

Invasion of *Hovenia dulcis* Thunb. (Rhamnaceae) in Southern Brazilian subtropical forest

Invasão de Hovenia dulcis Thunb. (Rhamnaceae) em floresta subtropical no Sul do Brasil

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ABSTRACT

This study aimed to evaluate the level of *Hovenia dulcis* (oriental-raisin-tree) invasion in an area under ecological restoration (area 1) and in a fragment area of araucaria forest with semi-deciduous seasonal forest (area 2), both located in the municipality of Dois Vizinhos, Paraná. In 1, the techniques of passive restoration, nucleation and plantation of high diversity of tree species were analyzed. In 2, there was a survey of young and adult individuals. In 1, 12 plots of 2,160 m² were sampled (25,920 m² sampled). In 2, 30 plots with an area of 30 m² each were sampled (900 m² sampled). In 1, the greatest proliferation of the species, with density of 334.5 plants.ha⁻¹, was observed in a period of 17 months. In 2, the invasive potential of *H. dulcis* was high, with a mean of 911 young plants.ha⁻¹ and 111 adult plants.ha⁻¹. Higher invasive capacity occurred in areas of initial and secondary stages of secondary succession. Sites that present hydromorphic soils and especially those where there are pteridophyte, bromeliaceae and bambusoid groups, practically prevent the development of young individuals of *H. dulcis*. The species presents great invading potential in areas under ecological restoration and in forest fragments, thus, attention in the monitoring and control of the species is recommended.

Keywords: ecological restoration; invasive alien species; secondary forest.

RESUMO

Objetivou-se avaliar o nível de invasão de *Hovenia dulcis* (uva-do-japão) em área sob restauração ecológica (área 1) e em área de fragmento de mata de araucária com floresta semidecidual estacional (área 2), ambas situadas no município de Dois Vizinhos, Paraná. Na área 1, foram analisadas as técnicas de restauração passiva, nucleação e plantio de alta diversidade de espécies arbóreas, numa amostra de 12 parcelas de 2.160 m² (25.920 m² amostrais). Observou-se a maior proliferação da espécie, com densidade de 334,5 plantas.ha⁻¹, em um período de 17 meses. Na área 2, houve levantamento dos indivíduos jovens e adultos. Foram amostradas 30 parcelas com área de 30 m² cada (900 m² amostrais). O potencial invasor de *H. dulcis* foi alto, com média de 911 plantas jovens.ha⁻¹ e 111 plantas adultas.ha⁻¹. Ocorreu maior capacidade invasora em áreas de estágio inicial e médio de sucessão secundária. Locais que apresentam solos hidromórficos e especialmente aqueles onde há grupos pteridófitas, bromeliáceas e bambusóides praticamente impedem o desenvolvimento de indivíduos jovens de *H. dulcis*. A espécie apresenta grande potencial invasor em áreas sob restauração ecológica e em fragmentos florestais. Assim, recomenda-se atenção no monitoramento e no controle da espécie.

Palavras-chave: espécies exóticas invasoras; florestas secundárias; restauração ecológica.

Recebido em: 24 set. 2017

Aceito em: 8 abr. 2018

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INTRODUCTION

Biological invasion causes serious problems to the diversity of life in the planet, being the second leading cause of loss of biodiversity and extinction of local species. Most environmental problems are absorbed with time, but this does not occur with biological invasion processes. Biological invasion occurs when a species, that is not part of a specific ecosystem, invades it and causes changes in the structure and functioning of this environment (VALÉRY *et al.*, 2008). It is estimated that between 0.1% and 1% of introduced species become invasive and, although at lower percentages, the biological invasion represents one of the main causes of biodiversity loss (HELENO *et al.*, 2010).

