

## EFFECT OF *Melanaphis donacis* Passerini (HEMIPTERA: APHIDIDAE) ON BIOMASS OF *Arundo donax* L. (Poaceae)

### EFFECTO DE *Melanaphis donacis* Passerini (HEMIPTERA: APHIDIDAE) EN LA BIOMASA DE *Arundo donax* L. (Poaceae)

Nicole Undurraga<sup>1</sup>, Jaime E. Araya<sup>1\*</sup>, Francisco Zuazúa<sup>2</sup>, and Máximo F. Alonso<sup>3</sup>

<sup>1</sup> Departamento de Sanidad Vegetal, Facultad de Ciencias Agronómicas, Universidad de Chile, Casilla 1004, Santiago, Chile.

<sup>2</sup> Escuela de Agronomía, Facultad de Ciencias, Universidad Mayor, Camino La Pirámide 5750, Huechuraba, Santiago, Chile.

<sup>3</sup> Instituto de Producción Animal, Facultad de Ciencias Agrarias, Universidad Austral de Chile, Casilla 567, Valdivia, Chile.

\* Corresponding author E-mail: jaimearaya@yahoo.com

#### ABSTRACT

Giant reed, *Arundo donax* (L.), is known for its potential as a bioenergy crop. To evaluate the effect of the aphid *Melanaphis donacis* (Passerini) on plants growing in the Metropolitan Region of Chile, three treatments with six plots each were compared: imidacloprid, the agricultural detergent TS2035, and an untreated control. Aphid density levels in the untreated control plants averaged 136.27 aphids leaf<sup>-1</sup> along the growing season, while TS2035 and imidacloprid averaged 8.26 and 0.98 aphids leaf<sup>-1</sup>, respectively. The greatest yield of *A. donax* (95.1 t dry matter (DM) ha<sup>-1</sup>) was obtained with the TS2035 detergent, followed by imidacloprid and the untreated control, with values of 88.8 and 84.1 t DM ha<sup>-1</sup>, respectively. However, there were no significant differences ( $p \leq 0.05$ ) in DM yields of *A. donax* between treatments. Thus, control of *M. donacis* with insecticides would be unnecessary in bioenergy crops of *A. donax* in this region.

**Key words:** Detergent TS2035, bioenergy crop, giant reed, *Arundo donax*, imidacloprid, Mediterranean region.

#### RESUMEN

El arundo, *Arundo donax* (L.) se conoce como cultivo para bioenergía en muchos países. Para evaluar el efecto del áfido *Melanaphis donacis* (Passerini) en arundo en la Región Metropolitana (Mediterránea) de Chile, se compararon tres tratamientos: imidacloprid, el detergente agrícola TS2035 y un control no tratado. Los niveles de densidad de áfidos en las plantas control no tratadas promediaron 136,27 pulgones hoja<sup>-1</sup> a lo largo de la temporada de crecimiento, mientras que TS2035 e imidacloprid promediaron 8,26 y 0,98 pulgones hoja<sup>-1</sup>, respectivamente. El mayor rendimiento de *A. donax*, equivalente a 95,1 t de materia seca (MS) ha<sup>-1</sup>, se obtuvo con el detergente TS2035, seguido de imidacloprid con 88,8 y el control sin tratar con 84,1 t MS ha<sup>-1</sup>, respectivamente. Sin embargo, no hubo diferencias significativas ( $p \leq 0,05$ ) en los rendimientos de MS de *A. donax* entre tratamientos. Por lo tanto, el control de *M. donacis* con insecticidas sería innecesario en cultivos de *A. donax* para bioenergía.

**Palabras clave:** Detergente TS2035, cultivo energético, caña gigante, *Arundo donax*, imidacloprid, Región Mediterránea.

## INTRODUCTION

Giant reed, *Arundo donax* L., a fast growing and high yielding Poaceae, has been highlighted as a potentially important bioenergy crop (Lewandowski et al., 2003; Angelini et al., 2005; 2009; Nassi o Di Nasso et al., 2011) that could satisfy part of the world's energy demands (Mariani et al., 2010), although some fear its invasive weed aggressiveness (e.g. Ahmad et al., 2008; Lambert et al., 2010). Because of its potential for bioenergy, *A. donax* is being experimentally cultivated in Chile.

