

DOI 10.7764/ijanr.v47i2.1971

RESEARCH PAPER

Population dynamics of *Melanaphis donacis* (Hemiptera: Aphididae) and its Coccinellidae and Syrphidae predators on *Arundo donax* L.

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Abstract

N. Undurraga, J.E. Araya, F. Zuazúa, and M.F. Alonso. 2020. Population dynamics of *Melanaphis donacis* (Hemiptera: Aphididae) and its Coccinellidae and Syrphidae predators on *Arundo donax* L. Int. J. Agric. Nat. Resour. 117-125. The population density of the aphid *Melanaphis donacis* (Passerini) was studied in experimental plots of *Arundo donax* (L.) at the Antumapu Campus of the University of Chile, La Pintana (33° 34' 08" S 70° 38' 40" W) and on wild populations at Rinconada de Maipú (33° 30' 0.17" S and 70° 49' 12.25" W), both in the Mediterranean zone of Chile. Sampling started upon the first colonization of the plants by the aphid on December 14, 2012, and continued every 15 days through December 14, 2013. Samples were taken from the 3rd leaf from the apex, and a total of 36 samples were collected per sampling date. The aphid occurred throughout the growing season of *A. donax*, especially in summer, with higher densities in the experimental plots than in the wild populations and means of 243 and 147 aphids leaf⁻¹, respectively. The main natural enemies observed were the coccinellids *Eriopis connexa* (Germar) and *Hippodamia convergens* (Guérin-Ménéville) and the syrphid *Allograpta pulchra* (Shannon). The predator populations followed the growth curves of the aphid population and of *A. donax*.

Keywords: *Allograpta pulchra*, energy crops, *Eriopis connexa*, giant reed, *Hippodamia convergens*.

Introduction

Renewable energy sources are being developed worldwide to reduce fossil fuel use and dependence, diversify the energy matrix, and reduce greenhouse gas emissions. Growing grasses

for renewable energy production is becoming popular. Giant reed, *Arundo donax* (L.) (Poaceae, Arundinoideae), is one of the rhizomatous grasses with high bioenergy potential (Lewandowski *et al.*, 2003; Angelini *et al.*, 2009).

A. donax it is believed to be of Asian origin, but it is also considered native to the Mediterranean basin. Today, it is distributed in many Mediterranean

climates and in temperate-warm and subtropical countries. It is grown in Asia, Southern Europe, North Africa and the Middle East for diverse purposes, especially for the industrial production of pulp (Canavan *et al.*, 2017).

This perennial grass grows in dense groups with 3-6 m high stems (Angelini *et al.*, 2009). They are 1-4 cm in diameter and commonly branched in 2-year-old and older plants (Mackenzie, 2004). Rhizomes grow near the surface (5-15 cm deep), and the roots grow more than 1 m deep. Leaves are 30 to 100 cm long and 2 to 7 cm wide. Flowers are vertical panicles 30 to 60 cm long. Blooming occurs late in summer. Reproduction is asexual because the seeds are sterile, and propagation occurs when rhizomes and stems are spread by water and then sprout; thus, propagation is slower in plants far from water sources (Mackenzie, 2004). This makes *A. donax* a good choice as an energy crop since photosynthesis is channeled to biomass production rather than seed production and *A. donax* has limited dispersion and thus limited potential to become an invasive weed (Pilu *et al.*, 2012).

A. donax has been studied in the Mediterranean basin and in the USA (Shatalov & Pereira, 2002; Lewandowski *et al.*, 2003). In addition to its high adaptability, it yields a large volume of biomass (Bentini & Martelli, 2013) that can be used to generate heat, electricity and biofuels (Yang & Wyman, 2008).

The potential yield reaches up to 100 t ha⁻¹ of fresh material in the 2nd or 3rd growth period (Shatalov & Pereira, 2002). In Italy, crops persist between 10 and 12 years with high yields and without fertilization, irrigation, or pesticides. Angelini *et al.* (2009) obtained 30 t dry matter (DM) ha⁻¹ during the 1st year, a maximum productivity of 45 to 50 t DM ha⁻¹ in years 2 and 3, and of 35 to 40 t DM ha⁻¹ between years 4 and 8. Yield decreased to 25 - 30 t DM ha⁻¹ after year 9.

