (plot) consisted of one infested vine with at least one untreated vine between plots in the row. Vines opposite the treated vines in adjacent rows remained untreated. The soil in an area of 1.4 m x 1.4 m (2 m²) around each treated vine was levelled and the sides were ridged to a height of 100 mm to 150 mm.

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Pesticides in liquid formulation were dissolved in 10 litres (L) of water and distributed evenly on the soil surface of the plot with a watering can fitted with a spray head. Pesticides in granular formulation were distributed evenly by hand, slightly incorporated into the soil and washed in with 10 L of water. In 2007, thiomethoxam was applied to a small area (300 mm x 300 mm) around the stem of the vine at 1.2 mL/m² to represent application through drip irrigation. The fumigant, dichloropropene, was applied with a handheld soil-injector gun at a depth of 200 mm with one application per 300 mm x 300 mm area. Within one to two hours after the treatment, another 10 L of water was applied to each plot to enable the products to move deeper into the soil profile.

The pesticides that were evaluated, along with their formulations, trade names and dosages applied per m², are shown in Table 1. The products are grouped according to their contact, fumigation or systemic action. The time of application and evaluation (month and year) for pre-pupae and adult females are also shown in Table 1.

In 2006, the contact pesticides for the control of pre-pupae were evaluated on 18 April, three weeks after application. In 2007 and 2008, evaluations were made on 18 and 22 April respectively, two weeks after application. Due to the long withholding period of the systemic pesticides, applications were made three and six weeks after harvest, on 2007-01-10 and 2008-01-30 respectively. The evaluation of these systemic applications for the control of pre-pupae was made on the same dates in April, as for the contact pesticides.

The same pesticides were evaluated for the control of adult females. In 2006 and 2007, contact pesticides were evaluated on 12 July and 10 July respectively, three weeks after application. In 2008, the evaluations were made on 24 June, two weeks after application. The systemic pesticides applied during January 2007 and 2008 were also evaluated for the control of females on 10 July and 24 June respectively, as for the contact treatments.

The same plots were used for each treatment each year for the application and evaluation of pre-pupae in April, as well as for the females during June and July.

The soil fumigant, dichloropropene A, was applied on 2006-03-29 for the control of pre-pupae, and dichloropropene B was applied on 2006-06-20 on five different plots for the control of females. Evaluations were done on the same dates as for the contact and systemic products.

During the evaluation of the treatments, the whole treated area of each plot (2 m²) was upturned manually to a depth of

TABLE 1

Time of application and evaluation of different pesticides for the control of male pre-pupae and adult females of *Margarodes prieskaensis* in South African vineyards.

Product and formulation	Trade name (dosage / m²)	Pre-pupae: time of application	Pre-pupae: time of evaluation	Females: time of application	Females: time of evaluation
Contact action					
Chlorpyrifos 48% ec[a]	Dursban (10 mL)	April 2006	April 2006	June 2006	July 2006
Furfural 90% ec	Crop Guard (25 mL)	April 2006; 2007	April 2006; 2007	June 2006; 2007	July 2006; 2007
Fenamiphos 40% ec	Nemacur (10 mL)	April 2006; 2007	April 2006; 2007	June 2006; 2007	July 2006; 2007
Cadusafos 10% ew[b]	Rugby (25 mL)	April 2006; 2007; 2008	April 2006; 2007; 2008	June 2006; 2007; 2008	July 2006; 2007; June 2008
Fumigation action					
Dichloropropene 100% al[c]	Telone II (15 mL)	March 2006	April 2006; 2007; 2008	–	July 2006; 2007; June 2008
Dichloropropene 100% al	Telone II (15 mL)	June 2006	April; 2007; 2008	June 2006	July 2006; 2007; June 2008
Systemic action					
Carbofuran 10% gr[d]	Curaturr (30 gr)	[e]Jan 2007	April 2007	Jan 2007	July 2007
Terbufos 10% gr	Counter (10 gr)	Jan 2007	April 2007	Jan 2007	July 2007
Fenamiphos 40% ec	Nemacur (2.5 mL)	Jan 2008	April 2008	Jan 2008	June 2008
Thiamethoxam 25% sc[f]	Actara (2.4 mL)	Jan 2007	April 2007; 2008	Jan 2007	July 2007; June 2008
Thiamethoxam 25% sc	Actara (2.0 mL)	Jan 2008	April 2008	Jan 2008	June 2008
Thiamethoxam 25% sc	Actara (1.2 mL)	Jan 2007	April 2007; 2008	Jan 2007	July 2007; June 2008
Imidacloprid 35% sc	Confidor (15 mL)	Jan 2007	April 2007; 2008	Jan 2007	July 2007; June 2008
Imidacloprid 35% sc	Confidor (3 mL)	Jan 2008	April 2008	Jan 2008	June 2008
Imidacloprid 35% sc	Confidor (1.5 mL)	Jan 2008	April 2008	Jan 2008	June 2008

