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Arundo donax L. Sustainable Uses To Control The Negative Growth Effects In Wildlife

Arundo donax L. Usos sostenibles para controlar los efectos negativos del crecimiento en la vida silvestre

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Resumen

La planta *Arundo donax* L., conocida comúnmente como carrizo, es una especie abundante en regiones cercanas a cuerpos de agua. Se puede considerar como especie invasora cuando crece en regiones no habituales y afecta la biodiversidad de la zona donde se desarrolla; por otro lado, se adapta fácilmente a condiciones ambientales adversas y diversas, así que puede desarrollarse en climas cálidos, fríos, húmedos o secos. Su método de reproducción es asexual, por lo que cualquier fragmento de la planta que sea transportado por el agua y/o el aire puede desarrollarse en el sitio donde llegue. Para controlar el crecimiento indiscriminado de la planta se propone hacer un uso de las cañas, hojas, rizomas o de la planta completa. En el presente documento se incluyen algunos usos sustentables que permitan disminuir la flora invasora tales como: material de construcción de casas en zonas rurales, combustible y materia prima para producción de biomasa, biogás, bioetanol mediante bio-refinerías, tratamiento de aguas residuales, fito-remediación, instrumentos musicales, extracción de compuestos para las industrias de alimentos, farmacéutica y cosmética.

Palabras clave: carrizo, preservación ecológica, planta invasiva, usos sustentables.

Abstract

The *Arundo donax* L. plant, commonly known as reed, is an abundant species in regions close to water bodies. It can be considered an invasive species when it grows in unusual regions and affects the biodiversity of the area where it develops; on the other hand, it adapts easily to adverse and diverse environmental conditions, so it can develop in hot, cold, humid, or dry climates. Its reproduction method is asexual, so any fragment of the plant that is transported by water and/or air can develop in the place where it arrives. To control the indiscriminate growth of the plant, it is proposed to make use of the canes, leaves, rhizomes, or the whole plant. This document includes some sustainable uses to reduce invasive flora such as construction material for houses in rural areas, fuel and raw material for biomass production, biogas, bioethanol through bio-refineries, wastewater treatment, phytoremediation, musical instruments, extraction of compounds for the food, pharmaceutical, and cosmetic industries.

Keywords: carrizo, ecological preservation, invasive plant, sustainable uses.

INTRODUCTION

Arundo donax L. is a fast-growing hardwood perennial plant and well adapted to several climatic conditions; it can grow in wetlands over a wide pH range from 5.5 to 8.3, drought, low oxygen, salinity, and heavy metals (Saynik and Moholkar, 2020; Cocozza et al., 2020). Several common names are giant cane, giant reed, Harwood (Zuccaro et al., 2021). It spreads at a high rate because of the asexual reproduction by steams and rhizomes; it belongs to the Poaceae family, Arundinoideae subfamily, and the Arundineae tribe (Ge et al., 2016).

Due to its fast-growing nature and abundance, it becomes a threat to native species. As a principal invader plant *A. donax* L. can generate negative consequences in the environment as increasing the risk of flooding and fire, use of the prodigious quantity of water, and reducing habitat value for wildlife; but also, it can be used as a primary sink to eliminate macro anthropogenic plastics in sandy beaches and counter some of the environmental negative effects using their branches (Battisti et al., 2020). Thus, it needs to control the spread and growth; few investigations are reported regarding the *A. donax* L. biocontrol where flies belonging to *Cryptonevra* sp. can kill the *A. donax* L shoots, it attacks the plant at an early stage of its development and targets the tight whorl of the leaves of the new shoots, which is not affected by the other biological control agents (Escobar et al., 2020). Its negative effects on plant fitness would thus be additive or synergistic, but not redundant, with the effects of these agents. Another important option is the "control through utilization" and some strategies that can be used to accomplish this objective are discussed in the present document.

Building Industry

Since ancient times, in Mexico, *A. donax* L. has been used for house building using the dry steams as a sealing component (in substitution to the wood steams); also, the crushed steams are component of the adobe bricks, that are made of native soil, with the addition of an organic additive (*A. donax* L. crushed steams) mixed with water until getting a stiff mix, the forms are filled with the mix and left to dry in an area sprinkled with sand using sunlight (Dominguez, 2011).