A. donax crops are exposed to pests and diseases, but unlike food crops, they do not have

problems due to pesticide residues or sanitary management regulations (Fitt, 2011). Usually, farmers apply broad-spectrum insecticides that have various consequences, such as effects on natural enemies, the emergence of secondary pests, the risk of resistance of the target pest and varied environmental impacts (Landis & Werling, 2010). As energy crops are becoming more common and a significant increase in their global production is foreseen in the coming years, it is likely that new pests and diseases will emerge. One of the challenges for the sustainable production of these crops is to ensure that producers adopt preventive approaches instead of applying pesticides.

Few insects have been found on *A. donax*, as their stems and leaves have substances that affect phytophagous species, such as silica, tri-terpenes, hydroxamic acid, alkaloids and others; therefore, the plant is considered resistant to pests (Lewandowski *et al.*, 2003). Spencer *et al.* (2007) also suggested that their tissue is difficult to digest for generalist herbivores, which favors their growth and spread. At maturity, *A. donax* has a C:N ratio of 22:1, which is considered unsuitable for generalist herbivores.

Studies about the insects associated with *A. donax* have aimed to reduce its invasive potential as a weed. These insects have been classified according to their host-specificity into (1) potentially monophagous species such as the hymenopteran *Tetramesa romana* (Walker), a main candidate for the biological control of *A. donax*; (2) oligophagous insects that develop in *Arundo* and *Phragmites*, for example, the hemipteran *Rhizaspidiotus donacis* (Leonardi); and (3) polyphagous insects that develop on many Poaceae species in addition to reeds. The third group includes several aphids, and *Melanaphis donacis* (Passerini) is the main aphid species that has also been found on the genera *Phragmites* and *Bambusa*. Other aphids found on *A. donax* are *Hyalopterus amygdali* (Blanchard), *H. pruni* (Geoffroy), *Hysteroneura setariae* (Thomas), *Macrosiphum euphorbiae*

(Thomas), *M. sacchari* (Zehntner), *Metopolophium dirhodum* (Walker), *Myzus ornatus* Laing, *M. persicae* (Sulzer), *Rhopalosiphum maidis* (Fitch), *R. padi* (L.), *R. rufiabdominale* (Sasaki), *Schizaphis graminum* (Rondani), and *Sipha maydis* (Passerini) (Blackman and Eastop, 2000).

In Chile, no insect pests of giant reeds have been described so far except for *M. donacis*, an aphid first detected by the Agricultural and Livestock Service in 2004 in Talagante, Metropolitan Region. *M. donacis* is also present in the regions of Arica and Parinacota, Atacama, Valparaíso and O'Higgins and, in all cases, is associated with *Chusquea* sp. (Poaceae) (Ortego *et al.*, 2004; Nieto-Nafría *et al.*, 2016). It has also been found in La Pintana on experimental plots of giant reed at the Antumapu Campus of the University of Chile.

Melanaphis (van de Goot) is a genus of Rhopalosiphina, Aphidinae, that is very closely related to *Rhopalosiphum*, is associated with Poaceae and Rosaceae, and has 25 species, a few with alternating hosts (Blackman & Eastop, 2000). *M. donacis* is easily recognized by its abundant white wax and dark purple dorsal-abdominal area with no wax. It forms compact groups on the leaves of *Arundo* (Ortego *et al.*, 2004).

Thus, this study describes the population dynamics of *M. donacis* and its predators on *A. donax* grown in experimental plots and wild populations in the Mediterranean zone of Central Chile.

Materials and Methods

The density of the aphid *Melanaphis donacis* (Passerini) and its Coccinellidae and Syrphidae predators on *A. donax* was studied in experimental plots of *Arundo donax* (L.) at the Antumapu Campus of the University of Chile, La Pintana (33° 34' 8" S 70° 38' 40" W) and on wild populations at Rinconada de Maipú, Maipú (33° 30' 0.17" S and 70° 49' 12.25" W), both in Santiago, Metropolitan Region, Chile.

