Efectividad biológica de insecticidas para el manejo de la resistencia del picudo del chile

Biological effectiveness of insecticides for resistance management of pepper weevil

Eficácia biológica de inseticidas para o manejo da resistência de gorgulho pimenta

Fabián Avendaño Meza
Universidad Autónoma de Sinaloa, México
fabian@uas.edu.mx

Resumen

Se realizó un estudio de efectividad biológica de los insecticidas clorpirifos etil, malation, oxamil, thiametoxam y zcipermetrina para el control del picudo del chile en campos de La Cruz de Elota, El Rosario y Culiacán, Sinaloa. Los experimentos se establecieron en un diseño de bloques al azar con arreglo en parcelas divididas, con la variante 'Insecticida' en las parcelas chicas y 'Dosis' en el factor de parcelas grandes. Los resultados indican que la población de picudos de La Cruz de Elota presentó los niveles más bajos de control al registrar porcentajes inferiores al 50 %; mientras que la población de El Rosario resultó ser más susceptible a los insecticidas evaluados, con porcentajes de efectividad superiores al 74 %. Todos los tratamientos insecticidas fueron diferentes estadísticamente al testigo.

Palabras clave: efectividad biológica, *Capsicum annuum*, *Anthonomus eugenii*, resistencia, insecticidas.

Abstract

Is a study of biological effectiveness of the insecticides chlorpyrifos ethyl, malathion, oxamil, thiamentoxam and zcipermetrina for the control of pepper weevil in the fields of La Cruz de Elota, El Rosario and Culiacan, Sinaloa. Experiments were established in a randomized blocks design with arrangement of split plots, with the variant 'Insecticide' in the plots and 'Dose' in the factor of large plots. The results indicate that the population of weevils of La Cruz de Elota presented lower control levels, recording percentages below 50%, while the population of El Rosario turned out to be more susceptible to insecticides evaluated, with percentages of effectiveness over 74%. All insecticides treatments were statistically different from the control.

Key Words: biological effectiveness, Capsicum annuum, pepper weevil, Anthonomus eugenii, resistance, insecticides.

Resumo

Um estudo de eficácia biológica do inseticida clorpirifós etil, malathion, oxamil, thiamentoxam e zcipermetrina pelo controle do bicudo pimenta em campos de Elota La Cruz, El Rosario e Culiacan, Sinaloa foi realizada. Os experimentos foram estabelecidos em um delineamento em blocos casualizados dispostos em parcelas subdivididas, com a variante 'inseticida' em meninas e fator de 'doses' em lotes grandes parcelas. Os resultados indicam que a população gorgulho de La Cruz de Elota apresentaram os menores níveis de controle ao registar percentagens inferiores a 50%; enquanto a população de El Rosario acabou por ser mais suscetíveis aos inseticidas avaliados, com percentuais acima de eficácia de 74%. Todos os tratamentos inseticidas foram estatisticamente diferentes para a testemunha.

Palavras-chave: eficácia biológica, Capsicum annuum, Anthonomus eugenii, resistência, inseticidas.

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Introduction

Mexico is the biggest exporter of chile (*Capsicum annumm* L.) for fresh worldwide consumption, with a planted area of 148 968 ha, a production of 2 732 635 t and a national average of 19 t ha^{-1} in the agricultural cycle 2014. The major producing States are Zacatecas, Chihuahua, San Luis Potosí and Sinaloa, with more than half of the area sown in the country, stands out the latter by the achieved production of 604 773 t and a performance of 50.44 t ha^{-1} (SIAP, 2016).

Among the main constraints of the culture of chile are the insect pests of these weevil *Anthonomus eugenii* Cano is considered the most important pest and a problem key during the stages of flowering and fruiting in all production areas (Jiménez, 2004; Toapanta et al., 2005; Rodríguez-Leyva et al., 2007). It is estimated that in Mexico lost 70 to 80 million dollars annually just by the weevil attack (Rodríguez-Leyva et al., 2012).