Houses built with adobe are eco-friendly because the bricks are thermal, it preserves the cool weather inside the house, so they do not need the air condition to regulate the temperature and the energetic consumption significantly decreases (Malheiro et al., 2021). This characteristic is desirable in the arid zones, where the temperature rises about 35-40 °C during the day, but at the night the temperature can decrease to 2-5 °C; or in places where the summer and/or the winter are so hard.

Unfortunately, adobe bricks are not recommended for high floor constructions because the mechanical resistance is not optimal for these designs. There is needed more engineering investigation to achieve the optimal resistance and improve the construction of large buildings using adobe bricks

Another way to use the steams is to build fences in the rural areas, dry steams are tied together and placed in the limits of the properties. These fences have low cost, but also the durability is low in comparison with the steel or wood fences, according to the people experience.

Biorefinery fuels

A. donax L. is a high-yielding energy plant, which can yield 15-49 Mg/ha biomass (dry weight) during fall and winter harvest seasons and the elemental carbon and fixed carbon contents of this biomass are around 44.76 and 15.36 % respectively, it means that the plant has higher water and nitrogen use efficiency and unusually high saturation levels in its photosystem than others C3 plants (Yang et al., 2020).

To get an excellent biomass biodegradability the pre-treatment is a desirable step before the anaerobic digestion, steam cooking, and steam explosion are recommended techniques (D´Imporzano et al., 2018); acid/alkaline pretreatments and as well as Pre-treatment to Pyrolysis (Tang et al., 2020; Saynik and Moholkar, 2020).

Another use for the plant is biogas production, in combination with other crops and/or in co-digestion with animal slurries (Vasmara et al., 2021). The disadvantage of *A. donax* L. is the low starch content because the plant does not produce seeds or other energy reserves but the fast growth and, as consequence, the high biomass productivity per hectare determines that the bio-methane production is higher than other crops as corn, sorghum, rye and triticale (Corno, Pilu and Adani, 2014).

The presence of siloxanes in the biogas is an undesirable problem derived from the *A. donax* L. biogas production, these compounds are volatile and generated from the silicon during the anaerobic digestion; are dangerous to the mechanical structure of reactors and motors (Payá et al., 2018).

Another compound derived from the *A. donax* L. biomass is bioethanol production, this is attributed to the fiber concentration and the yield is higher than other crops due to the biomass quantities. As well as anaerobic digestion, before the bioethanol production is the saccharification to remove recalcitrance (Jámbor and Török, 2019).

The use of the *A. donax* L. as fuel produces some problems related to the chemical composition, mainly the ashes quantity, that reduces the thermal conversion efficiency instead of the high yields; also, there is produced some harmful compounds as NOx, HCl, SO_2, CO, and fine dust (Payá et al., 2018; Corno, Pilu and Adani, 2014).

Wastewater treatment and phytoremediation

In the treatment and the purification of wastewater activated carbon can be obtained from *A. donax* L. plants. As well, from the fiber, some resins are obtained and its great adsorption capacity for ionic pollutants such as NO_3^-, SO_4^{2-}, PO_4^{3-}, NO^{2-}

and AsO^{2-}.

Methylene blue is an important textile dye, that can contaminate the effluents and cause diverse ecological disorders as sunlight block and as consequence the photosynthesis of the aquatic organisms, in humans an excessive dosage leads to nervous system disorder, kidney and liver diseases, skin allergies, among others (Lim, 2021); Üner (2019) reported that activated carbon obtained from *A. donax* L. can adsorb the dye with the best results at 23, 35, and 45 °C, but also can be used to hydrogen storage reaching values of 12.87, 0.11 and 0.09 mg/g under the pressure of 805 mmHg at 77, 273, and 298.15 K, respectively.

Phytoremediation is a sustainable technology that uses plants that can remove toxic metals from the soil, water, and recently from the air; in some cases, they can also accumulate heavy metals (Cadmium Cd, chromium Cr, cooper Cu, nickel Ni, and lead Pb) to make the removal effect (Tian et al., 2009). The importance is due to the toxicity that metals can promote if they enter the organism's bodies and cause diverse diseases or can be absorbed by the plants that exhibit the contamination by diverse mechanisms (Yan et al., 2022).

A. donax L. is used because it can tolerate heavy metals concentrations, Cano-Ruiz et al., (2020) reported that the heavy metals are accumulated mostly in subterranean organs with the following concentrations: cadmium 0.5 mM, chromium 0.2 mM, nickel 0.5 mM and lead 1 mM. These reports suggest the use of the plant to solve polluted soils.