Six 4-m² plots were planted with giant reeds at 20,000 plants ha⁻¹ (plant rows separated by 1 m and plants separated 0.5 m in the row) on October 1, 2012. The rhizomes that were planted were obtained from wild plants in nearby crops of small grains at Rinconada de Maipú at the edge of an irrigation channel with abundant weeds.

Starting at the date of planting, aphid monitoring was carried out weekly. Aphid sampling was performed every 15 d from the first colonization of *M. donacis* in *A. donax* plants on December 14, 2012, through December 14, 2013. Samples were taken both in the experimental plots at La Pintana and in wild populations at Rinconada de Maipú.

The plots and wild plants were not subjected to sanitary treatments. Three plants from each plot and 18 plants from the wild populations with similar levels of infestation were chosen at random. The 3rd leaf from the apex of a total of 36 plants per sampling date was cut at the insertion point to the shoot. The leaves were kept in individual plastic bags and were carried in a cooler to the Crop Entomology Laboratory at the Department of Plant Protection of the University of Chile, where wingless and winged aphids were counted under magnification. The number of aphids plant⁻¹ and the sampling date were recorded. The larvae of aphid predators on the sampled leaves were counted. The experimental plots were harvested on June 3, 2013.

The data collected were checked for normality and homoscedasticity. The results were evaluated by ANOVA, and differences among treatments were detected by a *post hoc* Tukey test at 5% significance using Infostat®.

Results

Population dynamics of *M. donacis*

Aphid counts began when the insects were abundant on the plants, on December 17, 2012. In the experimental plots (Figure 1), the high-

est count was 554 aphids leaf⁻¹, with an average of 243 aphids leaf⁻¹ at the beginning of March 2013. During the first months of data collection, the population dynamics of the aphids on the wild giant reed plants were more irregular than those of the aphid populations on the cultivated plants (Figure 1). Wild populations exhibited a maximum of 350 aphids leaf⁻¹ with an average of 147 individuals leaf⁻¹ in January 2013. In both cases, aphid density diminished at the beginning of autumn.

A new colonization period began in early September, following rhizome sprouting. At both sites, aphid populations increased towards spring-summer, when the populations presented an annual maximum. In this second growth period, the populations increased more gradually than those in the first year.

In general, aphid colonies were more abundant in the experimental plots than in the wild samples. The only exception to this trend occurred in October, when the wild plants were not harvested and remained larger than the experimental plants; therefore, more aphids were recorded in the counts on the wild plants. Once the plants in the experimental plots reached a height of 1 m, the aphid populations increased until they exceeded those in wild plants.

In general, *M. donacis* preferred to feed on the apical buds and newer tissues on the stem tops and on the undersides of the leaves. They were more abundant in the experimental plots due to the more active regrowth. In contrast, the wild plants had high proportions of senescent canes where aphids were not present.

Winged and wingless aphids occurred throughout the season, except after harvest in early June, reappearing with plant regrowth. Their highest numbers occurred during summer, from December to March.

Aphid predators

Several species (Castro, 2011) were recognized as efficiently preying on aphids. These were mostly juveniles of coccinellids (Coleoptera) and syrphids (Diptera), as presented in Table 1. Adult predators escaped sampling by flying, so only the larval stages are presented.

Table 1. Coccinellidae and Syrphidae larvae preying on *Melanaphis donacis* on *Arundo donax*.

Families	Species
Coccinellidae	<i>Eriopis connexa</i> (Germar), <i>E. schscholtzii</i> (Mulsant), <i>Cycloneda sanguinea</i> (L.), <i>Harmonia axyridis</i> (Pallas), <i>Hippodamia convergens</i> (Guérin-Méneville), <i>H. variegata</i> (Goeze)
Syrphidae	<i>Allograpta pulchra</i> (Shannon)