[a]Emulsifiable concentrate, [b]emulsion oil in water, [c]undiluted, [d]granules, [e]January, [f]suspension concentrate

80 mm to 120 mm and all live pre-pupae and females were collected by hand and counted in the field. All live individuals were then returned by distributing them evenly over the whole surface of the plot.

Because of the normally high variation in the cyst population between vines, and the time-consuming method to determine the number of cysts (De Klerk, 1987), no evaluations were made at the cyst stage.

Statistical analyses

The data were transformed with a square root transformation and then subjected to an analysis of variance using the SAS statistical software (SAS Institute, Inc., 2008). The Shapiro Wilk test (Shapiro & Wilk, 1965) was used to test the residuals for deviation from normality. In all cases there was not enough evidence against normality for the square root transformed data. Students t-LSD (least significant difference) (Ott, 1998) was calculated at the 5% significance level to facilitate comparison between treatment means. The percentage control over the untreated control was calculated to simplify a discussion of the results. The percentage control was calculated as: control, minus treatment, divided by control, multiplied by 100.

RESULTS

Control of male pre-pupae

The effect of the different treatments on male pre-pupae over a period of three years is shown in Table 2. The populations in the untreated control plots were very high in each year, with an average of 75/m². Among the contact pesticides, effective control was achieved each year with cadusafos, at an average control of 85.8% over three years. In each year the number of pre-pupae was significantly lower than in the untreated control. No differences were evident when the application was made two weeks (2007 and 2008) or three weeks (2006) before evaluation. Chlorpyrifos and furfural gave unsatisfactory control. Fenamiphos, applied as a contact pesticide at 10 mL/m², gave satisfactory control (85.8%) in the first year (2006), but poor control (35.8%) after a second application in 2007. Fenamiphos applied in January 2008 as a systemic pesticide at 2.5 mL/m² also gave poor control (33.9%).

TABLE 2

Mean number of live male pre–pupae of *Margarodes prieskaensis* per 2 m² and percentage control after treatment with different pesticides over three consecutive years.

Treatment (dosage / m²)	2006		2007		2008	
	Mean (√)	% Control	Mean (√)	% Control	Mean (√)	% Control
Contact action						
Untreated control	127 (10.9)^{a}	0	81 (8.5)^{a}	0	239 (14.6)^{a}	0
Chlorpyrifos (10 mL)	100 (7.6)^{abc}	21,2	–	–	–	–
Furfural (25 mL)	90 (8.7)^{ab}	29,1	53 (5.1)^{abc}	34,6	–	–
Cadusafos (25 mL)	20 (4.4)^{bcd}	84.3*	17 (3.4)^{bcd}	79,0*	14 (2,8)^{cd}	94,2*
Fenamiphos (10 mL)	18 (3,6)^{cd}	85,8*	52 (6.5)^{abc}	35,8	–	–
Fumigation action						
Dichloropropene A (15 mL)	0 (0)^{d}	100*	11 (2.4)^{cd}	86,4*	5 (2,1)^{d}	97,9*
Dichloropropene B (15 mL)	–	–	9 (2,3)^{cd}	88,9*	16 (3.5)^{cd}	93,3*
Systemic action						
Carbofuran (30 g)	–	–	86 (7,8)^{ab}	0	–	–
Terbufos (10 g)	–	–	65 (6.1)^{abc}	19,8	–	–
Fenamiphos (2.5 mL)	–	–	–	–	158 (12,0)^{a}	33,9
Thiamethoxam (2,4 mL)	–	–	10 (1,9)^{cd}	87,7*	51 (6,4)^{bc}	78,7*
Thiamethoxam (2,0 mL)	–	–	–	–	56 (6,9)^{bc}	76,6*
Thiamethoxam (1,2 mL)	–	–	64 (7,2)^{ab}	21,0	137 (10,7)^{ab}	42,9
Imidacloprid (15 mL)	–	–	0 (0)^{d}	100*	35 (4,9)^{cd}	85,4*
Imidacloprid (3,0 mL)	–	–	–	–	12 (3,2)^{cd}	95,0*
Imidacloprid (1,5 mL)	–	–	–	–	4 (1,5)^{d}	98,3*
LSD (P = 0.05) for (√)	(4,7)		(4,8)		(4,3)	