Alternative uses

Because of the high plant productivity, the industrial applications are wide, due to the economic return that represents, and some examples are reported in this document.

Few reports mentioned the use to produce musical instruments such as flutes and related instruments or for the mouthpieces of oboes, clarinets, bassoons, and saxophones (Obataya and Norimoto, 1999; Ukshini and Dirickx, 2020). Otherwise, the high cellulose contained in *A. donax* L. is also used to obtain crystalline micro cellulose and for the paper industry (Bessa et al., 2021).

For food, pharmaceutical, and cosmetic industries the *A. donax* L. plants can be used to obtain xylose and levulinic acid production (Di Fidio, Antonitti and Galletti, 2019), as well as γ-valerolactone (Raspolli-Galletti et al., 2013). These compounds are used to obtain solvents, antifreeze, food flavorings, and intermediates for plastic and pharmaceutical products; γ-valerolactone is also used as an additive for ethanol and diesel fuel. Also, some alkaloids can be isolated from *A. donax* L., the most representative are arundamine and donasine that are effective to reduce fever (Li et al., 2007; Jia et al., 2008).

Solid-state fermentation is eco-friendly biotechnology, where a fungal strain growth using as support-substrate a selected residue (mainly agro-industrial wastes) to give additional value to the residues and obtain an extra product, it can produce enzymes, polyphenols, carbohydrates, proteins, among others by the solid-state fermentation (Melendez-Renteria et al., 2012). *A. donax L.* fermentation is not reported yet, but it can support the fungal growth and some important metabolites can be obtained, more investigation is needed to elucidate the potential of the *A. donax* L. plant.

CONCLUSIONS

A. donax L. can be considered as an attractive plant because of the production low cost and high biomass yield, adaptation to several geographical and soil types, ecological applications, and alternative uses to remove important toxic compounds from the soli and wastewater. But at the same time, the rapid growth represents a threat to the environment because of the nutrient and water consumption, with the consequent decrease in the wildlife species.

Applications described in the document are an alternative to the *A. donax* L. use but is necessary to be careful about the plant harvest to avoid cross-contamination in the surrounded lands or to diminish the presence in places where the plant has been an environmental problem.

REFERENCES

Battisti C, Fanelli G, Filpa A, Cerfolli F. 2020. Giant Reed (*Arundo donax*) wrack as sink for plastic beach litter: First evidence and implication. Mar. Pollut. Bull. **155**: 111179.

Bessa W, Tarchoun AF, Trache D, Derradji M. 2021. Preparation of amino-functionalized microcrystalline cellulose from *Arundo donax* L. and its effect on the curing behavior of bisphenol A-based benzoxazine. Thermochim. Acta. **698**: 178882.

Cano-Ruiz J, Ruiz-Galea M, Amorós MC, Alonso J, Mauri PV, Lobo MC. 2020. Assessing *Arundo donax* L. in vitro-tolerance for phytoremediation purposes. Chemosphere. *252*: 126576.

Cocozza C, Brilli F, Pignattelli S, Pollastri S, Brunetti C, Gonnelli C, Tognetti R, Centritto M, Loreto F. 2020. The excess of phosphorus in soil reduces physiological performances over time but enhances prompt recovery of salt-stresses *Arundo donax* plants. Plant Physiol. Biochem. **151**: 556-565.

Corno L, Pilu R, Adani F. 2014. *Arundo donax* L.: A non-food crop for bioenergy and bio-compound production. Biotech. Adv. **32**: 1535-1549.

D´Imporzano G, Pilu R, Corno L, Adani F. 2018. *Arundo donax* L. can substitute traditional energy crops for more efficient, environmental-friendly production of biogas: A life cycle assessment approach. Bioresource Technol. **267**: 249-256.

Di Fidio N, Antonetti C, Galletti AMR. 2019. Microwave-assisted cascade exploitation of giant reed (*Arundo donax* L.) to xylose and levulinic acid catalyzed by ferric chloride. Bioresource Technol. **293**: 122050.

Dominguez T. ABCs of making adobe bricks. 2011. NM State University, Guide G-521. Electronic document available in ABCs of Making Adobe Bricks (nmsu.edu).