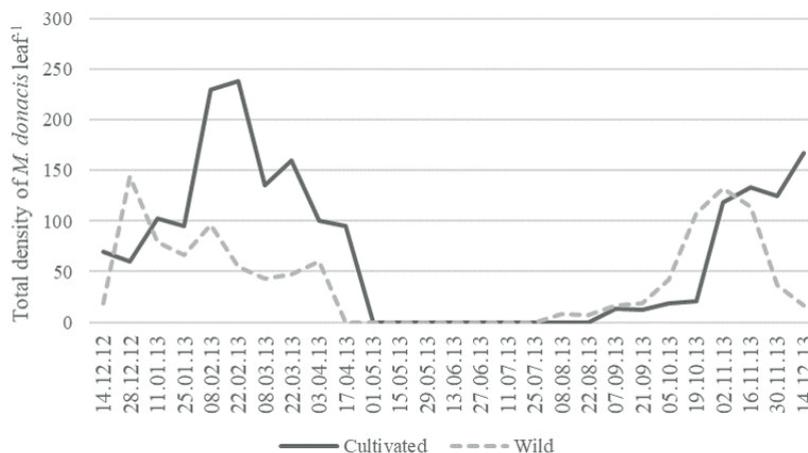


Figure 1. Total density of *Melanaphis donacis* on the leaves of cultivated (—) and wild (---) *Arundo donax* plants.

Coccinellid larvae were abundant at the beginning of autumn, with a maximum of 24 individuals leaf⁻¹ in March (Figure 2). After disappearing at the end of autumn (May), their populations increased gradually from July through December, following the increase in the aphid population and plant growth. Syrphid larvae numbers, on the other hand, increased gradually at the end of winter. In December, coccinellid and syrphid larvae reached 41 and 7 individuals leaf⁻¹, respectively. Those were the highest densities recorded for both natural enemies.

The variation in coccinellid larvae coincided with the population growth of *M. donacis*, whose greatest densities occurred in spring-summer and late autumn. During winter and after harvest, coccinellids practically disappeared, especially the juveniles, since they overwinter as adults and increase in density in early spring (September). Some aphids mummified by braconid hymenopterans were also found, most of them in the summer, but the species of the braconids were not determined.

Relationship between aphids and predatory coccinellids

Figure 3A and 3B present the populations of *M. donacis* and coccinellid larvae in the experimental

plots and on the wild plants, respectively. In the cultivated plants, an increase in the density of the aphid (but not coccinellids) was observed in early summer (December 2012). During January, *M. donacis* density began to decrease, while predator density slowly increased in the autumn. Both aphid and predator densities decreased during winter and increased again the following spring.

The evolution of *M. donacis* and coccinellid larvae populations on the wild giant reed plants was similar to the patterns on their cultivated counterparts. Predators require a minimum prey density for their establishment and reproduction; thus, there is an evident relationship between the populations.

Discussion

Population dynamics of M. donacis

There is little information on the population dynamics of *M. donacis*. Only Dudley *et al.* (2007) described their abundance in wild reed plants in California during spring. As in our study, California's aphid populations decreased at the end of spring, which was attributed to the presence of coccinellid larvae on the shoots. Our observations agree with those of Dudley & Lambert (2007), who recorded *M. donacis* densities of up to 500 individuals leaf⁻¹ in wild reed plants.

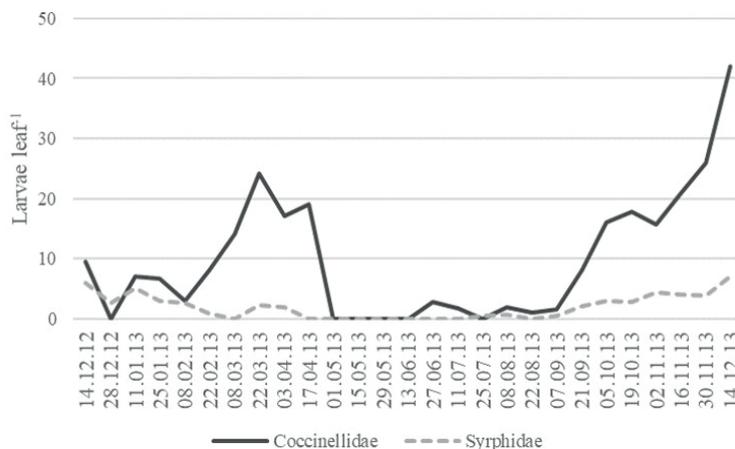


Figure 2. Coccinellidae and Syrphidae larvae leaf⁻¹ on cultivated *Arundo donax* plants.