The practices that are used to control the weevil chili consist of a combination of cultural and chemical control, which maintains populations of the plague at low levels, but as a result of the intensive use of insecticides, every day is reduced the number of those able to exercise satisfactory control, mainly due to the development of resistance (Riley and King, 1994; Servín et al., 2007). The management of this pest has previously had focused on the use of tolerant varieties (Quiñonez and Lujan, 2002), collection of fallen fruit (Capinera, 2002), mass adult trapping and use of fungi entomopathogenic (Coudriet and Kishaba, 1988). However, in practice the pepper weevil management rests with chemical insecticide applications and even exist in the market combinations of groups neonicotinoids with pyrethroid Insecticides, which have been widely accepted by the producers (Ruíz et al., 2009) but they represent a potential risk since they generate an extra selection on the pest pressure.

A fundamental part in chemical combat pests is the Insecticide Resistant Management strategies (IRM) (FAO, 2012), which was encouraged by the growing documentation of cases of arthropods resistant to pesticides (Georghiou and Lagunes, 1991) and the start of an interactive database on the subject (Whalon et al., 2008). The IRM consists of strategies that are intended to keep the susceptibility of arthropods plague available pesticides and the effectiveness of these inputs, to prevent or delay the development of resistant races to prevent the increase of the dose of field required and, therefore, not increase the costs of combat or risks to health or the environment (Lagunes-Tejeda et al., 2009).

Proper management of Chilean weevil depends on careful monitoring of adult populations and their control by insecticides, applied in the morning or at sunset when the insect is exposed on the surface of the plant (Corrales, 2002). At the moment of selecting the insecticide, products of proven effectiveness should be used, since there are reports that in the state of Sinaloa, the Chilean weevil showed tolerance to several of them (Gastélum-Luque et al., 2004; Avendaño-Meza et al. Al., 2010, 2014, 2016). In addition, chemical control should be based on studies of biological effectiveness of insecticides in the field, which will allow to use those with better control of the pest and avoid the use of non-effective products and, therefore, the development of resistant populations And unnecessary applications that increase the risks of pesticide contamination and intoxication and make production more expensive (Lagunes-Tejeda et al., 2009). Taking into account the previous problem, the present work was carried out with the objective of conducting studies of biological effectiveness of the insecticides chlorpyrifos ethyl and malathion (phosphorates), oxamyl (carbamate), thiametoxam (neonicotinoid) and zypermethrin (pyrethroid), commonly used against weevil Of chile in three populations in the state of Sinaloa to fill a void of information about this topic and serve as a tool in decision making for an adequate management of resistance to insecticides in populations A. eugenii.

Materials and methods

Three experiments were carried out on commercial plantations of chile from the state of Sinaloa: one in Field 5 in La Cruz de Elota, Sinaloa (23 ° 59'44"N, 106 ° 53'48"O), in a chile crop Bell to harvest in green and / or red set to open field on September 15, 2014; Another experiment in the village of Potrerillo in El Rosario (23 ° 0'47"N, 105 ° 57'12"O), in serrano chile in the open field on October 3, 2014 and a third in Agrícola Sabino in Culiacán (24 ° 37'31"N, 107 ° 27'35 "), in Bell pepper established under shade mesh on September 19, 2014. The low and high doses recommended on the label of chlorpyrifos ethyl insecticides (Lorsban 75 WG, Dow Agrosciences), malathion (Malathion 1000, Indiapac), oxamyl (Vydate L, DuPont), thiametoxam (Actara, Syngenta) and zypermethrin (Mustang Max, FMC). The treatments considered were: chlorpyrifos ethyl 0.8 kg ha-1, chlorpyrifos ethyl 1.2 kg ha-1, malation 1.0 L ha-1, malation 2.0 L ha-1, oxamyl 1.5 L ha-1, oxamyl 3.0 L ha-1, thiametoxam 0.2 kg ha-1, thiametoxam 0.4 kg ha-1, zcipermetrine 0.3 L ha-1 and zcipermetrin 0.6 L ha-1, in a randomized block design divided into split plots, distributed in two large plots with dose variants Low and high, compared to a control where no insecticide was applied, for a sum of six variation factors and a total of 12 treatments, which were replicated four times. Four applications of each insecticide were carried out on 3, 10, 17 and 24 March 2015 in La Cruz de Elota; On March 4, 11, 18 and 25, 2015 in El Rosario and on May 1, 6, 12 and 16, 2015 in Culiacán. The applications were performed with a motorized backpack pump calibrated to spray 300 liters of water per hectare. The evaluation parameter was the average number of adults counted in 30 terminals per experimental unit (flower buds, flowers and terminal buds were visually checked), samples were taken the next day of application between 7:00 and 10:00 am when Most weevils are feeding (Corrales, 2002). The percentage effectiveness was calculated with the average adult weevil in each treatment for each insecticide, using the Abbott formula (Abbott, 1925). Statistical analysis was performed using the SAS® program for Windows® Ver. 9.3 (SAS Institute Inc, 2011), the comparison of means was done with the Tukey test with 5% significance.