(√) Square root transformation: Means followed by different letters differ significantly at the 5% level of probability

* Differs statistically (5% level) from the control

The contact fumigant, dichloropropene A, gave excellent control for three years after only one application, in March 2006. The percentage control was still 97.9% in the third year. Excellent control of the pre-pupae was also obtained over two years with one application of dichloropropene B in June 2006. The average control for the two treatments over three years was 93,3%. The mean number of live pre-pupae was significantly lower than in the untreated control in each year. Dichloropropene is phytotoxic and all the treated vines were dead three months after treatment. The few pre-pupae still present after application were probably from cysts occurring deeper in the soil than the fumigant could penetrate.

The systemic pesticides carbofuran and terbufos gave unsatisfactory control. Thiomethoxam at 2.4 mL/m² gave good control (87.7%) in the first year after treatment in 2007. The effect of the treatment was still evident in the second year after treatment (2008), with 78.7% control. In both cases the mean number of live pre-pupae was significantly less than in the untreated control. With a dosage of 2.0 mL/m² applied in 2008, the percentage control was also high (76.6%). However, unsatisfactory control was obtained with a dosage of 1.2 mL/m² in 2008. Unsatisfactory control was also obtained in 2007 when this dosage was applied only on a small area around the stem of the vine.

Imidacloprid at 15 mL/m² gave 100% control in the first year (2007) and 85.4% in the second year without a follow-up treatment. Single applications in 2008 of 3.0 mL/m² and 1.5 mL/m² also gave excellent control, of 95.0% and 98,3% respectively. The mean number of live pre-pupae in each treatment was significantly lower than in the untreated control. The treatments did not differ statistically from each other.

Control of adult females

The effect of the different treatments on adult females over a period of three years is shown in Table 3. The number of live females in the untreated control plots was high in each year, with an average of 25/m². None of the contact pesticides provided significant control of the females. Cadusafos, which gave effective control of the pre-pupae, did not control adult females

TABLE 3

Mean number of live adult females of *Margarodes prieskaensis* per 2 m² and percentage control after treatment with different pesticides over three consecutive years.