The highest diversity and abundance of invasive alien plants from temperate climate into Brazil is located in the southern part of the country (LORENZI *et al.*, 2003) where several of these species have been cultivated for timber purposes and urban forestry (GUIDINI *et al.*, 2014). Among these, *Pinus* sp., *Ligustrum* sp. and *Melia azedarach* L. are some of the main pervasive botanic taxa of forest fragments (BECHARA *et al.*, 2013; INSTITUTO HÓRUS DE DESENVOLVIMENTO E CONSERVAÇÃO AMBIENTAL, 2015a). The Oriental raisin tree, *Hovenia dulcis* Thunb. (Rhamnaceae) also is one of those species, causing serious problems, especially in the southwestern region of the State of Parana, as it has rapid proliferation in degraded areas and understory of native forests, usually associated with their planting for wood use or as windbreaks (CARVALHO, 1994).

Historically, *Hovenia dulcis* has been cultivated in Argentina, Paraguay and in southern Brazil, mainly in regions of climate types: Cfa, Cfb and Cwa, according to Koppen classification (ALVARES *et al.*, 2013), in isolation or in small stands. Nowadays, in Brazil, along the basin of river Uruguay, in the states of Santa Catarina, Rio Grande do Sul and Parana, small plantations of *H. dulcis* are common in farms, implanted by seedlings or possibly by direct sowing into the field (RIGATTO *et al.*, 2001).

On rural properties, it is important that the farmers have knowledge of the harmful effects of this biological invasion in order to enable them to take actions of control. This control must be based on technically tested methods that will, at first, make a survey of the degree of the invasive species infestation in the ecosystem and, after, undertake its control. This can be made by cutting or provoking the death of standing trees, among other methods.

On the other hand, this species has high economic potential. The knowledge of their population's dynamics, diameter's distribution as well as invasion control techniques and exploitation with minimal impact should be considered.

Thus, the objectives of this study were: i) to evaluate the incidence of *H. dulcis* in degraded areas under different ecological restoration technologies: passive restoration, nucleation and planting a high diversity of native species; ii) to assess the degree of infestation of *H. dulcis* in a forest fragment in southwestern Paraná, correlating the incidence of individuals to environmental variables such as successional stage and soil hydromorphism; and iii) to provide information for monitoring and eradication programs of the invasive species in the studied forest.

MATERIAL AND METHODS

ECOLOGICAL RESTORATION AREAS

The search was conducted in an area of 7.2 ha, located within the farm of Federal Technological University of Paraná, *Campus* Dois Vizinhos, Southern Brazil (figure 1A). The region is located on the third Plateau of Paraná, Southwestern region in the state of Paraná, with an average altitude of 500 m, latitude 25°44'S and longitude 53°04'W (GERBER *et al.*, 2017).

According to Koppen, the climate is Cfa (humid subtropical mesothermal), without a dry season, with an average temperature of the coldest month less than 18°C and average temperature of the warmest month greater than 22°C. The annual rainfall of Dois Vizinhos is 2.044 mm, August and March are the driest months of the year and October the wettest. The soil belongs to the typic hapludox (red latosol) (ALVARES *et al.*, 2013).

The experimental area was established in December 2010, when the area was divided into 4 blocks which received three treatments each: Treatment T1 – passive restoration; Treatment T2 – nucleation; and Treatment T3 – planting of a high diversity of native tree species, totaling 12 plots of 40 x 54 m each, subdivided into plots of 10 x 9 m.

Treatment 1 (passive restoration) occurred without human intervention, through the natural regeneration of the present species in the plots.

Treatment 2 (nucleation) was developed in plots and each one included a set of nucleation techniques, based in Reis *et al.* (2010), comprising: seed bank of transposition and seed rain, with 6 repetitions each one, with a dimension 1 x 1 m; 24 Anderson's groups using a spacing of 1 m between plants, 5 trees *per* group, totaling 120 seedlings *per* plot, these belonging to 36 native species to the region; 12 core groups of 3 x 4 m with a coverage of pigeon pea (*Cajanus cajan* (L.) Huth.; 6 islands of bromeliads (*Bromelia antiacantha* Bertol.) measuring 1 x 1 m (5 bromeliads *per* group); and 2 artificial perches like a "vine tower" with a height of 10 m.