Results

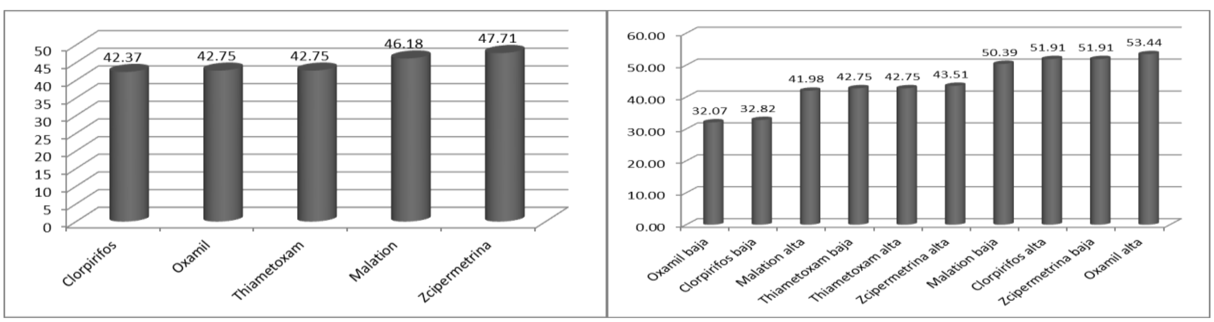
The analysis of the results obtained in La Cruz de Elota, Sinaloa indicates that there is a significant difference in the interaction between insecticides and doses; As well as among insecticide factor treatments, no difference was found between the adult averages recorded in the factor 'Dose'. The comparison of means performed with the interaction of insecticides with high and low doses shows differences between these and the control (Table 1). In all treatments values between 4.28 and 4.72 adults were recorded on average and are not statistically different from each other, but they do differ from the control. The percentage of insecticide participation was relatively low in this region, as they only provided between 42.37 and 47.71% of pest control, considering low and high dose averages and only four treatments (low dose malaria, ethyl chlorpyrifos At high dose, zcipermetrin at low dose and oxamil at high dose) were able to exceed 50% of control (figure 1).

Cuadro 1. Promedio de adultos de picudo del chile *Anthonomus eugenii* Cano en cuatro muestreos realizados en La Cruz de Elota, Sinaloa, 2015.

Interacción Dosis x Insecticida				Insecticida			Dosis		
Tratamiento	Dosis	N	Media*	Tratamiento	N	Media*	Tratamiento	N	Media
Testigo	Alta	4	8.19 a	Testigo	8	8.19 a	Baja	24	5.32
Testigo	Baja	4	8.19 a	Clorpirifos	8	4.72 b	Alta	24	5.00
Oxamil	Baja	4	5.56 b	Oxamil	8	4.69 b			
Clorpirifos	Baja	4	5.50 b	Thiametoxam	8	4.69 b			
Malation	Alta	4	4.75 b	Malation	8	4.41 b			
Thiametoxam	Baja	4	4.69 b	Zcipermetrina	8	4.28 b			
Thiametoxam	Alta	4	4.69 b						
Zcipermetrina	Alta	4	4.62 b						
Malation	Baja	4	4.06 b						
Clorpirifos	Alta	4	3.94 b						
Zcipermetrina	Baja	4	3.94 b						
Oxamil	Alta	4	3.81 b						

*Medias con la misma letra son estadísticamente iguales, según Tukey α=0.05
Baja = Dosis bajas de insecticida en la parcela grande
Alta = Dosis altas de insecticida en la parcela grande
N = Número de observaciones
Fuente: elaboración propia.

Figure 1. Effectiveness percentages of five insecticides in the Chilean weevil population *A. eugenii* de La Cruz de Elota, Sinaloa. 2015.



Fuente: elaboración propia.