Treatment (dosage / m²)	2006		2007		2008	
	Mean (√)	% Control	Mean (√)	% Control	Mean (√)	% Control
Contact action						
Untreated control	34 (5,7)^{a}	0	29 (5,3)^{c}	0	86 (9,0)^{a}	0
Chlorpyrifos (10 ml)	67 (6,9)^{a}	0	–	–	–	–
Furfural (25 mL)	29 (5,1)^{ab}	14,7	38 (5,4)^{c}	0	–	–
Cadusafos (25 mL)	61 (7,7)^{a}	0	169 (11,8)^{a}	0	67 (6,9)^{ab}	22,1
Fenamiphos (10 mL)	60 (7,4)^{a}	0	74 (8,1)^{b}	0	–	–
Fumigation action						
Dichloropropene A (15 mL)	10 (2,9)^{bc}	70,6	6 (2,1)^{def}	79,3*	2 (1,0)^{d}	97,7*
Dichloropropene B (15 mL)	2 (0,9)^{c}	94,1*	4 (2,0)^{def}	86,2*	3 (1,7)^{cd}	96,5*
Systemic action						
Carbofuran (30 g)	–	–	31 (5,2)^{c}	0	–	–
Terbufos (10 g)	–	–	19 (4,3)^{cd}	34,5	–	–
Fenamiphos (2.5 mL)	–	–	–	–	98 (8,5)^{a}	0
Thiamethoxam (2,4 mL)	–	–	3 (1,5)^{ef}	89,7*	17 (3,6)^{bcd}	80.2*
Thiamethoxam (2,0 mL)	–	–	–	–	17 (4,0)^{bcd}	80,2*
Thiamethoxam (1,2 mL)	–	–	15 (3,6)^{cde}	48,3	56 (6,5)^{ab}	34,9
Imidacloprid (15 mL)	–	–	1 (0,8)^{f}	96,6*	10 (2,2)^{cd}	88,4*
Imidacloprid (3,0 mL)	–	–	–	–	17 (3,5)^{bcd}	80,2*
Imidacloprid (1,5 mL)	–	–	–	–	25 (4,5)^{bc}	70,9*
LSD (P = 0.05) for (√)	(3,1)		(3,0)		(3,4)	

(√) Square root transformation: Means followed by different letters differ significantly at the 5% level of probability

* Differs statistically (5% level) from the control

even with three consecutive applications over three years on the same plots.

Dichloropropene A and B, applied once in March 2006 and June 2006 respectively, resulted in excellent control for three consecutive years, with an average of 87.4%. The number of females was statistically lower than in the untreated control in each year at the 5% level, except during 2006, when the significance was at the 10% level.

The systemic pesticides carbofuran and terbufos were unsuccessful in controlling the females. No control was obtained with fenamiphos applied as a systemic pesticide. Thiamethoxam at 2.4 mL/m² gave good control (89.7%) in the first year after treatment in 2007. With no follow-up treatment, control was still 80.2% in 2008. Effective control was also obtained in 2008 with a dosage of 2.0 mL/m². The mean number of females was significantly lower than in the untreated control, and the two dosages did not differ statistically. However, poor control was obtained with a dosage of 1.2 mL/m² in 2008. Thiamethoxam, applied in 2007 at 1.2 mL/m² on a small area of 300 mm x 300 mm around the stem of the vine, also resulted in poor control.

One application of imidachloprid at 15 mL/m² gave 96.6% control in the first year (2007). Without any further applications, excellent control of 88.4% was still obtained in 2008. Dosages of 3.0 mL and 1.5 mL in 2008 resulted in good control of 80.2% and 70.9% respectively. The mean number of live females for each treatment was significantly lower than in the untreated control and did not differ statistically from each other.

DISCUSSION

The results show that no or poor control of *M. prieskaensis* was obtained with chlorpyrifos, furfural, fenamiphos, carbofuran and terbufos. Cadusafos at 25 mL/m² was effective for the control of male pre-pupae. Application should be applied at the start of leafdrop in the last week of March or the first week of April. Cadusafos was, however, not effective for the control of females.

Dichloropropene was very effective for the control of pre-pupae as well as females. The best time of application was in April, when the pre-pupae emerged. As dichloropropene is phytotoxic, it can only be used before an infested block is replanted or when a few single infested vines need to be replaced.

Excellent control of pre-pupae as well as females was obtained with thiamethoxam at 2.4 mL/m² and 2.0 mL/m² respectively, as well as with imidacloprid at 15 mL/m², 3.0 mL/m² and even 1.5 mL/m². These systemic pesticides should be applied after harvest in January/February, at the time when the new annual populations of cysts are actively feeding on the roots and when translocation in the vines is still active.

As only a small percentage of a population of cysts develops into pre-pupae and females annually, and as cysts could lie in the soil for long periods without feeding, treatment with these contact and systemic products needs to be repeated in subsequent years. The population density needs to be determined on an annual basis after treatment.

At this stage, none of these products is registered for the control of *Margarodes* in South Africa.

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