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IMIDACLOPRID INJECTIONS EFFECTIVENESS FOR CONTROL OF SNOW SCALE OF CITRUS TRUNK

Efectividad de inyecciones de imidacloprid para el control de cochinilla blanca del tronco de los cítricos

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ABSTRACT. The aim of this study was to evaluate the efficiency of injections with Imidacloprid in controlling snow scale of citrus (*Unaspis citri* Comstock) in sweet orange plants. The test was carried out for two consecutive production cycles, the trees implanted on red yellow podzolic soil were nine years old. The treatments were T0: control; T1: one application of two injections of Imidacloprid in October; T2: two applications of Imidacloprid of two injections of each, the first in October and the second 100 days after; T3: trunk spraying of Chlorpyrifos 48 (0,1 %) in October. The number of live nymphs, males and females insects per cm^2 of trunk and efficiency of the applications at 45, 90, 135 and 180 days after application of treatments was evaluated. Treatments injections of Imidacloprid and sprays of Chlorpyrifos affected the snow scale, although the efficiency of those were variable, 45 days after applying the products treatments, differences in the number of insects were detected compared to the control in both crop cycles. Applications of Imidacloprid injections were as effective as spraying of Chlorpyrifos for control of the snow scale.

Key words: *Citrus sinensis,* insect control, insecticide

RESUMEN. El objetivo de este trabajo fue evaluar la eficiencia de inyecciones con Imidacloprid en el control de cochinilla blanca del tronco de los citrus (*Unaspis citri*, Comstock) en plantas de naranjo dulce. Para esto el ensayo se realizó durante dos ciclos productivos consecutivos en árboles de nueve años de plantados en suelo rojo amarillo podzólico. Los tratamientos fueron T0: Testigo; T1: una aplicación de dos inyecciones de Imidacloprid en octubre; T2: dos aplicaciones de dos inyecciones de Imidacloprid cada una, la primera en octubre y la segunda 100 días después y T3: pulverización al tronco de Clorpirifós 48 al 0,1 % en octubre. Se determinó el número de ninfas, adultos hembras y machos vivos por cm^2 en troncos y se calculó la eficiencia de la aplicación después de 45, 90, 135 y 180 días. Las inyecciones de Imidacloprid y pulverizaciones de Clorpirifós controlaron a la cochinilla blanca del tronco, aunque la eficiencia de los mismos fue variable. Cuarenta y cinco días después de aplicados los productos, se registraron diferencias en la cantidad de insectos entre los tratamientos con aplicación y el testigo en ambas campañas. Las inyecciones de Imidacloprid resultaron tan efectivas como las pulverizaciones de Clorpirifós para el control de la cochinilla blanca.

Palabras clave: *Citrus sinensis,* control de insectos, insecticida

INTRODUCTION

Citrus production occupies the first place among fruit trees in Argentina and in Corrientes province, where more than 50 % of the area planted with citrus fruits corresponds to orange trees (*Citrus sinensis* L. Osbeck (1).

Snow scale of citrus (*Unaspis citri* Comstock) (CBT) is a polyphagous species; however its main hosts of economic importance belong to the genus Citrus. This species, although native to Asia, is present in most of South America countries, it is cited in many citrus regions of the world (2), including Argentina (3).

CBT mainly affects the trunk and the main branches of the tree. The leaves, smaller branches and fruits are infested when the advance of the infection in the main branches is intense, arriving to cause cracks in branches and trunk in severe attacks (4).

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The chemical control of this insect is relatively difficult, because the body of the adult is covered in wax; its food is intermittent and can be found seven or eight overlapping individuals which makes contact of the sprays with insects (5). The proposed control for this pest contemplates sprays to the trunk of chemical products with different levels of toxicity for the pest, but also for beneficial insects and the environment (6).

Chlorpyrifos is an organophosphorus insecticide that inhibits acetylcholinesterase by affecting the nervous system of insects and encounters numerous commercial brands. It is one of the most used pesticides due to its high efficiency of pest control, although when it is applied improperly its residues can remain in the soil, generating an important route of human exposure and environmental contamination (7). The effect of paraffinic oil supplemented with Chlorpyrifos was significant in the control of Unaspis yanonensis Kuwana with mortality of 92 % (8).