Most recent research on *A. donax* grown for biomass has focused almost solely on its potential yield, physiology and the optimal agronomic practices for its cultivation. Little attention has been given to insect populations that can develop on the crop and could become potential pests for the species, in particular aphids the most important pests in herbaceous crops (Blackman and Eastop, 2000). However, it is difficult to accurately assess the economic losses caused by aphids, since their density varies greatly throughout the year (Michaud and Sloderbeck, 2005). Thus, year-round studies of aphid population dynamics should be carried out.

The presence of the giant reed aphid, *Melanaphis donacis* (Passerini), has been reported in wild plants of *A. donax* in the Mediterranean Region of Chile (Nieto-Nafria et al., 2016), but its effect on the biomass production is unknown.

The broad spectrum of neonicotinoid insecticides has a long residual effect on juvenile and adult insects acting by contact and ingestion, and interfere with the nervous stimuli (Bayer CropScience, 2014). The agricultural detergent dissolves the wax layers of the insect's cuticle and breaks cell membranes, which dehydrates and kills aphids; also reduces the superficial tension, allowing water to enter through spiracles and drown insects. It also dislodges individuals from the foliage (Curkovic and Araya, 2004).

This research studied the effect of *M. donacis* on the biomass yield of *A. donax* grown in experimental plots throughout the year under three conditions: an untreated control, a treatment with the insecticide imidacloprid, and a treatment with an agricultural detergent.

## MATERIALS AND METHODS

This study was carried out at the Antumapu Campus and Experimental Station, University of Chile, La Pintana (33°34'8" S; 70°38'40" W), Santiago, in eighteen 4 m<sup>2</sup> giant reed plots planted at 20,000 plants ha<sup>-1</sup>, with 3 rows of 5 plants each and a total of 15 plants per plot.

The soil of the plots belongs to the Santiago series, a member of the sandy Mollisol family. It is of alluvial origin, slightly deep and flat topography (0-1% slope), with little micro relief in a wide fan on both banks of the Maipo river. The effective soil depth varies from 30 to 73 cm. The average annual temperature is 15-16°C. The soil is well-drained and moderately dry areas occur only occasionally (Casanova et al., 2004).

Rhizomes for planting were obtained from wild *A. donax* plants located at the side of the road to Rinconada de Maipú, next to the Joaquín Olivares area (33°30'0.17" S, 70°49'12.25" W). The canes were cut 10 cm high from the ground and removed to collect the rhizomes down to a ~50 cm depth, with the least possible damage. Clean rhizomes (without wetting) were taken to the Antumapu Campus, where they were cut and prepared. Those weighing 200-300 g, with at least one sprout, were taken used for planting the plots. The soil of the trial area was plowed once and crumbled twice with a disc plow. The crop was established in October 1, 2012, on ridges separated 1 m with rhizomes at 0.5 m in the row, in 4 m<sup>2</sup> plots (20,000 plants ha<sup>-1</sup>). Based on soil and water analyses and the recommendations of Angelini et al. (2005), 50 g of urea (equivalent to 300 kg N ha<sup>-1</sup>) and 30 g of triple super phosphate (equivalent to 200 kg of P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup>) were applied per plant at the establishment of the plots and at mid-season. Glyphosate (Cortador® 48% SL) was applied three times during the growing season at 2.5 L ha<sup>-1</sup> for post-emergence control of Poaceae, Cyperaceae and broadleaf weeds. In addition, weeds were hand controlled three to four times a month. Furrow irrigation was carried out twice a week to keep the soil close to field capacity.

The study included three treatments: the application of imidacloprid, the agricultural detergent TS2035 using a hand sprayer (SOLO 1 gal, Santiago, Chile), plus an untreated control. The detergent TS2035 (Pace International) was applied every ~15 d at 0.5% v/v the first five sprays and at 1.0% v/v the next five sprays. The detergent was sprayed slowly until dripping to ensure good covering. To ensure good residual action, the insecticide imidacloprid (Confidor® 350 SC) was sprayed twice using ~330 mL of the corresponding solution per plot. Dosages and spraying dates are presented in Table 1.

