CONTROL OF SAN JOSE SCALE NYMPHS, *Diaspidiotus perniciosus* (Comstock), ON ALMOND AND APPLE ORCHARDS WITH PYRIPROXYFEN, PHENOXYCARB, CHLORPYRIFOS, AND MINERAL OIL

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ABSTRACT

The effect of pyriproxyfen, phenoxycarb, chlorpyrifos, and mineral oil in the control of first generation nymphs of the San Jose scale (SJC), *Diaspidiotus perniciosus* (Comstock), in almond, *Prunus dulcis* (Mill.) D.A. Webb, and apple, *Malus domestica* Borkh. orchards was studied in the 2001-2002 season in central Chile. One and two sprays of pyriproxyfen 0.07% and phenoxycarb 0.05% were applied, the first at the beginning of the appearance of nymphs in early spring (biofix), and the other 15 days later, and were compared with one spray of chlorpyrifos 0.08% applied at the biofix. Also, one and two sprays of mineral oil 1% were evaluated, the first applied 7 days after the biofix, and the second 15 days after the first spray. Evaluations were done in the laboratory at the end of the dispersion of first generation nymphs, on December 27 and 28 for almonds and apples, respectively, counting the number of nymphs fixed per lineal meter of new twigs collected at infested sectors, percentage of infested apples, and the number of scales fixed per fruit. Results were subjected to ANOVA and Duncan multiple range tests. At low level infestation, one application of pyriproxyfen 0.07%, phenoxycarb 0.05%, or mineral oil 1% in spring reduced significantly ($P \leq 0.05$) the number of nymphs fixed per twig, at a level similar to that of a traditional treatment of chlorpyrifos 0.08%. However, at greater infestations, one spray of pyriproxyfen or mineral oil in spring was insufficient to control ESJ.

Key words: mineral oil, phenoxycarb, pyriproxyfen, San Jose scale.

INTRODUCTION

The San Jose Scale (SJS) is a cosmopolitan and polyphagous insect that infests about 700 hosts (Gentile and Summers, 1958), particularly apple, *Malus domestica* Borkh., cherry, *Prunas avium* L., peaches, *Prunus persica* (L.) Batsch, and other orchards in Chile, from Antofagasta Region through Region de Los Lagos (Prado, 1991). Despite having no quarantine importance for important markets such as Europe, Japan, China, Canada, and the USA, this pest is under obligatory control since 1992 in the whole country (SAG, 2004). This insect overwinters mainly as black cap nymphs (~80% of the population) and the remainder as grey cap nymphs and gravid females. During the season it completes three generations, with the nymphs of the first generation beginning to hatch at the end of October, the second at the end of December, and the third in the middle of March and extending through June under mild weather (Sazo and Campos, 1986).

Density of this pest in commercial orchards is generally low, and sometimes imperceptible, but severe infestations can kill plants in 1-3 years (Zalom *et al*, 2005). It is found mostly on the top of trees, as well as in orchard perimeter, where sprays are usually defective. However, control measures are permanent to avoid the populations to increase rapidly because of high fecundity of females; each one may produce up to 400 nymphs (Rice and Jones, 1997). A worrisome increase of this pest has occurred in the last 5 years in some plum, *Prunus salicina* (Lindl.) and apple orchards subjected to chemical control programs in the central zone of Chile, which would be related, among other things, with resistance of this insect to chlorpyrifos (used in orchards because it has registry of use, it is effective against the SJS scale, and has tolerance levels

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in countries importing Chilean fruit) and diazinon (research in progress), insecticides that are applied repeatedly two to three times in the season.

The pest is controlled in winter, when the trees have no foliage and the scales are more exposed, together with other pests present; besides, the beneficial fauna is protected because it is overwintering under the bark and into the bodies of scales, thus its destruction is avoided (Sazo and Campos, 1986; Zalom *et al*, 1999). Control is based in the use of mineral oil at 1.5-2.0% (Sazo and Campos, 1986), applied alone or together with phosphorous insecticides, such as chlorpyrifos or metidathion in winter (Sazo, 1996; Bentley *et al.*, 2000; Shaw *et al.*, 2000). Pesticides such as chlorpyrifos or metidathion are also applied directed to migratory nymphs and white cap nymphs, the most susceptible stages, as a complement during spring and/or summer (Sazo and Campos, 1986). Also, control of first generation males in the spring has been proposed, particularly because this insect reproduces only sexually and most activity concentrates in eight to 10 days in the spring. Sazo *et al.* (1987) determined in nectarine peaches (*Prunus amygdalus* Batsch) that one spray of chlorpyrifos directed to males in the spring is as effective as one or two against nymphs. In relation with other management alternatives, Shaw *et al.* (2000) observed that growth regulator phenoxycarb applied on mobile stages obtained a low level of infested fruit at harvest, similarly to traditional treatments of chlorpyrifos or diazinon.