An alternative for the control of CBT is the use of injections of phytotoxic products. This type of application reduces the risk of environmental contamination and the risk of contact in workers, in addition to reducing the loss of effectiveness of the product by washing it in case of rain after injection (9).

The injections allow the translocation to the xylem of the active principle that you want to introduce to the cup (10). They are a precise system of pesticide application since they avoid the release of the same to the environment, eliminate the drift effect and minimize the effects on the beneficiary population. They are currently used in plant protection and nutrition, offering numerous advantages in the optimization of pest management in fruit trees (11, 12).

Because the control of this pest is hindered by the characteristics of the insect, the objective of this work was to evaluate the injection efficiency with Imidacloprid in the control of Snow scale of citrus (*Unaspis citri*, Comstock) in plants of Orange tree Valencia.

MATERIALS AND METHODS

The evaluations were carried out during two consecutive productive campaigns (2008-2009 and 2009-2010) in plants of Valencia Late orange (*Citrus sinensis* L. Osbeck), of nine years, grafted on Rangpur lime (*Citrus limonia* L. Osbeck). Planted on a podsolic yellow red soil, with a density of 285 plants ha^{-1}, in Santa Rosa town (Lat 28 ° 16 'S and Long 58 ° 7' W), Corrientes province, Argentina.

The treatments consisted in the application of Imidacloprid trunk injections and sprays with Chlorpyrifos as detailed in Table 1.

The injections were placed in areas of healthy and active wood located on both sides of the trunk, approximately 40 cm above ground level. The average diameter of the trunk of the plants was of 20 cm. They were applied by means of a plastic injector (provided by Company Árboles Sanos SA) (13), for which a 5 cm deep hole was made in the trunk of the tree with the help of a drill (DeWalt brand). XRP Thammer 18v) (Figure 1,1) with 5,5 mm diameter metal drill bits (Figure 1).

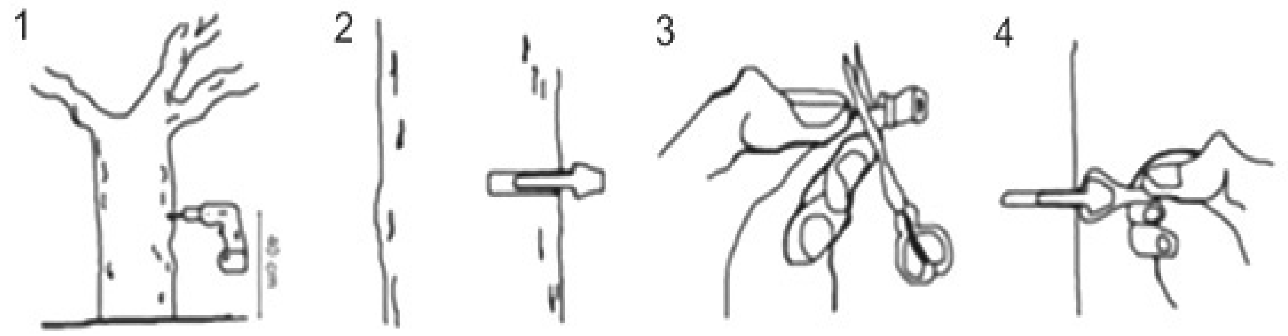
Sprays of Chlorpyrifos 48 % (Lorsban 48E® Dow AgroScience) were made with fumigation backpack (Stihl SR 420) at a rate of three liters of solution per plant, directed to the trunk and ensuring a uniform application in the affected area.

In each studied plant, the evaluations were carried out in six places of the trunk and main branches by means of magnifying glass with ten magnifications, determining the number of nymphs (N), adult males (M) and females (H) alive per cm^2.

Prior to the application of the products (T0), a count of the initial population was carried out per stage of the insect and subsequently others were performed at 45, 90, 135 and 180 days after the application (daa).

Table 1. Treatments for control of snow scale (*Unaspis citri* Comstock) in orange Valencia Late

Denomination	Treatments	Origin	Application	
			Moment 1	Moment 2
T0	Control (without application)		------	-----
T1	2 injections of 250 mL each of 0.49 g imidacloprid	Empresa Comercial Árboles Sanos S.A	100 % petal fall	-----
T2	4 injections of 250 mL each of 0.49 g imidacloprid		100 % petal fall (2 injections)	100 days after falling petals (2 injections)
T3	1 spray with Chlorpyrifos 48 % to 0.1 % plus 0.5 % emulsive oil		100 % petal fall	-----



1. Drill the trunk or branch with the help of a drill. 2. Position the injector until it fits perfectly in the hole. 3. Cut the undilated end of the injection to eliminate the metal closure. 4. Connect the injection to the head of the injector. Adapted from Healthy Trees S.A.