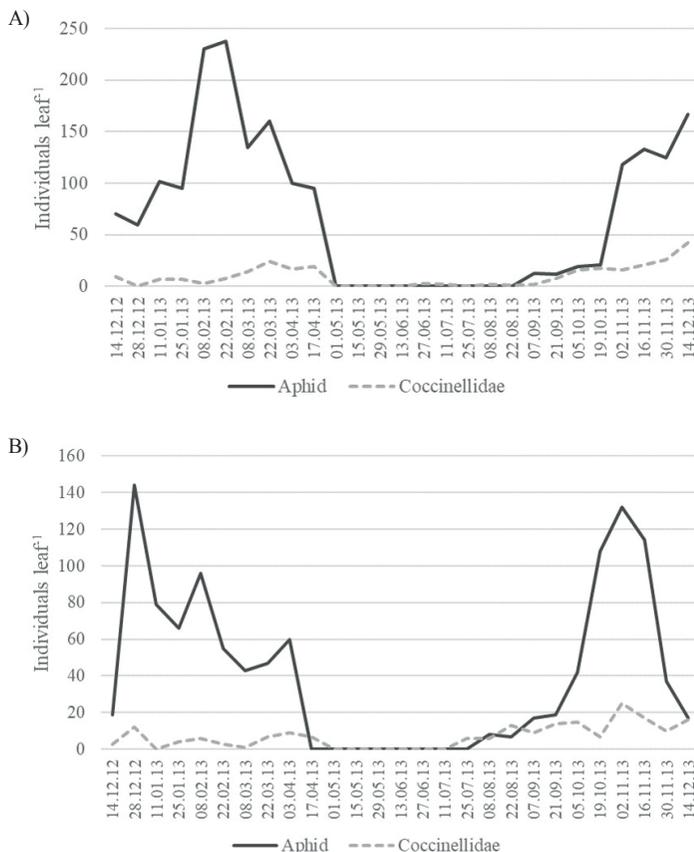


Figure 3. Population density of *Melanaphis donacis* (—) and coccinellid larvae (---) leaf⁻¹ in cultivated (A) and wild (B) *Arundo donax* plants.

The feeding preferences of *M. donacis* and coccinellid larvae observed in this study are similar to those of other herbivores that feed on *A. donax*. Spencer *et al.* (2007) indicated that this feeding strategy is due to the high C:N ratio in the tissues of the plant, which can reach up to 22:1 in mature individuals, making it undesirable to herbivores. Although the higher palatability of new shoots would allow some consumption, the rapid growth of *A. donax* makes this a short-term risk (Dudley *et al.*, 2007).

In addition to being affected by the C:N ratio, insect growth, fecundity and survival are affected by the N content in leaves and other plant structures where aphids feed. Thus, herbivores compensate for the poor quality of plant materials with a

C:N ratio >17 by increasing their consumption (Spencer *et al.*, 2011).

Only minor levels of visual damage by *M. donacis* have been reported in *A. donax*, principally in the form of occasional foliar chlorosis on wild plants (Dudley & Lambert, 2007). Our observations of chlorosis on leaf edges and tips and the reddish to violet colors on leaf tips may not be due to aphids. However, when the *M. donacis* population increased on the leaves, the excretion of honeydew also increased, and the level of sooty mold increased until the surface of the leaves was completely covered during the period of the highest aphid abundance.

M. donacis has also been associated with several ants that consume aphid honeydew and protect

the aphids from predatory arthropods, allowing the establishment of large aphid colonies (Dudley & Lambert, 2007). This symbiotic relationship was also observed in our study.

Other aphids have been observed on Poaceae bioenergy crops. Ingwell *et al.* (2014) suggested that *Rhopalosiphum maidis* (Fitch), 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. Bradshaw *et al.* (2010) found *Sipha flava* (Forbes) and *R. maidis* on *Miscanthus x giganteus* in the USA and noted that both aphids had the potential to damage young plants, as they do in other crops, so they could become a problem with economic relevance in energy crops.

These studies must be considered when studying the potential of *A. donax* as an energy crop in Chile. Since there is no information concerning the aphid species associated with new Poaceae crops used for bioenergy purposes, it is necessary to study the effects of aphids on these crops as well as the utilization of these crops and their wild populations as hosts for many small-grain aphids (Burd *et al.*, 2012) and their natural enemies.

