Chapter

The Spotted Wing Drosophila in the South of the World: Chilean Case and Its First Productive Impacts

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Abstract

The spotted wing drosophila *Drosophila suzukii* Matsumura (Diptera: Drosophilidae) is endemic in Asia. This species was first reported in Chile in early 2017 in the region of La Araucanía, Los Ríos, and Los Lagos, but it has dispersed to other regions of the south-central area of the country, currently being in the category of plague present with restricted distribution. *D. suzukii* is a polyphagous pest, and it infests a wide range of fruit crops, including grapes, cherries, as well as an increasing number of wild fruits. Chile is the main cherry-producing country in the south of the world, providing mainly to the Asian market, so, although the pest is not a quarantine problem for this destination of the fruit, its potential damage is high due to the decrease in yield, fruit deterioration, and increased pre- and postharvest rot. The local productive reality also provides various hosts to the plague, allowing its expression and adaptation, for example, in blueberry orchards. This report summarizes the first signs of economic damage and explores the first results of control delivered by various insecticides: alpha-cypermethrin, acetamiprid, chlorantraniliprole, cyantraniliprole, emamectin benzoate, lambda- and gamma-cyhalothrin, spinetoram, and spinosad. Also, repellent effect of other compounds was studied.

Keywords: fruit fly, insecticides, Drosophilidae, invasive pest, economic losses

1. Introduction

Drosophila suzukii Matsumura (Diptera: Drosophilidae) is classified by the European and Mediterranean Plant Protection Organization (EPPO) as an emerging and invasive pest [1]. This insect is native to east and southeast Asia, although its real geographical origin is still discussed [2]. It has been introduced in several Hawaiian Islands [2], North America [3], Europe [4], and recently in Iran [5], Argentina [6], and later Chile [7], reflecting its high adaptive capacity. Its relevance is due to high economic importance because of the severity of the damage it causes in various productive crops [8–15]. It is a very polyphagous pest, with more than 50 hosts reported in literature [16].

In contrast with *Drosophila melanogaster*, the spotted wing fruit fly develops in mature and undamaged fruits, injecting its eggs into fruits when they preferably begin to turn color [17]. The larvae develop inside the fruits, finally pupating on or inside them [15, 17]. If there is not enough healthy fruit, it can also attack fallen or damaged fruit [18].

Since only 2 years ago its presence was reported in Chile, until now there was no corroboration of its productive impact in the country. At the same time, for the design of the management proposals, there was only external literature; however, the objective of this work was to monitor the economic damage caused by the plague in cherry and blueberry orchards and also evaluate the control achieved with insecticides of different chemical groups: alpha-cypermethrin, acetamiprid, chlorantraniliprole, cyantraniliprole, emamectin benzoate, lambda- and gamma-cyhalothrin, spinetoram, and spinosad.

The possible repellent effect of garlic and chili-based products, as well as an extract of *Chenopodium ambrosioides*, was also investigated.

2. Methodology

2.1 Fruit damage monitoring

Five commercial orchards were selected from localities Cachapoal and Culenar, Ñuble Region, in areas with positive *D. suzukii* detections since 2017. From the newly formed fruit state, in September 2019, cherry orchards and blueberry orchards were monitored three times per week until January 2020. Production areas of more than 10 hectares were addressed and with at least 10 years of operation. The orchards correspond to conventional production, with drip technified irrigation and with similar agricultural management conditions with each other.

Three varieties of cherries (Lapins, Santina, and Regina) and two of blueberries (Brigitta and Elliot), as also material from live fences of *Aristotelia chilensis*, *Rubus ulmifolius*, and *Prunus cerasifera*, were included in this monitoring. From each substrate and on each occasion, 100 random fruits were collected, and some insect individuals were selected for analysis with traditional taxonomy and/or PCR analysis for the larva and pupa states extracted from the samples. The monitoring record was carried in parallel to the climate record of temperature and relative humidity.

At harvest, losses associated with the pest were estimated in orchard and prepackaged fruit inspection.

2.2 Efficacy test

Once the start of the attack of *D. suzukii* on fruits was determined, the cherry orchard with the highest severity of attack was selected to perform efficacy studies. In this step, a cherry orchard of cv. Regina (1200 plants/ hectare) was used. Insecticides from five chemical groups were compared [19]: group 3A (pyrethroids: alpha-cypermethrin and lambda- and gamma-cyhalothrin), group 4A (neonicotinoids: acetamiprid), group 5 (spinosyns: spinetoram and spinosad), group 6 (avermectins: emamectin benzoate), and group 28 (diamides: chlorantraniliprole and cyantraniliprole).