The analysis of variance of the data from the experiment conducted in El Rosario, Sinaloa indicates that there are significant differences between the treatments in the interaction with insecticides and in the factor 'Insecticide'; There is no difference between the components of the factor large plots (low and high doses). The comparison of means performed with the interaction of high and low doses and insecticides located in the small plot shows differences between treatments and places it as the most effective to high dose chlorpyrifos ethyl, since in the four samples was not recorded A single insect (Table 2). The comparison test of Tukey's averages (α =

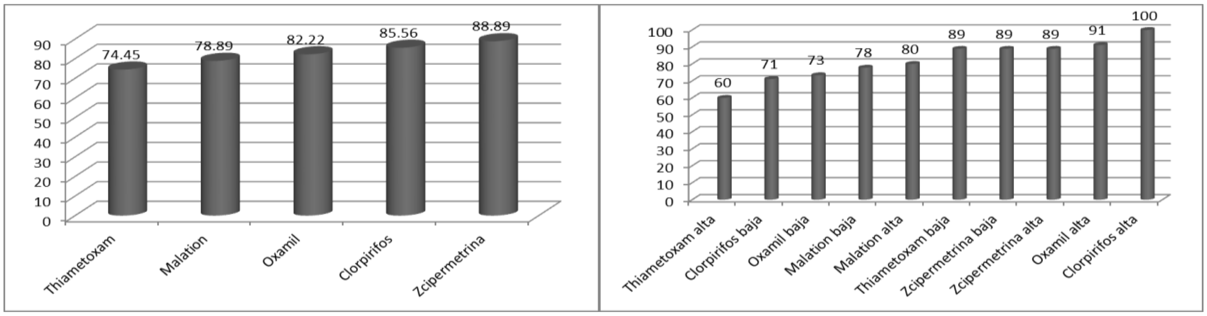
0.05) performed on insecticides with the average of both doses separated the treatments into two groups; All treatments recorded values between 0.31 and 0.72 adults on average and are not statistically different from each other; However, differed from the control recorded by an average of 2.81 adults of Chilean weevil. In this region, unlike the previous one, an effectiveness of more than 74% in pest control was observed for all insecticides (figure 2). This is due to the fact that the pest in this region has been little subject to the pressure of selection by insecticides, which is reflected in a superior effectiveness of the same and constitutes, for the moment, as a reservoir of individuals susceptible to the management Of resistance to this pest.

Cuadro 2. Promedio de adultos de picudo del chile *Anthonomus eugenii* Cano en cuatro muestreos realizados en El Rosario, Sinaloa, 2015.

Interacción Dosis x Insecticida				Insecticida			Dosis		
Tratamiento	Dosis	N	Media*	Tratamiento	N	Media*	Tratamiento	N	Media
Testigo	Baja	4	2.81 a	Testigo	8	2.81 a	Baja	24	0.94
Testigo	Alta	4	2.81 a	Thiametoxam	8	0.72 b	Alta	24	0.84
Thiametoxam	Alta	4	1.12 b	Malation	8	0.59 b			
Clorpirifos	Baja	4	0.81 bc	Oxamil	8	0.50 b			
Oxamil	Baja	4	0.75 bc	Clorpirifos	8	0.41 b			
Malation	Baja	4	0.62 bcd	Zcipermetrina	8	0.31 b			
Malation	Alta	4	0.56 bcd						
Thiametoxam	Baja	4	0.31 cd						
Zcipermetrina	Alta	4	0.31 cd						
Zcipermetrina	Baja	4	0.31 cd						
Oxamil	Alta	4	0.25 cd						
Clorpirifos	Alta	4	0.00 d						

*Medias con la misma letra son estadísticamente iguales, según Tukey α=0.05
Baja = Dosis bajas de insecticida en la parcela grande
Alta = Dosis altas de insecticida en la parcela grande
N = Número de observaciones
Fuente: elaboración propia.

Figure 2. Percentages of effectiveness of five insecticides in the weevil population of chile *A. eugenii* de El Rosario, Sinaloa. 2015.



Fuente: elaboración propia.