Mineral oil is an insecticide-miticide refined from crude oil, of high quality and purity, very efficacious against scales, mites, aphids, and other pests. It is mixed with pesticides, and its low solubility in water allows it to remain under rainy conditions (Davidson *et al*., 1991). Oil reduces gas exchange and asphyxiates the insect, and does not generate insecticide resistance (Bentley *et al.*, 2000). It also acts repelling oviposition and feeding, penetrates egg membrane, and coagulates embryo protoplasm. It interferes also the balance of water, enzymes, or hormone activity (Davidson *et al.*, 1991). Phenoxycarb is a non-neurotoxic growth regulator (GR), with little action on natural enemies and not toxic to mammals (Valentine *et al.*, 1996; González *et al.*, 1998; Liu and Chen, 2001; Licht *et al.*, 2004), which is used against diverse insects, including scales. Pyriproxyfen, another GR derived from phenoxycarb, acts similarly, but it is more stable and efficient in the juvenile hormone receptors (Sullivan, 2000). Applied mixed with mineral oil in winter on plums, it has controlled SJS effectively, similarly to mineral oil + diazinon in orchards where no resistance to this phosphorous insecticide has been detected (Rice and Jones, 1997).

The objective of this research was to evaluate the effect of pyriproxyfen, phenoxycarb, mineral oil, and chlorpyrifos onto first generation SJS nymphs in the growing season on apple and almond orchards

MATERIALS AND METHODS

The study was done in 2001-2002 season in two non commercial orchards with no treatments against the SJS in previous seasons, one with 15 years old 'Granny Smith' and 'Royal Gala' apple trees planted at 7 x 3.7 m in San Fernando (34º35`7" S; 70º59`18" W), and another of 5 years old 'Non Pareil' and 'Texas Prolific' almond trees planted at 5 x 4 m in Requinoa (34º16`59" S; 70º48`23" W), both in central Chile. The experimental unit (EU) included two and three almond and apple trees, respectively, obtaining 1 m of new growth twig samples (ten 10 cm twigs) from infested branches, and 100 apple fruits. EU were marked and grouped according to infestation intensity, evaluated by visual inspection. A randomized complete block design was set, with eight treatments and four replicates. The blocks were set and treatments were sorted. Treatment of pyriproxyfen (Admiral 10EC), phenoxycarb (Insegar 25 WP), chlorpyrifos (Lorsban 75WP), and mineral oil (Sunspray Ultrafine), plus a water control, were applied.

Sprays were done with spraying equipment with membrane pump (Lévera, 120 L, Santiago, Chile) providing 40 L min^{-1} at 2070 x 10^3 pascal (300 psi) and volumes of 2500 and 3500 L ha^{-1} in almond and apple trees, respectively. Treatments evaluated and concentrations applied appear in Table 1, and application dates in Table 2. Sprays were done at the beginning of hatching of nymphs of the season's first generation, determined using double sided standard scotch tape (three per tree) set at places with visible infestation, on four trees per orchard. Evaluation on new growth twigs was done at both orchards, and an additional evaluation was conducted on apple fruit. A control treatment was used in both experiments.

Evaluation on twigs was done at the end of movement of first generation nymphs (27 and 28 December 2001, on almond and apple trees, respectively). Apples were evaluated previous to harvest on 25 February 2002, determining percentage of fruit infested and number

Table 1. Active ingredients, concentrations, and application time of treatments evaluated.

Treatments	Concentration (%)	1st spray	2nd spray
Piryproxyfen	0.07	Biofix	-
Piryproxyfen	0.07	Biofix	15 DAB
Phenoxycarb	0.05	Biofix	-
Phenoxycarb	0.05	Biofix	15 DAB
Chlorpyrifos	0.08	Biofix	-
Mineral oil	1.00	7-10 DAB	-
Mineral oil	1.00	7-10 DAB	15 DAB
Control	-	-	-

Biofix: the moment when nymphs captured with standard double side scotch adhesive tapes increase clearly; DAB: days after biofix.