Treatments were distributed in a completely randomized experimental design with six replicates. Plots were harvested on June 3, 2013, and the fresh weight of the canes was determined with an electronic crane scale OCS 0.5T. Canes were cut 10 cm above the ground. To estimate dry matter (DM) yield, three canes of each treatment and replicate were selected at random and dried

**Table 1. Schedule of control treatments against *M. donacis*.**

Commercial products	Dosages	Spraying dates
Confidor® 350 SC	330 mL 4 m <sup>-2</sup>	05 Dec 2012 05 Mar 2013
TS2035	0.5 L pl <sup>-1</sup>	05 Dec 2012 17 Jan 2013 01 Feb 2013 22 Feb 2013 05 Mar 2013
	1 L pl <sup>-1</sup>	20 Mar 2013 15 Apr 2013 09 May 2013 24 May 2013

at 70 ± 3°C for 7-10 d until constant weight. In each plot, canes plant<sup>-1</sup> and canes m<sup>-2</sup> were recorded.

Aphids in each treatment were sampled every 15 d once they began to colonize the plants, from December 26, 2012 through the harvest. For the counts, 3 plants were randomly chosen from each plot. The 3<sup>rd</sup> most recent leaf of each plant (later the leaf representative of infestation) was cut, for a total of 18 samplings per treatment. These leaves were taken in individual cold plastic bags to the Crop Entomology Laboratory, Department of Plant Protection, University of Chile, where the aphids on both sides of each leaf were counted under a stereoscopic magnifier (Zeiss Stemi DV4, Fisher Scientific SL - C / Luis L 9, 28031 Madrid, Spain).

Data collected were revised for normality and homoscedasticity. Results were evaluated by an ANOVA and differences among treatments were detected by a *post-hoc* Tukey test at 5%, using Infostat®.

## RESULTS

**Yield of *A. donax*.** Mean fresh and dry matter yields obtained in each treatment are presented in Table 2.

Although treatments were not significantly different for yield component's parameters (Table 2), treatments with aphid control tended to have higher yields than the untreated control.

**Population of *M. donacis*.** Aphid densities in the treatments with TS2035 and imidacloprid were statistically similar after the first spray compared to the untreated control (Table 3). These densities were maintained until harvest, thus both treatments were similarly effective in reducing aphid density.

Means of aphids leaf<sup>-1</sup> for each treatment from December 2012 through May 2013 are presented

in Fig. 1. Mean aphid counts per leaf were significantly different ( $p \leq 0.05$ ) between treated plots and untreated control plots. While the untreated control reached a mean of 136.27 aphids leaf<sup>-1</sup> during the growing season, the means of the treatments with TS2035 and imidacloprid were 8.26 and 0.98 aphids leaf<sup>-1</sup>, respectively. Differences between treatments with TS2035 and imidacloprid applications were not significant ( $p \leq 0.05$ ).

## DISCUSSION

**Effect of *M. donacis* populations on yield of *A. donax*.** Results obtained suggest that no significant yield loss of *A. donax* occurred at the aphid density levels reached in the untreated control plots, with a maximum of 242.72 aphids leaf<sup>-1</sup> at the end of the summer. Thus, the application of products with insecticide effect to control the aphid under the conditions of the trial should not be justified.

Decision making regarding the need for control is generally based on experimental studies investigating about the relationship between the level of infestation and yield loss. The ability to determine this relationship is limited, since the presence of the insect does not always generate damages resulting in economic loss (Fabre et al., 2003).

The applications of insecticides could be justified by the prevention of viral crop diseases. Thus, it is necessary to examine the sanitary risks associated to the production of raw material from *A. donax*, especially the potential of this plant to be infected with pathogens like Barley Yellow Dwarf Virus (BYDV) and the risk of spreading it to neighboring crops. According to Ingwell et al. (2014), who first reported BYDV-PAV vectored by *Rhopalosiphum padi* L. in *A. donax* growing in the USA under controlled conditions, giant

**Table 2. Cane characteristics and fresh and dry matter yields ( $\pm$  SD) of *A. donax* under different aphid control methods (n = 54 canes).**