Figure 1. Procedure for placing injections

For each evaluation moment, the efficiency of the applications (E) was calculated, following the formula proposed by Henderson and Tilton (14), which contemplates the natural reduction of the insect population throughout the cycle and the situation prior to the applications (T0):

$$E\,(\%) = \left[1 - \frac{\text{n in control before treatment x n in treatment after treatment}}{\text{n in control after treatment x n in treatment before treatment}} \times 100\right]$$

During the trial, the average monthly rainfall occurred in both campaigns (Agrometeorological Station of the National Institute of Agricultural Technology (INTA) Bella Vista Agricultural Experimental Station) was recorded (Table 2).

Prior to making the comparisons of the measured variables, the assumptions of normality of the data (Shapiro-Wills test) and homogeneity of variance were tested. To comply with the assumption of variance homogeneity, the counting data (N, H and M) were transformed by applying the log10 function to the insect count data plus the constant 1. Subsequently, analysis of the variance (ANOVA) and comparison of the means using the Tukey test (α = 0.05), with the InfoStat software version 2015 (15).

Table 2. Precipitations (mm), during two campaigns 2008-2009 and 2009-2010

Month	Precipitations (mm)	
	Campaign 2008-2009	Campaign 2009-2010
October	241,0	82,5
November	24,0	375,5
December	57,0	191,5
January	82,9	354,5
February	128,0	348,0
March	16,0	109,0
April	49,8	92,4

RESULTS AND DISCUSSION

Campaign 2008-2009

Table 3 shows the number of insects observed from the beginning of the evaluations (September) and until the end of the same (March). The values represent averages of four repetitions.

Nymphs and adults (females and males) decreased an average of 88,23; 66,66 and 71,42 % respectively, in natural form (T0). After 45 days of applications, a marked effect of the treatments was found in the population of the pest with respect to the control, observing that the spraying with Chlorpyrifos (T3) showed greater efficiency in the control of the nymphs (Table 3).

After 90 days in all treatments with application of insecticides (T1, T2 and T3) the number of insects decreased with respect to the control without application (T0).

After 135 days of application and after 35 days of the second injection of Imidacloprid, a significant effect was observed in the decrease of females and males in treatments 2 and 3 to control. After 180 days in the plants treated with two injections of Imidacloprid (T2) and in the plants where Chlorpyrifos (T3) was applied, the populations of nymphs significantly decreased with respect to the control (T0). However, no differences were observed in insect control between the applications of Imidaclopid and Chlorpyrifos.

Observations made indicate that injections of Imidacloprid applied to the stipe in palm trees can control between 50 and 90 % of Red Palm Weevil larvae for a period of two to three months after treatment (16). This period coincides with that found in this work, showing that Imidacloprid applied as an injection to the trunk, continued to control after 90 days of placement.

Table 3. Snow scale of the trunk (*Unaspis citri* Comstock) in Valencia Late orange plants and control efficiency, according to the time of application and treatment in the 2008-2009 season