Table 2. Treatments and application dates on almond and apple trees.

Treatments	Orchards	1st spray	2nd spray
Pyriproxyfen	Almonds	Nov. 12, 2001	-
	Apples	Nov. 09, 2001	-
Pyriproxyfen	Almonds	Nov. 12, 2001	Nov. 27, 2001
	Apples	Nov. 09, 2001	Nov. 26, 2001
Phenoxycarb	Almonds	Nov. 12, 2001	-
	Apples	Nov. 09, 2001	-
Phenoxycarb	Almonds	Nov. 12, 2001	Nov. 27, 2001
	Apples	Nov. 09, 2001	Nov. 26, 2001
Chlorpyrifos	Almonds	Nov. 12, 2001	-
	Apples	Nov. 09, 2001	-
Mineral oil	Almonds	Nov. 19, 2001	-
	Apples	Nov. 16, 2001	-
Mineral oil	Almonds	Nov. 19, 2001	Nov. 27, 2001
	Apples	Nov. 16, 2001	Nov. 26, 2001
Control (water)	Almonds	Nov. 12, 2001	-
	Apples	Nov. 09, 2001	-

of nymphs per fruit. For this, collected twigs and apple fruits were carried in coolers to the laboratory to count under stereoscopic magnifiers. All nymphs appearing swollen and lemon yellow were considered alive.

Numbers of nymphs per twig lineal meter, and scales per fruit were transformed by natural log (x + 1), and infested fruits per experimental unit were transformed by arcsen (%), before ANOVA test and Duncan (1955) multiple range tests to separate means were performed. Piriproxyfen was applied at 0.07% because of a recommendation from the producer as needed to ensure control. Concentration of mineral oil applied in spring cannot exceed 1% because larger concentrations cause phytotoxicity (up to 2% is used in winter); this product is effective againts codling moth eggs, *Cydia pomonella* (L), and mobile stages of red mites, *Panonychus ulmi* Koch.

RESULTS AND DISCUSSION

SJS nymphs fixed by twig lineal meter (Table 3) revealed a larger infestation on almonds than on apples trees. Also, on apples all chemical treatments were statistically different ($P \leq 0.05$) from the control, while on almonds, the pyriproxyfen and mineral oil treatments applied only once at the biofix were similar to the control with only water applied (Table 3). This would be because the pyriproxyfen treatment was done too early, onto too few juveniles present, on which this GR acts mainly, and also, because under heavy infestation, application of contact products with no residual action as mineral oil (Bentley *et al.*, 2000) or GR with little systemic effect (Lee *et al.*, 2002) do not reach all scales, as some are located under dead scales at the base of buds.

On almonds, two sprays of pyriproxyfen 0.07% or mineral oil 1.0% with a two weeks interval had a similar effect to one single spray of chlorpyrifos 0.08% in the spring, which allow widening the alternatives against SJS nymphs, a pest that has been controlled for decades only with phosphorous insecticides. These results permit to manage the pest with insecticides with different modes of action, thus reducing the risk of inducing resistance. Resistance to chlorpirifos has been detected in a population of SJS from a plum orchard in María Pinto county (33º31`16" S; 71º08`39" W), Metropolitan Region of Chile, that has been treated during five years with four sprays per season, which presents a near 40 resistance factor (RF = LC_{50} of the study population/LC_{50} in untreated plots; research in progress).

On apples, infestation of twigs (Table 4) was not correlated with percentage of infested fruits, as the control, despite the low number of nymphs fixed per lineal meter of twig (10.5), had a high percentage of infested fruits (65.5%), and 14.9 scales per fruit. However, only treatments of pyriproxifen or mineral oil applied at the biofix, and at the biofix + 15 days were statistically equal to chlorpyrifos, an insecticide effective to control this pest. These results agree with Beers and Himmel (2002), who controlled the SJS on apples with pyriproxyfen with two sprays, at the end of winter, and during the first generation of nymphs, and with Bentley *et al.* (2000) in California with mineral oils on stone fruit orchards.

Table 3. Mean alive scales fixed on almond and apple trees, after spring treatments against nymphs of first generation San Jose scales.