The treatments evaluated were Mageos® (15% w/w alpha-cypermethrin dispersible granulated formulation; 15 g of commercial product/100 L) (Basf Chile S.A); Bull® (6.12% w/v gamma-cyhalothrin encapsulated suspension; 10 mL of commercial product/100 L) (FMC Chemical Chile Ltd); Karate® Zeon (5% w/v lambda-cyhalothrin encapsulated suspension; 20 mL of commercial product/100 L) (Syngenta S.A); Mospilan® (20% w/w acetamiprid soluble powder; 50 g/100 L) (Basf Chile S.A); Success® 48 (45% w/v spinosad concentrated suspension;

14 g/100 L); Delegate® (25% w/w spinetoram concentrated suspension; 16 g/100 L); Proclaim® Forte (5% w/w emamectin benzoate dispersible granulate: 30 g/100 L) (Syngenta S.A); Coragen® (20% w/v chlorantraniliprole concentrated suspension; 20 mL/100 L) (FMC Chemical Chile Ltd); and Exirel® (10% w/v cyantraniliprole suspoemulsion; 75 mL/100 L) (FMC Chemical Chile Ltd). A control without insecticide was included.

A completely randomized design was used, with four repetitions of each treatment. The experimental unit corresponded to groups of 10 plants of the same row treated with 4 isolation plants between them.

All applications were performed once, on November 15 (when fruit begins to take color), with a conventional hydraulic sprayer (Line Patasa 2000) with 1800 L of water per hectare. A control treatment without insecticide applications was considered.

Two parameters of relevance were evaluated: the incidence of damage (established as mean of fruits damaged by the pest) and the severity of the damage (wound or presence of live larvae) on samples of 100 fruits collected randomly within each experimental unit. Fruits were reviewed at 3, 5, 7, 10, 12, and 14 days after application (DAA). The cutoff criterion to stop evaluations was unified when the incidence of damage was equal to or greater than 20%.

The data obtained from field and laboratory measurements was subjected to analysis of variance (ANOVA) by taking appropriate transformations. Mean comparisons in significant ANOVAs were performed with a Tukey's test. Statistical analyses were conducted using the software Minitab®16.1.0 (Minitab Inc.).

2.3 Repellency test

In a cherry orchard of var. Regina located in the town of Culenar, the possible effect of repellency (expressed as a lower incidence of eggs laid of *D. suzukii* on cherries) achieved by the use of two commercial products based on natural compounds, Amarex® (Captiva® Prime) which is formulated by 7.60% v/v capsicum oleoresin extract, 23.40% v/v garlic oil, and 55% v/v canola oil (Gowan Chile SpA) and Requiem® Prime which is formulated by 9.1% w/v α-terpinene, 3.4% w/v p-cymene, and 2.73% w/p d-limonene (Bayer S.A), was studied. Both were applied three times every 5 days as fruit starts to change color.

Treatment with Amarex® was applied at 200 mL/100 L, and treatment with Requiem® Prime was applied at 240 mL/100 L, using a conventional hydraulic sprayer (Line Patasa 2000) with 1800 L of water per hectare. One check control using only water treatment was included.

All treatment had four repetitions of 10 plants, randomly drawn inside the orchard. Evaluations were performed at 3 days between applications and at 3 and 7 days after the last application.

On each occasion the frequency of egg of *D. suzukii* laid in fruits was evaluated, in samples of 100 fruits collected at random.

After each evaluation involved in the present work, the destruction of the contaminated material was carried out via freezing at -30C for 5 days.

3. Results

All monitored hosts showed damage and development of immature states of the pest from the beginning of fruit maturity. The above adds *A. chilensis*, a Chilean native plant, and *Prunus cerasifera* (**Figure 1**) to the list of secondary hosts of the pest.

Figure 1.
Inmature stages of D. suzukii *collected from fruits of* Prunus cerasifera.

The period of greatest incidence of the pest was at the beginning of fruit color breakage and increases as it approaches maturity. Development persists in remnants of the orchard after harvest (**Figures 2** and **3**).

There were no indications of preference of attack of one fruit variety over another nor signs of preference among fruit species when comparing the incidence between cherry trees and blueberries in similar conditions. The foregoing could vary according to different pesticides or nutritional programs or driving management used among these crops, but at least the records collected suggest that similar precautions should be handled in these fruit trees.