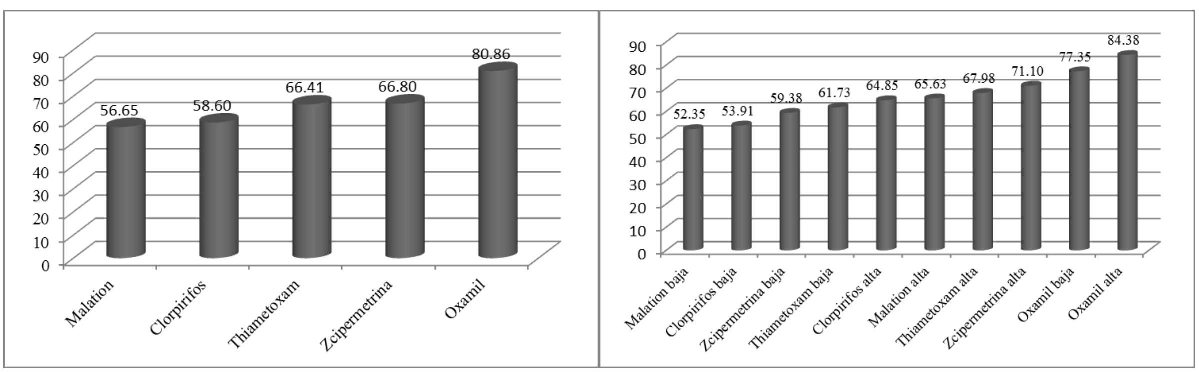
In the experiment carried out in Culiacán, in a shade mesh culture, an intermediate response between the populations of La Cruz and El Rosario was presented. The analysis of variance performed with the data of the dose x insecticide interaction showed a significant difference between the treatments. There were also differences between the events of the factor 'Insecticide', there was no statistical difference with the factor 'Dosis'. The highest number of insects was recorded in the control and was significantly different ($p \leq 0.05$) from the insecticide treatments, from these a greater efficacy was observed in oxamil treatment with the lowest insect average (Table 3) and Better control percentage (figure 3), this treatment was statistically similar to thiametoxam and zcipermethrin and different from malathion and ethyl chlorpyrifos. The test of means of the dose-insecticidal interaction separates the control from the other treatments, which had the same level of statistical significance. The control percentages fluctuated between 56 and 80% for the insecticidal factor and between 52 and 84%.

Cuadro 3. Promedio de adultos de picudo del chile *Anthonomus eugenii* Cano en cuatro muestreos en cultivo en malla sombra realizados en Culiacán, Sinaloa, 2015.

Interacción Dosis x Insecticida				Insecticida			Dosis		
Tratamiento	Dosis	N	Media*	Tratamiento	N	Media*	Tratamiento	N	Media
Testigo	Alta	4	8.00 a	Testigo	8	8.00 a	Baja	24	3.85
Testigo	Baja	4	8.00 a	Malation	8	3.47 b	Alta	24	3.36
Malation	Baja	4	3.81 b	Clorpirifos	8	3.31 b			
Clorpirifos	Baja	4	3.69 b	Thiametoxam	8	2.69 bc			
Zcipermetrina	Baja	4	3.25 b	Zcipermetrina	8	2.66 bc			
Thiametoxam	Baja	4	3.06 b	Oxamil	8	1.53 c			
Clorpirifos	Alta	4	2.81 b						
Malation	Alta	4	2.75 b						
Thiametoxam	Alta	4	2.56 b						
Zcipermetrina	Alta	4	2.31 b						
Oxamil	Baja	4	1.81 b						
Oxamil	Alta	4	1.25 b						

*Medias con la misma letra son estadísticamente iguales, según Tukey α=0.05
Baja = Dosis bajas de insecticida en la parcela grande
Alta = Dosis altas de insecticida en la parcela grande
N = Número de observaciones
Fuente: elaboración propia.

Figure 3. Percentages of effectiveness of five insecticides in the weevil population of chile *A. eugenii* de Culiacán, Sinaloa. 2015.



Fuente: elaboración propia.

Discussion

In the population of La Cruz de Elota the lowest percentages of control were presented, since the effectiveness of the insecticides barely exceeded 50% with malation at low dose, and chlorpyrifos, zcipermetrina and oxamil at high dose. The above is related to an increase in the tolerance of the A. eugenii population to the insecticides used for its combat, mainly those included in the present study (Avendaño-Meza et al., 2010, 2016). In this area no significant difference was observed between low and high doses for all insecticides, which makes it unnecessary to increase doses when the insect population increases. In addition, by limiting the use of these insecticides, priority is given to the use of pest management techniques that are alternatives to the use of agrochemicals, such as legal and cultural control. It is important to respect and, if possible, increase the time of the phytosanitary window free of the crop, as well as a rigorous program of monitoring and manual collection of adults to reduce the selection pressure on the pest and to favor an adequate management of the resistance, As suggested by Lagunes-Tejeda et al. (2009). Corrales (2002) carried out a work in La Cruz de Elota, Sinaloa, to compare conventional chemical control and a biorrational strategy against weevil of Chile; Points out that the greatest efficiency was obtained with the application of chemical insecticides, but not before exerting an enormous selection pressure on the pest, since 27 applications were made to keep this insect below the economic threshold.