Treatment 3 was planting plots of high diversity of native tree species and the model of filling lines and diversity (*sensu* RODRIGUES *et al.*, 2009) was used, with spacing of 3 m between rows and 2 m between plants. There were 70 introduced native species, interspersed, so that the filler species (pioneers, shade trees) protected the native diverse species (non-pioneering, shaded trees) and there were 18 lines with 20 plants each, resulting in 360 seedlings *per* plot.

To sample the biological invasion by *H. dulcis*, we used a graduated scale of 5 by 5 cm to perform the measurement of the plant total height. After the measurements and density recording, we removed (on humid days) each weed (with roots) with the lever aid, during two different periods: May 2012 (population with 17 months of age) and May 2014 (population with 24 months of age). After removal, the plants were taken out of the plot and eliminated. The results of the *H. dulcis* impact assessments in each ecological restoration technique were subjected to analysis of variance by R program. Data were compared by Tukey test at 5%.

FOREST REMNANT

The region of the studied forest has a gentle undulated topography, which is predominantly comprised of Red latosol, Oxisol, Cabisol e Nitosol (EMBRAPA, 1984).

It is a fragment of araucaria forest (WADE *et al.*, 2003), with influence of semi deciduous forest, in a medium stage of regeneration (approximately 25 years old), located in the Federal Technological University of Paraná, *Campus* Dois Vizinhos. This fragment has an area of 31.13 ha and there is a biological invasion of *H. dulcis* in almost the entire extent (figure 1B).

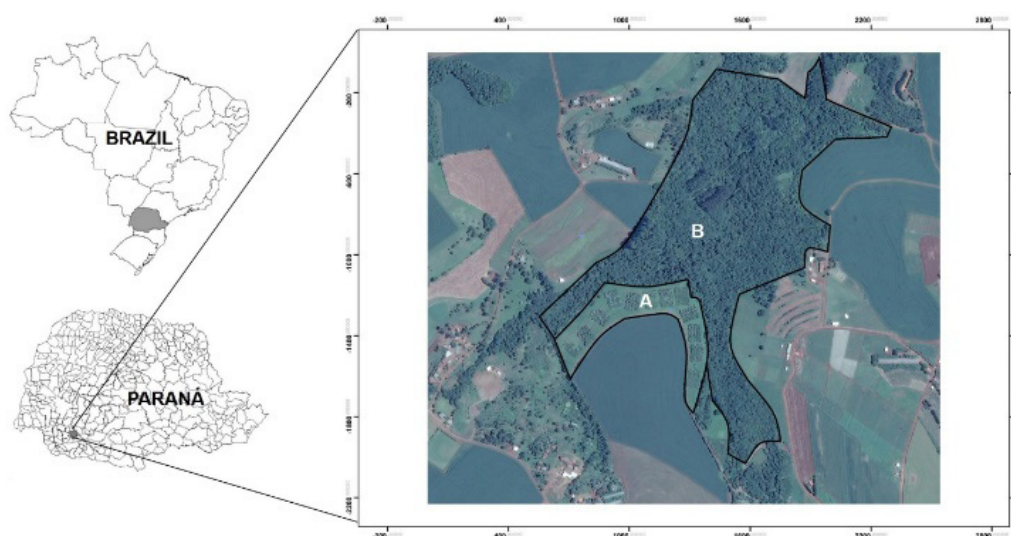


Figure 1 – Experimental area at the Federal Technological University of Paraná – *Campus* Dois Vizinhos, Brazil. A) Ecological restoration areas; B) Forest remnant.

The area was previously used for agricultural activities, later abandoned and then the process of natural regeneration of the forest began. There is, inside this forest, a reforestation field of oriental raisin tree (*H. dulcis*) which covers an area of 0.83 ha, aged of about nine years. This field is probably one of the source areas of the invasion by *H. dulcis*. Several reproductive adult *H. dulcis* are found in places around the forest, especially in pastures and on forest edges.