		Campaign 2008-2009					
		Number of Insects ± EE			Control efficiency (%) ± EE		
MO (dda)	T	N	H	M	N	H	M
45	T0	17,8A ±2,32	10,37A ±0,94	14,17A ±2,29	-------	-------	-------
45	T1	5,9 B ±1,56	4,22 B ±0,80	4,17 B ±1,65	56,73A ± 9,8	60,81 A ±8,08	74,99 A ±11,26
45	T2	6,4 B ±2,47	4,77 B ±0,79	5,7 B ±1,67	60,71 A ±9,96	63,99 A ±6,27	66,54 A ±8,29
45	T3	0,67 C ±0,11	2,3 B ±0,40	2,52 B ±0,56	96,73 B ±0,36	82,02 A ±5,36	86,85 A ±1,8
90	T0	10,33 A ±4,13	11,25 A ±4,04	12,08 A ±5,06	-------	-------	-------
90	T1	4,2 B ±0,34	3,00 B ±0,98	3,25 B ±0,68	80,54 A ±16,06	86,43 A ±7,42	85,45 A ±5,07
90	T2	2,11 B ±0,76	1,86 B ±0,46	2,34 B ±0,47	77,89 A ±6,95	86,46 A ±1,61	77,84 A ±7,22
90	T3	0,39 B ±0,09	0,45 B ±0,08	0,43 B ±0,09	95,10 A ±1,98	96,34 A ±0,82	96,06 A ±1,43
135	T0	7,45 A ±3,73	7,90 A ±4,71	9,40 A ±6,20	-------	-------	-------
135	T1	3 ,00 A ±2,37	3,78 AB ±2,78	4,34 AB ±3,45	73,60 A ±11,59	66,11 A ±7,00	73,09 A ±2,79
135	T2	0,98 A ±0,68	1,46 B ±0,68	1,14 B ±0,52	91,23 A ±4,11	81,61 AB ±4,82	84,02 AB ±6,37
135	T3	0,21 A ±0,07	0,29 B ±0,03	0,24 B ±0,07	96,69 A ±1,92	96,60 B ±0,61	96,32 B ±1,91
180	T0	1,60 A ±0,08	3,92 A ±2,5	3,34 A ±2,79	-------	-------	-------
180	T1	0,25 AB ±0,65	0,66 A ±0,51	0,78 A ±0,64	95,20 A ±4,80	86,92 A ±5,22	91,42 A ±14,56
180	T2	0,65 B ±0,12	0,34 A ±0,10	0,07 A ±0,05	83,69 A ±8,47	77,25 A ±13,22	81,06 A ±11,20
180	T3	0,05 B ±0,05	0,12 A ±0,09	0,05 A ±0,03	97,86 A ±2,14	98,72 A ±0,75	91,42 A ±12,55

Nymphs (N), females (H) and males (M): MO: moment of application of the Treatments (T).
Means ± standard error (EE).Different letters in columns per daa, indicate significant differences. Tukey test (p≤0.05)

Regarding the efficiency of control, significant differences were found in the control of nymphs after 45 days, between the efficiency of the treatment with Chlorpyrifos (T3) and the treatments with Imidacloprid (T1 and T2). At 90 days, all treatments behaved similarly, while at 135 days of Imidacloprid applications a greater control of males and females of T3 compared to T1 was observed, without significant difference of these with respect to T2. After 180 days no significant differences were found between the treatments.

Campaign 2009-2010

The number of insects per cm^2 is shown in Table 4. A smaller amount is observed compared to the 2008-2009 campaign. The low rainfall registered in the month of October (Table 2), which was 66 % lower than in the same month of the first season and low vegetative activity, could have been the cause of the low initial population of insects.

However, after the second month of evaluation, rainfall was high, which would explain the natural decrease of the percentage of individuals.

In both campaigns, the period of abundant rainfall coincided with the natural decrease in the percentage of females, compared with the percentage of males and nymphs present in the trees. From the beginning of the trial in this campaign until the end of the trial, the natural decrease of nymphs, females and males was 93,75; 76,47 and 96 % respectively.

The effect of the treatments on the population of insects was similar and all superior to the control at 45 days after applying them. This response was similar for the control of females and males at all the observed moments, although at 135 daa T1 did not show differences with the control. However, in the case of nymphs, at 90 daa only the treatment with Chlorpyrifos differed from the control; however, after 135 days, no differences were observed between treatments for this stage.

Regarding the efficiency of control, for the second campaign there were significant differences at 45 dda between the treatments applied and for all the stages studied (Table 4); showing a 100 % efficiency treatment of 1 spray with Chlorpyrifos (T3) in all cases.