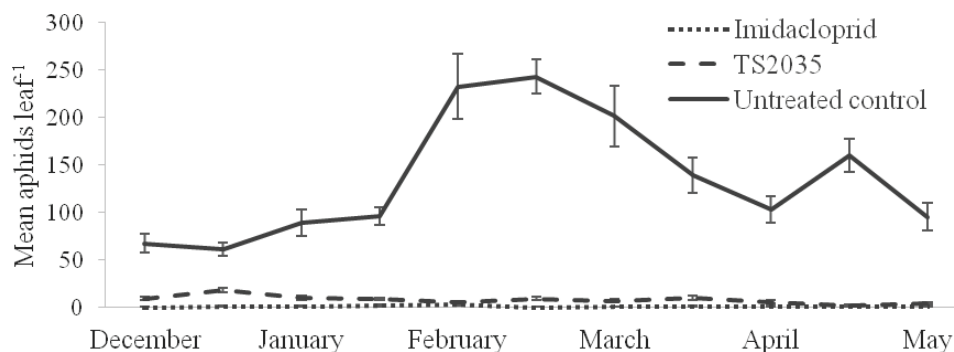
Treatments	Parameters				
	Canes plant <sup>-1</sup>	Canes m <sup>-2</sup>	Cane weight, g	Fresh weight, kg m <sup>-2</sup>	Dry matter, kg m <sup>-2</sup>
Imidacloprid	11.23 $\pm$ 1.30 a	42.13 $\pm$ 4.90 a	210.29 $\pm$ 10.03 a	20.27 $\pm$ 4.25 a	8.88 $\pm$ 1.86 a
TS2035	10.67 $\pm$ 1.25 a	40.00 $\pm$ 4.67 a	237.34 $\pm$ 12.17 a	21.72 $\pm$ 4.24 a	9.51 $\pm$ 1.86 a
Untreated	11.03 $\pm$ 1.36 a	41.33 $\pm$ 5.08 a	201.39 $\pm$ 8.90 a	19.18 $\pm$ 4.34 a	8.41 $\pm$ 1.90 a

Different letters in a column indicate significant differences ( $p \leq 0.05$ ) in Tukey tests.

**Table 3. Density of *M. donacis* leaf<sup>-1</sup> before and after the first control on December 5, 2012.**

Means	Treatments		
	TS2035	Imidacloprid	Untreated control
Pre application	64.72 a	68.33 a	68.77 a
Post application	9.22 b	0.11 b	67.33 a

Different letters in a column indicate significant differences ( $p \leq 0.05$ ), in Tukey tests.

**Fig. 1. Means of *M. donacis* leaf<sup>-1</sup> in the treatments from December 26, 2012 through harvest on June 3, 2013.**

reed would be tolerant to the infection and its production would not be affected. However, more studies are needed to confirm this.

The transmission of BYDV by aphid species has been studied worldwide (e.g., Fabre et al., 2003). Previous studies have evaluated whether *A. donax* can be a source of BYDV, like the one by Tóth et al. (2011), who found a collection of Italian reed ecotypes and some Hungarian ecotypes free of the virus. On the other hand, Bradshaw et al. (2010) found *Sipha flava* (Forbes) and *Rhopalosiphum maidis* (Fitch) on *Miscanthus x giganteus* in the USA, and noted that both aphids have the potential to damage young plants as they do in other crops, so they could become a problem of economic importance. Ingwell et al. (2014) suggested that *R. maidis*, common in cereals

and forage grasses may inoculate BYDV-PAV, and that growing *A. donax* could influence the ecology and epidemiology of this virus affecting neighboring small grains.

**Effectiveness of treatments in the control of *M. donacis*.** The two products with insecticide effect evaluated significantly reduced *M. donacis* densities until harvest.

Although imidacloprid was applied only twice, it kept *M. donacis* populations under control throughout the 6-month study, as expected from its mode of action on the nervous system of insects. In general, imidacloprid is effective in suppressing aphids for extended periods (Joshi and Sharma, 2009; El-Naggar et al., 2013). Mizell and Sconyers (1992) found that this neonicotinoid

insecticide affect some beneficial predators, but Jeschke et al. (2011) estimated that this compound would represent a relatively low risk for non-target organisms and the environment, and it is necessary to promote the development of practices without environmental impacts and look for aphid control alternatives.

Sprays of the TS2035 detergent at 0.5% v/v, starting when the plants were approx. 40 cm tall until harvest, were effective in controlling *M. donacis*, with no toxicity to the plants, and with no significant differences when compared to the conventional insecticide imidacloprid. A high elimination of epicuticular wax was observed in the field and in the samples collected, which darkened the aphids when they were left without their characteristic whitish wax. This suggests that mortality of *M. donacis* occurred mainly by dehydration as a consequence of the removal of the epicuticle wax. This effect has also been observed in studies on mealybugs (Hemiptera), along with mortality by washing and removal of specimens from the plant (Curkovic and Araya, 2004; Burett, 2005).