Treatments	Concentration (%)	1st spray	2nd spray	Means of nymphs alive per lineal meter of twig	
				Almonds	Apples
Pyriproxyfen	0.07	Biofix	-	24.50ab	0.50c
Pyriproxyfen	0.07	Biofix	15 DAB	9.75b	1.50bc
Phenoxycarb	0.05	Biofix	-	17.50b	3.50b
Phenoxycarb	0.05	Biofix	15 DAB	15.75b	0.25c
Chlorpyrifos	0.08	Biofix	-	5.75b	1.25bc
Mineral oil	1.00	7 DAB	-	24.50ab	1.25bc
Mineral oil	1.00	7 DAB	15 DAB	8.00b	2.00bc
Control	-	-	-	94.00a	10.50a

Biofix: the moment when nymphs captured with standard double side scotch adhesive tapes increased clearly; DAB: days after biofix.

Table 4. Percentage apples infested and means of scales fixed per fruit, after spring treatments with pyriproxyfen, phenoxycarb, chlorpyrifos and mineral oil directed against first generation nymphs.

Treatments	Concentration (%)	1st spray	2nd spray	Infested fruits (%)	Mean scales per fruit
Piryproxyfen	0.07	Biofix	-	11.75cd	2.09c
Piryproxyfen	0.07	Biofix	15 DAB	7.50d	1.60c
Phenoxycarb	0.05	Biofix	-	39.25b	4.79bc
Phenoxycarb	0.05	Biofix	15 DAB	28.50bc	4.31bc
Chlorpyrifos	0.08	Biofix	-	10.75d	2.47c
Mineral oil	1.00	7 DAB	-	33.75b	11.34ab
Mineral oil	1.00	7 DAB	15 DAB	22.00bcd	3.54c
Control	-	-	-	65.50a	14.90a

Means in a column followed by the same letter do not differ significantly according to Duncan (1955) tests ($P \leq 0.05$).
Biofix: the moment when nymphs captured with standard double side scotch adhesive tapes increased clearly; DAB: days after biofix.

CONCLUSIONS

Under low infestation levels of SJS on apples, one spray of pyriproxyfen 0.07%, phenoxycarb 0.05%, or mineral oil 1.0% directed to the nymphs of the first generation reduced the number of nymphs fixed on twigs, and their effect was similar to that of a traditional spray of chlorpyrifos 0.08%. Under heavier infestations on almonds, a spray of pyriproxyfen 0.07% or mineral oil 1.0% in the spring were insufficient to control the pest.

R E S U M E N

Control de ninfas de la Escama de San José, *Diaspidiotus perniciosus* (Comstock), en almendros y manzanos con piriproxifen, fenoxicarb, clorpirifos y aceite mineral. Luis Sazo[1]*, Jaime E. Araya[1], y Sergio Esparza[1]. En la temporada 2001-2002 se estudió el efecto de piriproxifen, fenoxicarb, clorpyrifos y aceite mineral en el control de las ninfas de la primera generación de la Escama de San José (ESJ), *Diaspidiotus perniciosus* (Comstock), en almendros, *Prunus dulcis* (Mill.) D.A. Webb, y manzanos, *Malus domestica* Borkh., en Chile central. Se hicieron una y dos aplicaciones de piriproxifen 0,07% y fenoxicarb 0,05%, la primera en el inicio del nacimiento de ninfas de primavera (biofix) y la segunda 15 días después, y se las comparó con una aplicación de clorpirifos 0,08% en el biofix. Además, se evaluaron una y dos aplicaciones de aceite mineral 1%, la primera 7 días después del biofix y la segunda 15 días después de la primera aplicación. La evaluación se hizo en laboratorio al concluir el movimiento de ninfas de la primera generación, el 27 y 28 de diciembre en almendros y manzanos respectivamente, considerando el número de ninfas fijadas por metro lineal de nuevas ramillas colectadas desde sectores infestados, el porcentaje de manzanas infestadas y el número de escamas fijadas por fruto. Los resultados se sometieron a análisis de varianza y pruebas de rango múltiple de Duncan. Bajo condiciones de baja infestación, una aplicación de piriproxifen 0,07%, fenoxicarb 0,05%, o aceite mineral 1,0% en primavera redujo significativamente ($P \leq 0,05$) el número de ninfas fijadas en ramillas, en un efecto similar al de un tratamiento tradicional de clorpirifos 0,08%. Sin embargo, bajo infestaciones mayores, una aplicación de piriproxifen o aceite mineral en primavera fue insuficiente para el control de la ESJ.

Palabras clave: aceite mineral, Escama de San José, fenoxicarb, piriproxyfen.

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