To assess the degree of infestation, there was an inventory of the invasive individuals of *H. dulcis*, which were sampled in 30 plots with dimensions of 10 x 3 m, covering an area of 30 m² for each sample unit, totaling a sample total area of 900 m². The plots were allocated along a trail, every 50 m. For the installation of the plots, a border of 10 m away from the trail was always left, trying to minimize potential interference.

The presence of adults and young individuals of *H. dulcis* was assessed and individuals with DBH greater than or equal to 0.7 m. were considered adults.

For the computation of trees, all individuals with at least 0.3 m high were considered. The environmental variables collected in each plot were: successional stage of the forest (initial, average or advanced) according to CONAMA (1993); presence of humidity in the soil established by the distance of the nearest water course (0-5 m, 5-10 m and above 10 m from the beginning of the parcel to the water course); presence of specific ecological groups in the plot such as ferns, bromeliads and bambusoids and the presence of flowers or fruits in adult individuals.

RESULTS

ECOLOGICAL RESTORATION AREAS

The results obtained in the areas of ecological restoration demonstrate that there was a greater incidence of *H. dulcis* in passive restoration areas. After 17 months of isolation of the ecological restoration area, we encountered 334.5 plants.ha⁻¹ (table 1).

Table 1 – Incidence of oriental raisin tree (*Hovenia dulcis*) in areas with different ecological restoration technologies.

Ecological restoration technologies	Number of individuals	
	17 months	24 months
T1 (passive restoration)	289 a	92 a
T2 (nucleation)	0	0
T 3 (filling lines and diversity)	1 b	5 b
Total	290	97

In the passive restoration area, there was a lower incidence of *H. dulcis* individuals after 24 months from the previous control but still high compared to the other two technologies. At the nucleation area there were no *H. dulcis* individuals during the study period. In the filling lines and diversity area, there was an increase in the number of *H. dulcis* individuals from 1.2 to 5.8 plants. ha⁻¹ along the period.

FOREST REMNANT

The results of the sampling units in the semi deciduous forest remnant show that there was a greater number of young individuals compared to adult individuals of *H. dulcis*. Adults amounted to an average of 111 plants.ha⁻¹ and young individuals to an average of 911 plants ha⁻¹ (table 2).

Table 2 – Number of adult and young individuals of *Hovenia dulcis* in a fragment of semideciduous forest of different successional stages in Dois Vizinhos, Paraná, Brazil.

Successional stages	Adults (Number ind./ha)	Young (Number ind./ha)
Initial	67 b	3267 a
Medium	121 a	500 b
Advanced	111 a	0

This result indicates that the species is proliferating in the forest remnant.

The average height of adults was 13 m and the average diameter 12.9 cm. The relationship between total height and diameter of adults is in figure 2. Most of the diameters were between 4 and 16 cm, which features a large number of mature individuals of *H. dulcis* with potential development in the forest remnant. The relationship was linear, showing that the trees of this species are in a rapid growing process. The equation that best describes this relationship is: $y = 11.89\ln(x) - 17.45$.