There was no rainfall in the period of pest incidence, and daily temperatures ranged from 6 to 36°C. Relative humidity varied from 40 to 65%, that is, adjusted to favorable climatic requirements for the development of the pest [20]. The area of cherries in Chile currently exceeds 27,000 hectares, concentrated in areas that have favorable climatic conditions for this pest, a situation that is even more marked in the case of blueberry production.

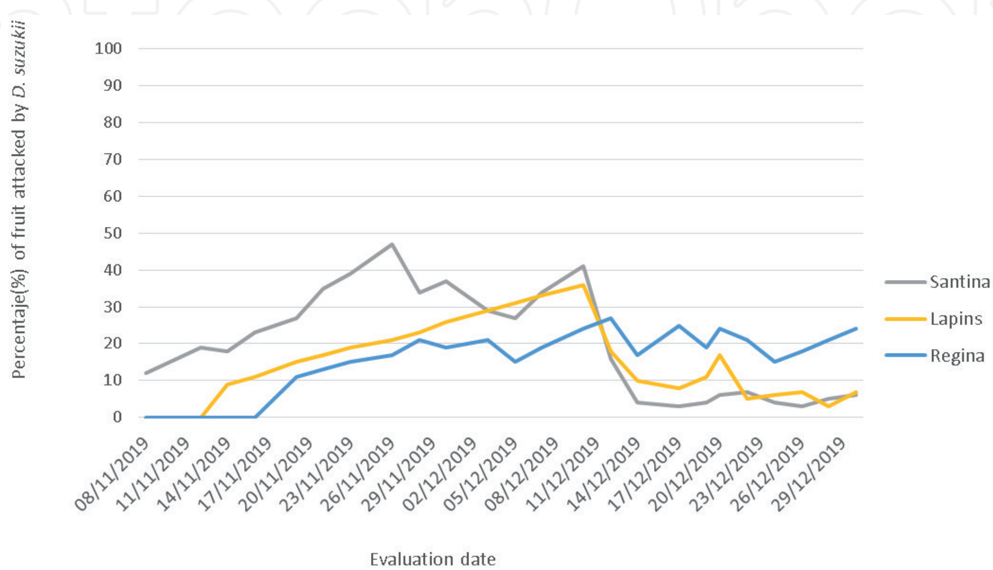

Figure 2.
Percentage (%) of cherry fruits attacked by D. suzukii *separated by cultivar.*

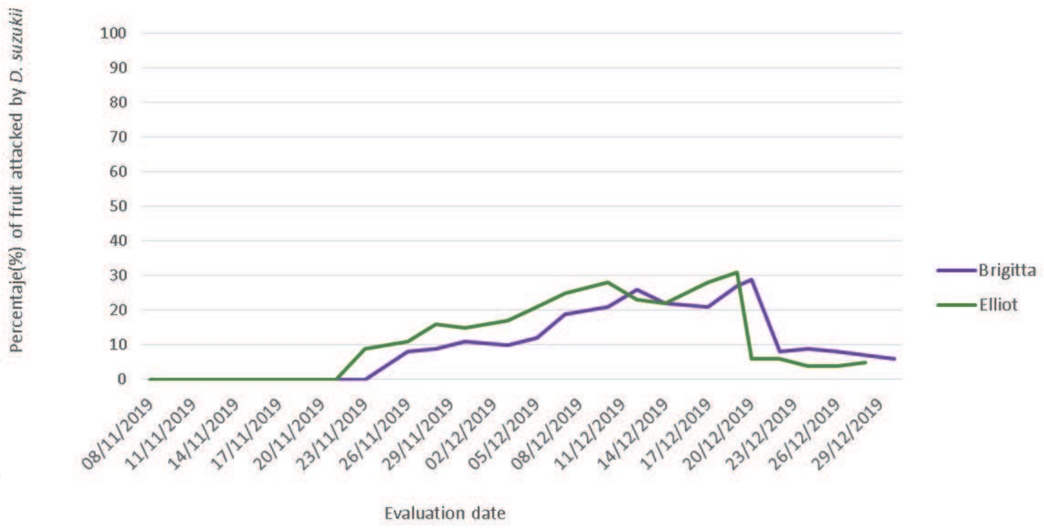

Figure 3.
Percentage (%) of blueberry fruits attacked by D. suzukii *separated by cultivar.*

Since Chile is a country focused on the export of fruits, the damages observed until now can be categorized in two categories: complete loss of the fruit (**Figure 4**) or loss of quality due to deterioration or damage to the skin of the fruit (**Figure 5**).