The lowest mean number of weevil adults was observed in the population of El Rosario, Sinaloa, the control percentages ranged from 74 to 89% for the insecticides evaluated, regardless of the applied dose. The above allows to recognize that with the low doses will be achieved a satisfactory control of the pest and an increase of these does not necessarily result in an improvement of the efficiency of the product, allowing with this a rational management of the used inputs and the conservation of the Susceptibility of weevil to insecticides. The goal of resistance management is to prevent or delay the buildup of resistant individuals in pest populations, so as to preserve the effectiveness of available pesticides. Resistance management can also be called susceptibility management as a means of maintaining a high percentage of susceptible genes within the pest population and thus keeping resistance genes to a minimum, as suggested by FAO researchers (2012).

In the insect population of Culiacán, there was an intermediate response between the three populations. The malathion and chlorpyrifos treatments (low doses) had a response similar to that obtained in La Cruz de Elota, with effectiveness of 52.35 and 53.91%, respectively. While in oxamyl treatment, percentages of effectiveness higher than 77% were obtained, results consistent with those obtained by Seal and Schster (1995) and related to laboratory bioassays of studies of susceptibility to insecticides carried out by Avendaño-Meza et al (2010, 2014). The population of billfishes in this area is responding to the selection pressure of the insecticides zcipermethrin and thiamethoxam, as only satisfactory controls were achieved using high doses of insecticides. These failures in the control are related to the increase in the tolerance levels to them, since the aforementioned products are applied intensively and in the critical moments of attack of this pest, reason why the selection pressure continues increasing and difficult The return to susceptibility in a short to medium term. Gutiérrez-Olivares et al. (2007) have documented the instability of resistance of neonicotinoid insecticides; In laboratory conditions decreased from 6.9 to 2.8x for thiametoxam in four generations free of selection pressure, for that reason the importance of applying this type of insecticides only in the critical periods of the development of the crop. García-Nevarez (2012) evaluated the efficacy of biorrational and conventional insecticides on Chilean boll weevil in Chihuahua and found that thiametoxam, chlorpyrifos ethyl and lamda-cyhalothrin showed an impact on reducing the population of this pest up to five days After application, the biorrational treatment behaved just like the control. On the other hand, Ruiz et al. (2009) conclude that azadirachtin is a good alternative in the control of A. eugenii and could substitute for the use of oxamyl and neonicotioides when populations of the pest are not high, thus minimizing the selection pressure for resistance to these Pesticides. In a study by Addesso et al. (2014) to investigate the effect of low risk products (kaolin clay, diatomaceous earth, neem and Chenopodium ambrosioides extract) against chilli beetles, compared to thiametoxam and oxamil insecticides applied in rotation and an untreated control, Found that the only treatment where yield increased was in the rotation of conventional insecticides. On the other hand, organic yields were not significantly increased, but their use reduced total damage, indicating their potential utility in combination with conventional pesticides or low environmental impact under an integrated pest management strategy.

Conclusions

The Chilean weevil population of La Cruz de Elota was tolerant to the chlorpyrifos insecticides ethyl, malathion, oxamyl, thiametoxam and zcipermethrin, with low levels of control.

The insect population of Culiacán is responding to the selection pressure exerted by insecticide applications, mainly organophosphates malathion and chlorpyrifos ethyl, and neonicotinoid thiametoxam, since low doses and low doses were observed. Good efficacy was obtained with zciperemethrin only at high dose, while with oxamyl good efficacy was observed even at the low dose.

In the population of weevil of El Rosario, all insecticides evaluated had good percentages of control, reason why it is considered a susceptible population and a reservoir of genes of susceptibility for this pest.

In the three areas under study there was no significant difference between the high and low doses of insecticides, so if it is necessary to apply one of these inputs it is advisable to apply them at low dose to reduce costs and delay the development of resistance, and to maintain Thereby making the products more efficient for a longer period of time.

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