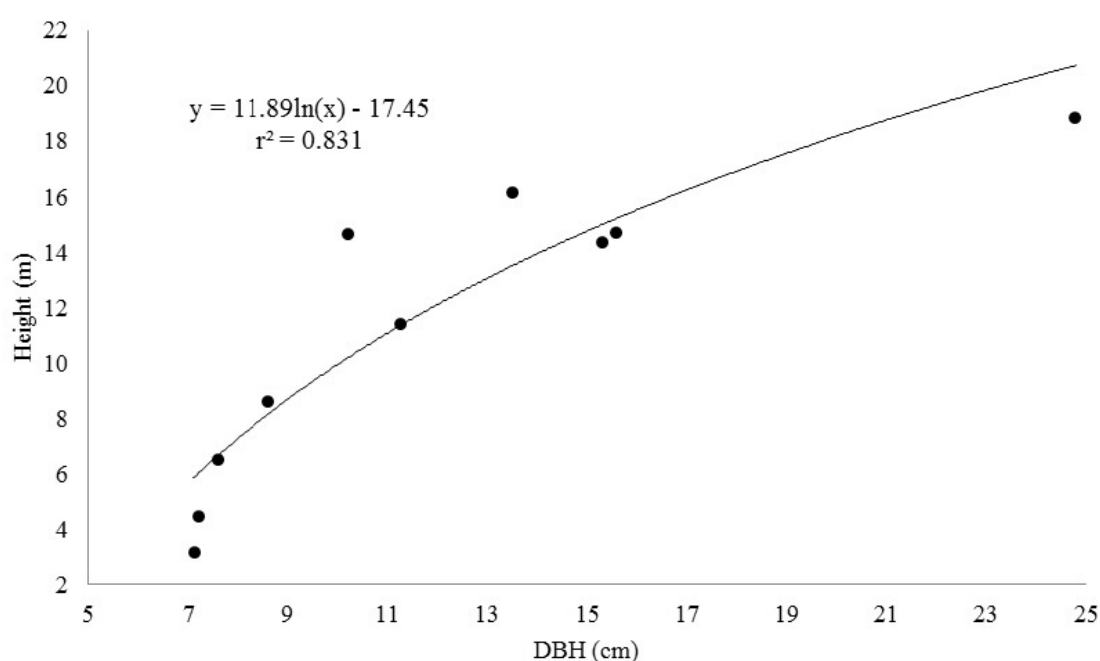


Figure 2 – Relation between the diameter at breast height (DBH) with the total height of *Hovenia dulcis* adult individuals, considering all successional stages studied.

Of the 30 plots inventoried, 10% were in advanced stages of secondary succession, 17% in early stages and the remaining 73% of the plots were in intermediate stages of regeneration.

The correlation between the presence of moisture in the soil with the occurrence of *H. dulcis* occurred in 13% of the sample units with hydromorphism and in 87% of the sample units without hydromorphism. In humid places, the amount of *H. dulcis* individuals decreased, due to the soil characteristics and also to the type of vegetation in these places where it was common to find aggressive species, like the fern *Blechnum* sp., and the bromeliad *Bromelia antiacantha*, which have a large degree of soil cover.

DISCUSSION

The average height and diameter of adults, considered small even for adult individuals, explains the fact that 27% of the trees are not bearing fruits yet. They are young or have not reached the canopy, where there is enough light for the formation of flowers and fruits. Schumacher *et al.* (2008)

observed, in a population of *H. dulcis* in Santa Maria (RS), that flowering occurs from August to February and fruits between March and October, respectively. Eleotério *et al.* (2012), analyzing the growth in diameter, height and volume of *H. dulcis*, said that this species decreases in rate, with maximum increment up to five years of age and maximum average increase up to 11 years.

Because it is an heliophytic species, *H. dulcis* tends to thrive less with decreasing ambient light, even with a significant number of mature trees in successional stages. The advanced successional stage of a forest practically prevents development of *H. dulcis* and average stages also inhibits it, although these stages do not fully protect the forest from an *H. dulcis* invasion.

An indicator of the large amount of potential young individuals of *H. dulcis* in remaining forests is the quantity of seeds produced by the trees. According to the present inventory, 73% of adults are producing fruits, demonstrating thus the potential of invasion that the species have in the environment, because birds and mammals aid in their dispersal. The time of data collection was detected as part of the period of fruiting and dispersion for the species in the region, that is, between the months of February and March.