Escobar Y, Guermache F, Bon MC, Kerdellant E, Petoux L, Desurmont GA. 2020. Biology, ecology, and impact of

Cryptonevra nigritarsis Duda, a potential biological control agent against the giant reed *Arundo donax*. Biol. Control. **147**: 104287.

Ge X, Xu F, Vasco-Correa J, Li Y. 2016. Giant reed: A competitive energy crop in comparison with miscanthus. Renew. Sust. Energ. Rev. **54**: 350-362.

Jámbor A, Török A. 2019. The economics of *Arundo donax*-A systematic literature review. Sustainability-Basel. **11**: 4225.

Jia AL, Ding XQ, Chen DL, Chao ZZ, Liu ZY, Chao RB. 2008. A new indole alkaloid from *Arundo donax* L. J. Nat. Prod. Res. **10**: 105-109.

Li X, Yang L, Chao R. 2007. Isolation and identification of dimeric indole alkaloid from rhizome *Arundo donax* L. and study on its pharmacodynamics. West. Chin. J. Pharmacol. Sci. **5**: 522:524.

Lim D-J. 2021. Methylene blue-based nano and microparticles: Fabrication and applications in photodynamic therapy. Polymers. **13**: 3955.

Malheiro R, Ansolin A, Guarnier C, Fernandes J, Amorim MT, Silva SM, Mateus R. 2021. The potential of the reed as regenerative building material-characterization of its durability, physical, and thermal performances. Energies. **14**: 4276.

Meléndez-Rentería P, Nevárez-Moorillón V, Rodríguez-Herrera R, Aguilar CN. 2012. Solid state fermentation of mexican oregano (*Lippia berlandieri* Schauer) waste. Am. J. Agri. Biol. Sci. **7**: 76-81.

Obataya E, Norimoto M. 1999. Mechanical relaxation processes due to sugars in cane (*Arundo donax* L.). J. Wood. Sci. **45**: 378-383.

Payá J, Roselló J, Monzó JM, Escalera A, Santamarina MP, Borrachero MV, Soriano L. 2018. An approach to new supplementary cementing material: *Arundo donax* straw ash. Sustainability. **10**: 4273.

Raspolli-Galletti AM, Antonetti C, Ribechini E, Colombini MP, Nassi o di Nasso, N, Bonari E. 2013. From giant reed levulinic acid and gamma-valerolactone: a high yield catalytic route to valeric biofuels. Appl. Energ. **102**: 157-162.

Tang S, Cao Y, Xu C, Wu Y, Li L, Ye P, Luo Y, Gao Y, Liao Y, Yan Q, Cheng X. 2020. One-step or two-step acid/alkaline pretreatments to improve enzymatic hydrolysis and sugar recovery from *Arundo donax* L. Energies. **13**: 948.

Tian D, Zhu F, Yan W, Xi F, Xiang W, Deng X, Wang G, Peng C. 2009. Heavy metal accumulation by panicled goldenrain tree (*Koelreuteria paniculata*) and common *Elaeocarpus* (*Elaeocarpus decipens*) in abandoned mine soils in southern China J. Environ. Sci. **21**: 340-345.

Ukshini E, Dirckx JJJ. 2020. Longitudinal and transversal elasticity of natural and artificial materials for musical instrument reeds. Materials. **13**: 4566.

Üner O. 2019. Hydrogen storage capacity and methylene blue adsorption performance of activated carbon produced from *Arundo donax*. Mater. Chem. Phys. **237**: 121858.

Vasmara C, Cianchetta S, Marchetti R, Ceotto E, Galletti S. 2021. Potassium hydroxide pre-treatment enhances methane yield from giant reed (*Arundo donax* L.). Energies. **14**: 630.

Yan X, An J, Yin Y, Gao C, Wang B, Wei S. 2022. Heavy metals uptake and translocation of typical wetland plants and their ecological effects on the coastal soil of a contaminated bay in Northeast China. Sci. Total. Environ. **803**: 149871

Yang J, Wang X, Shen B, Hu Z, Xu L, Yang S. 2020. Lignin from energy plant (*Arundo donax*): Pyrolysis kinetics, mechanism, and pathway evaluation. Renew. Energ. **161**: 963-971.

Zuccaro G, del Mondo A, Pinto G, Pollio A, de Natale A, 2021. Biorefinery-based approach to exploit mixed cultures of *Lipomyces starekeyi* and *Chloroidium saccharophilum* for single-cell oil production. Energies. **14**: 1340.