Table 4. Count of snow scale of the trunk (*Unaspis citri* Comstock) in Valencia Late orange plants and control efficiency, according to the moments of application and treatment in the 2009-2010 campaign

		Campaign 2009-2010					
		Number of Insects			Control efficiency		
MO (dda)	T	N	H	M	N	H	M
45	T0	2,7 A ±1,05	4,27 A ±0,90	6,47 A ±1,94	-------	-------	-------
45	T1	0,77 B ±0,30	0,83 B ±0,39	0,43 B ±0,30	75,28 A ±9,19	81,65 A ±3,11	95,00 A ±3,85
45	T2	0,73 B ±0,09	0,60 B ±0,15	0,50 B ±0,21	76,68 A ±16,86	88,69 A ±5,58	95,52 A ±1,43
45	T3	0,00 B ±0,00	0,00 B ±0,00	0,00 B ±0,00	100,00 B ±0,41	100,00 B ±1,90	100,00 A ±2,57
90	T0	2,16 A ±0,84	3,99 A ±0,52	5,45 A ±1,68	-------	-------	-------
90	T1	0,45AB±0,23	0,60 B ±0,37	0,41 B ±0,26	80,82 A ±4,31	83,67 A ±3,83	92,06 A ±2,55
90	T2	0,30 AB ±0,10	0,20 B ±0,03	0,10 B ±0,10	87,21 A ±9,74	96,09 A ±3,31	98,64 A ±4,67
90	T3	0,00 B ±0,00	0,00 B ±0,00	0,00 B ±0,00	100,00 A ±0,00	100,00 A ±0,00	100,00 A ±0,00
135	T0	1,67 A ±0,67	3,67 A ±1,00	4,67 A ±1,22	-------	-------	-------
135	T1	0,20 A ±0,06	0,20 AB ±0,12	0,40 AB ±0,31	83,18 A ±8,70	89,41 A ±7,07	94,72 A ±2,80
135	T2	0,07 A ±0,03	0,00 B ±0,00	0,03 B ±0,03	97,78 A ±3,19	100,00 A ±0,00	98,92 A ±1,08
135	T3	0,00 A ±0,00	0,00 B ±0,00	0,00 B ±0,00	100,00 A ±0,00	100,00 A ±0,00	100,00 A ±0,00
180	T0	0,50 A ±0,29	1,73 A ±0,37	1,67 A ±0,67	-------	-------	-------
180	T1	0,07 A ±0,03	0,03 B ±0,03	0,23 B ±0,15	92,22 A ±2,78	97,67 A±2,33	89,51 A ±3,70
180	T2	0,00 A ±0,00	0,00 B ±0,00	0,00 B ±0,00	100,00 A ±0,00	100,00 A ±0,00	100,00 A ±0,00
180	T3	0,00 A ±0,00	0,00 B ±0,00	0,00 B ±0,00	100,00 A ±0,00	100,00 A ±0,00	100,00 A ±0,00

Nymphs (N), females (H) and males (M): MO: moment of application of the Treatments (T).
Means ± standard error (EE).Different letters in columns per daa, indicate significant differences. Tukey test ($p \leq 0.05$)

The results obtained in both campaigns denote the importance of the number of individuals at the beginning of the controls, since with high populations of insects (campaign 2008-2009), the effectiveness of Chlorpyrifos exceeds that of injections of Imidacloprid.

However, it was observed that the control efficiency of CBT in both campaigns after 90 days is the same with the application of the active principles used in this work (Tables 3 and 4). Therefore, the use of Imidacloprid injections would be a more environmentally friendly alternative, coinciding with other investigations (17) who conclude that the supply of injections in the trunk is safe for farmers, agricultural workers and consumers, at the same time it reduces the drift of pesticides, the exposure of workers and the risks to the environment.

In the second campaign, the more limited control of Imidacloprid could be due to the fact that, although this product is detected in trunk and roots, the greater accumulation of it is observed in leaves and they remain until a year after the injection (18). Taking into account these criteria and the results obtained during the second campaign, the application of a second dose of Imidacloprid injections for the control of snow scale of citrus would not be justified.

Similar results were obtained by other authors (19) in ash trees (Fraxinus pennsylvanica Marsh.), who used a combination of a trunk injection of Imidacloprid and a basal ditch of Imidacloprid reaching 100% control of emerald borer larvae of ash tree.

CONCLUSIONS

- Applications Imidacloprid injections and sprays the trunk Chlorpyrifos, both 45 and 90 days after placement, able to reduce the population of snow scale of citrus (*Unaspis citri* Comstock) present in orange Valencia Late plants.
- No significant differences were found between the injections of Imidacloprid and the sprays with Chlorpyrifos, reason why the use of first in reason the benefits for the environment is justified.
- Only one application of Imidacloprid injections per campaign is enough to control the snow scale of citrus trunk under the conditions studied.

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