In the monitored cases, for cherries, the first category reached between 10% and15% of the production (approximately 10% Santina, 12% Lapins, and 15% Regina), that is, the equivalent of 1, 2.16, and 2.7 ton/ha. Economically speaking, it is a loss equivalent to 5,000–17,550 USD/hectare. The second item is still difficult to quantify. The second item was estimated at 1–2%.

In the case of blueberries, the percentage of compromised fruit was close to 8%, which could increase as the plague increases its local population. This corresponds to the equivalent of 1–1.5 ton/ha or a loss equivalent to 4,000 USD/hectare.

In fruits of live fences (*A. chilensis*, *R. ulmifolius*, and *P. cerasifera*), at the end of the season, the recorded frequency was greater than 60%, possibly since they do not receive pesticide treatments and not necessarily because there is a greater attraction or preference to those substrates. Unfortunately, at least two of these three species are widely distributed in the country, such as ornamental plants or live fences, which contribute to the spread of the pest.

Figure 4.
Losses caused in cherry trees by massive attack of D. suzukii.

Figure 5.
Cherries showing damage by egg laying attempts.

Secondary damage due to attempts to lay eggs occurred in some sectors that received certain insecticidal treatments and allowed the fruit to be redirected to the domestic market, although at a significative lower return value than expected in an export fruit. Concordant with what happened in other countries, greater complexity is expected from the point of view of the increase of residues present in fruit due to the management of this pest [21].

Control delivered by the microencapsulated pyrethroid treatments, both spinosyns, and cyantraniprole was highly efficient not only in reducing the incidence of infestation (**Figure 6**) but also in decreasing the severity of the attack (**Figure 7**).

Spinosyns and some pyrethroids such as l-cyhalothrin are indicated with high efficacy in the control of damage of this pest, at short intervals of application to avoid egg postures [22].

In the case of acetamiprid, emamectin benzoate, and chlorantraniliprole, these showed weaker insecticidal action than the previous group, considering that the control action was only expressed once the fruit was affected by the pest. Even so, because they show a significant decrease in the incidence of damage for an approximate period of 5 days, future work may focus on complementing these mechanisms of action with others (such as repellents) that allow reducing the severity of the damage. These results are consistent with what was raised by specialists in the United States [23]. Nevertheless, despite being promising in management, the high rate of dispersal, reproduction, and adaptation of the pest is consistent with the high risk of economic damage reported globally [24].

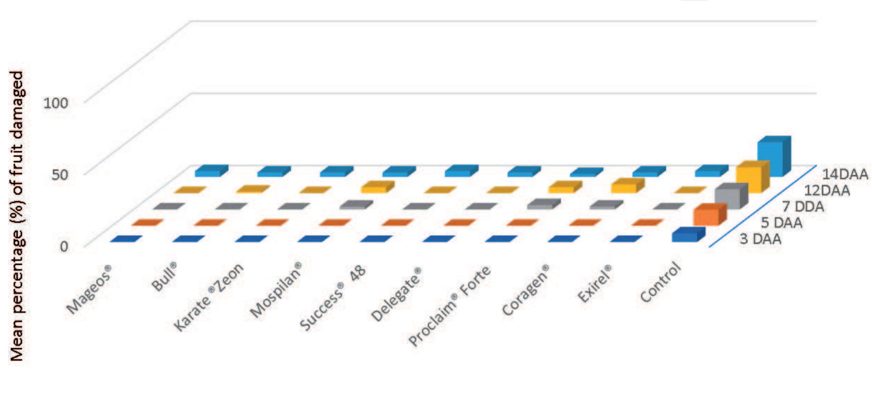

Figure 6.
Mean percentage (%) of fruits damaged by D. suzukii *days after each insecticide treatment.*

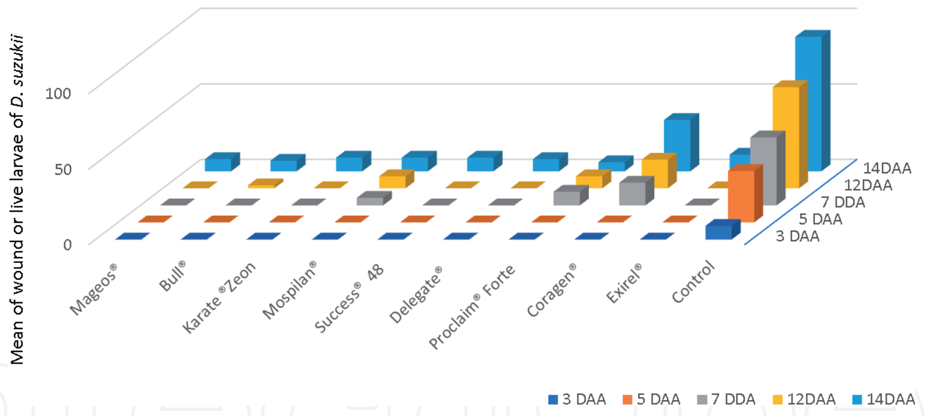

Figure 7.
Mean of wound/or live larvae of D. suzukii *in fruits days after each insecticide treatment.*