Ziller (2001) lists some hypotheses to explain the fact that some environments are more susceptible to biological invasion, among which are the following: 1 – the lower the diversity and natural wealth of an ecosystem, the more susceptible to invasion it will be because of vacant niches (which will be occupied by alien species); 2 – invasive species, free of competitors, predators and parasites of their areas of origin, would have competitive advantages over native species; 3 – the greater the degree of disturbance of the ecosystem, the easier the dispersal and establishment of the invasive species, especially when there is a reduction in the natural diversity by species extinction or over exploitation. Several studies have demonstrated that the greater the degree of disturbance to the ecosystem, the easier it becomes for biological invasions (ZENNI & ZILLER, 2011; BECHARA *et al.*, 2013; JOSHI *et al.*, 2015). Nascimento (2008), studying the pervasive behavior of trupillo (*Prosopis juliflora* (Sw.) DC.) in the flood plains of the biome *Caatinga*, reports that the degradation of this environment facilitates the entry of the mentioned invasive species and that in areas where the natural ecosystem is preserved, the invasive species can not disperse indiscriminately nor occupy the space of native vegetation. Zanchetta & Diniz (2006), studying the biological contamination by *Pinus* spp. in three different areas in the Ecological Station of Itirapina (SP), reported that some environments tend to be more susceptible to biological invasion than others, and listed three possible factors to explain this susceptibility: a) reduction of natural diversity; b) absence of competitors, predators and parasites for the invasive species and c) in the case of pioneer species, the fact that open environments are more susceptible to invasion.

According to Instituto Hórus (2015b), *H. dulcis* has a rapid growth in the early years of age, with potential to spread into forest areas in Brazil, competing for light, nutrients, space and with native species. Today the species is established not only in the experimental area as well as throughout the city of Dois Vizinhos (PR) and region. *H. dulcis* has easy dispersion through riparian forests and, in some places in Paraná, it already constitute the dominant stratum of alluvial forests, aggressively taking the space of several native species.

CONCLUSION

In the passive restoration treatment (Treatment 1), *H. dulcis* proliferated more, with a density of 334.5 plants.ha⁻¹, in only 17 months after the initial cleaning of the plots. In the nucleation and planting of high diversity of tree species treatments (treatments 2 and 3), there were relatively low levels of invasion by *H. dulcis*. However, it is pointed out that if *H. dulcis* is not eliminated, it will probably constitute a new infestation focus in the future. A permanent control of this species is recommended for the decontamination of protected natural areas, avoiding new catalysts of biological invasion.

H. dulcis has more success in biological invasion of secondary forests at early and medium stage of succession. The invasive potential of *H. dulcis* was high as the average number of young individuals found in the forest fragment was 911 plants.ha⁻¹ and that of adults, 111 plants.ha⁻¹, most of them (73%) bearing fruit. In advanced successional stages of forest, *H. dulcis* lost ground to

native species, with the decrease of seedlings, from the advanced stages to the medium and early stages. These facts show that environments disturbed by human activities are the most susceptible to biological invasion of *H. dulcis*.

Places that have hydromorphic soil and especially those where there are specific ecological groups such as ferns, bromeliads and bambusoids, practically prevent the development of young individuals of *H. dulcis*. The fact that humid formations with presence of *Bromelia antiacantha* are capable of inhibiting the growth of *H. dulcis* can be a management recommendation: planting this regional native aggressive species to contain the invasion. The *Blechnum* groups are also strongly associated with hydromorphic land, aiding to prevent thriving of *H. dulcis*. It is thus recommended, after monitoring and controlling *H. dulcis*, to introduce an enrichment of native plants in the region, including bromeliads groups, ferns, bambusoids and other vegetation.

The depicted situation deserves attention and care as it shows the gravity of the invasion of *H. dulcis* and its potential damage in the future. Measures to circumvent the situation are suggested.

ACKNOWLEDGEMENTS

We thank the Conselho Nacional de Desenvolvimento Científico e Tecnológico – CNPq – (National Council for Scientific and Technological Development) Brazil for financial support (Process 575081/2008-2). To the field interns Natália Aires, Hemílio Schroeder, Tayna Ribeiro, Vinicius Rubetti and editing Rory Kawika O'Connor.

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