Predators of M. donacis

Coccinellidae includes numerous predators that are highly valued for their natural and biological control of pests, particularly aphids. One larva consumes from 300 to 500 aphids during its development. In general, adults are less voracious and consume approximately 100 aphids a day, but this number is very variable depending on the host plant, temperature, season, species, size, developmental stage, physiological condition and density of aphids and coccinellids (Nichols, 2008).

Most of the coccinellids found in our study are recognized as active and important predators of aphids. For example, *E. connexa*, a very common

coccinellid in Chile, exhibits high population density during spring and summer, as does *H. convergens*, a frequent coccinellid in the Metropolitan Region, especially at the beginning of autumn (González, 2006).

Syrphid larvae prey on a variety of arthropods, mainly aphids, of which they consume several hundred during their growth. Adults feed on nectar and pollen in addition to the honeydew excreted by aphids (Smith *et al.*, 2008). The only species identified was *Allograpta pulchra* (Shannon), the most common in the Metropolitan Region (López *et al.*, 2012). It is possible that no more syrphid species were found on *A. donax* due to the absence of flowers with nectar for feeding adults.

Frchette *et al.* (2007) suggested using predatory syrphids in integrated pest management, especially for aphid management (López *et al.*, 2012), and Weems (2000) found that dense populations of *Allograpta obliqua* (Say) larvae can control 70-100% of aphid populations with an approximate consumption of 34 aphids day⁻¹.

Relationship between aphids and their predators

Predation on aphids by their natural enemies regulates aphid density and keeps populations at tolerable levels during crop development. This benefits growers economically by decreasing the growth rate of pest populations, provided that the population density of the natural enemies is maintained at levels sufficient to achieve this effect (Blackman & Eastop, 2000).

Generalist predators such as coccinellids have an immediate effect on the population dynamics of aphids but reduce aphid populations only when these predators are numerous and adjust their life cycle according to the availability of aphids. However, aphids reach equally high densities when generalists are the only abundant natural enemies as when no enemies are present (Snyder & Ives, 2003).

It is evident that some predators have high potential as aphid biological control agents because they are able to keep aphid populations below the economic damage threshold. Therefore, the ef-

fect of *M. donacis* population levels on *A. donax* yields should be evaluated to support pest control decision making.

Resumen

N. Undurraga, J.E. Araya, F. Zuazúa, y M.F. Alonso. 2020. Dinámica poblacional de *Melanaphis donacis* (Hemiptera: Aphididae) y sus depredadores Coccinellidae y Syrphidae en *Arundo donax* L. Int. J. Agric. Nat. Resour. 117-125. La densidad del áfido *Melanaphis donacis* (Passerini) fue estudiada en parcelas experimentales de *Arundo donax* (L.) en el Campus Antumapu de la Universidad de Chile, La Pintana (33° 34' 8" S 70° 38' 40" W) y en poblaciones silvestres de Rinconada de Maipú (33° 30' 0.17" S and 70° 49' 12.25" W), ambos en la Zona Mediterránea de Chile. Los muestreos comenzaron a la primera colonización de las plantas por el áfido en Diciembre 14, 2012 y continuaron cada 15 d hasta Diciembre 14, 2013. Las muestras fueron tomadas de la 3^a hoja desde el ápice para un total de 36 muestras para cada fecha de muestreo. La presencia del áfido ocurrió durante toda la temporada de crecimiento de *A. donax*, especialmente en verano, con mayores densidades en las parcelas experimentales que en las poblaciones silvestres, con medias de 243 y 147 áfidos hoja⁻¹, respectivamente. Los principales enemigos naturales registrados fueron los coccinélidos *Eriopis connexa* (Germar) e *Hippodamia convergens* (Guérin-Méneville) y el syrífido *Allograpta pulchra* (Shannon). Las poblaciones de depredadores siguieron las curvas de crecimiento poblacional del áfido y de las plantas de *A. donax*.

Palabras clave: *Allograpta pulchra*, cáñamo gigante, cultivos energéticos, *Eriopis connexa*, *Hippodamia convergens*.

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