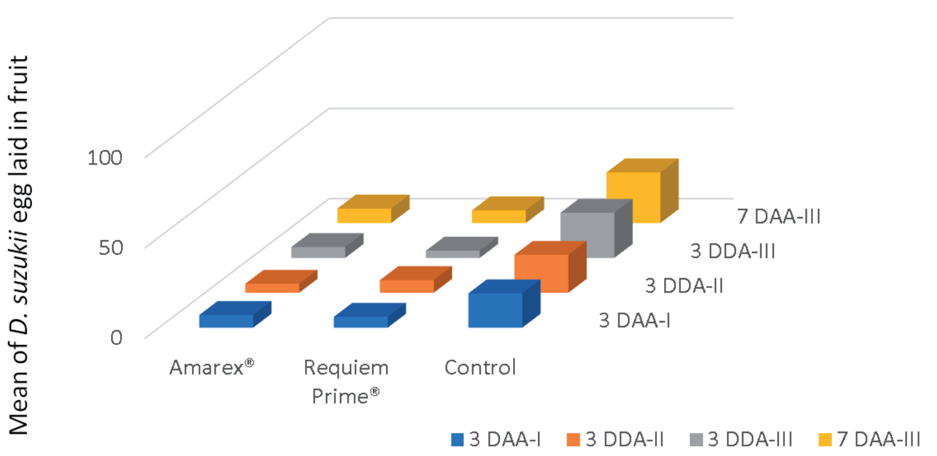

Figure 8.
Severity of attack (frequency of D. suzukii *egg position).*

On the other hand, although the history of efficient biological control has been weak [23], several authors agree on the need to advance in the integral knowledge of the management of this insect, including predators, parasitoids, repellents, insecticides, and cultural management [25–30].

Regarding the effect granted using products based on natural compounds, both Requiem® Prime and Amarex® demonstrated at least the decrease in the severity of attack of the pest under conditions of use in the orchard (**Figure 8**). However, it should be considered that the only use of these treatments may not be enough to reduce the economic impact when faced with increased *D. suzukii* pressure. More studies should be realized about their possible contribution inserted in a program or in mixture with conventional insecticides in order to contribute to complement mode of action.

The mode of action as insecticide reported for Requiem® Prime are explained because the active ingredient cause degradation of soft insect cuticles results in the disruption of insect mobility and respiration [31]. In the case of Amarex®, its action would also be explained by destruction of membranes added to the repellent effect [32].

4. Conclusions

The results of the monitoring of damage in fruits and its evolution during the season reflect that the potential risk of the plague in a country with the productive reality of Chile is high and that locally *D. suzukii* has found new shelters that allow it to spread and maintain its development. Although, in the search for its control, adequate tools were determined to reduce its damage, a greater understanding of the mechanism of action of each product is required in order to position it properly, in order to reduce the potential damage of the insect.

Given the high-quality requirement presented by the export fruit, there is a high risk of selection of less sensitive individuals of the pest, and those cases of violations of the maximum limits of pesticide residues occur due to an overheating of applications. For this reason, future work should consider other integrated management edges. In this line, it is necessary to investigate locally the use of possible mixtures of repellents with insecticides, the use of biological controllers in parallel to a management program, and the use of mass capture traps.

For now, two formulated products (Requiem® Prime and Amarex®) have promising results to achieve a lower severity of damage without adding residues to the fruit, which can be complementary to the use of insecticides aimed primarily at the management of adults of this pest.

Of the insecticides compared, the control delivered by cyantraniliprole and both spinosyns stands out. All microencapsulated pyrethroids showed stable control for at least 7 days. Acetamiprid, emamectin benzoate, and chlorantraniliprole were not efficient in reducing the attempt to lay eggs but were enough to decrease the incidence of damage. Therefore, in the short term, in Chile there are adequate tools for the management of this insect, but adequate use should be provided in order to preserve food safety.

Caution should also be taken with the selection of less sensitive individuals of the pest, because, due to the characteristics of the species, the expression of resistance to insecticides can enhance their economic damage.

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Conflict of interest

The author declares no conflict of interest in the delivery information.

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