Regarding those few individuals that remained attached to the leaves, observations under magnification revealed that some aphids moved erratically and/or did not move their legs, suggesting that their survival would be unlikely in the field.

Previous studies (Vincent et al., 2000) described the negative effect of imidacloprid, especially on ladybirds, such as larvae and adults of *Harmonia axyridis* (Pallas). Santos et al. (2017) and Schiess et al. (2017), verified its high toxicity for *Hippodamia convergens* (Guérin-Méneville), a coccinellid abundant on the plants in our study. As the populations of *M. donacis* did not affect yield and imidacloprid is toxic to the beneficial fauna (Mizell and Sconyers, 1992), its application is not advisable for the management of this aphid, and natural control should be considered. Additionally, some authors have indicated that, in case of crops destined for biomass, it is possible to increase the natural control of pests through the conservation of beneficial insects (Werling et al., 2011; Prasifka and Gray, 2012). Thus, the use of agricultural detergents would be the most viable option to protect natural enemies, since the detergents appear to be less toxic than a conventional insecticide, as observed by Ripa et al. (2006) in an assay to control the whitefly *Aleurothrixus floccosus* (Maskell) (Hemiptera: Aleyrodidae) and the red mite *Panonychus citri* (McGregor) (Acarina: Tetranychidae) on citrus.

Quantifying yield loss and economic damage is essential to establish an efficient pest control program. In energy crops these thresholds are

expected to be higher than in conventional crops, since a low level of damage does not decrease the quality of the biomass, so energy crops should support higher pest densities (Fitt, 2011).

Angelini et al. (2005) stated that DM biomass production of giant reed is affected by harvest date, plant density, water supply, and fertilization. In our study, harvest of *A. donax* was conducted between the end of autumn and the beginning of winter to favor lower water content in the canes, obtaining a similar value (~56.2%) to those obtained in studies worldwide. For example, Angelini et al. (2005) reported that water content of the raw material was reduced 10% from autumn to winter, ranging between 52 and 58%. Christou et al. (2003), on the other hand, harvested giant reed with 54% moisture.

Angelini et al. (2005; 2009) emphasized that production of the first year is the result of the biomass generated from individual rhizomes, and that plants growing at lower densities would have higher individual productions. In the following years, yield increases with plant density, until plant competition starts affecting yield. Angelini et al. (2009) obtained the highest yield of *A. donax* at densities of 20,000 plants ha<sup>-1</sup>.

For wild *A. donax* plants in California, Giessow et al. (2011) obtained 15.5 kg DM m<sup>-2</sup> and Spencer et al. (2006) reported 17.1 kg DM m<sup>-2</sup> of aerial biomass. In trials established in Greece's temperate climate, annual yields from 15 to 39 t DM ha<sup>-1</sup> have been sustained for several years, while Hidalgo and Fernández (2000) obtained a first year annual yield of 45.9 t DM ha<sup>-1</sup> in Spain. Angelini et al. (2009) reported yields of 30 t DM ha<sup>-1</sup> in Italy. Because of irrigation of the plots, DM yield reached higher values in our study. In plots treated with the TS2035 detergent, the greatest average yield obtained reached 95.1 t ha<sup>-1</sup>, followed by the treatment with imidacloprid with 88.8 t ha<sup>-1</sup>, and a mean yield of 84.1 t ha<sup>-1</sup> in the untreated plots.

To some extent, the high yields obtained in our trial during the first year of growth of *A. donax* could be explained by the irrigation and fertilization of the crop. Applications of imidacloprid and TS2035 during the growing season kept the crop with low aphid populations through harvest. However, as *M. donacis* density did not significantly affect DM yields in the untreated control plots, control of *M. donacis* with insecticides would be unnecessary in bioenergy crops of *A. donax* infested with this aphid at the levels observed during this study. The DM yields obtained are considered promising for cultivating giant reed for energy purposes in the Mediterranean Region of Chile. However, as maximum yields of the crop are obtained on its 3<sup>rd</sup> year (Christou et al., 2003), long-term evaluations are still needed.

## CONCLUSIONS

Control of *M. donacis* with insecticides would not be necessary in bioenergy crops of *A. donax* infested with *M. donacis* at the levels observed. However, long-term evaluations of DM yields are still needed.

## ACKNOWLEDGEMENTS

This work was made possible by the funding from INNOVA-CHILE, Project BIOCOMSA 08CTE02-06, Desarrollo de Cultivos Energéticos.

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