# CHAPTER: 6
# ECOLOGICAL AND ECONOMIC VALUES OF GIANT REED (*ARUNDO DONAX* L.)

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**Abstract**

Giant reed is one of the most promising biomass crops for bioenergy or biochemical production (*Arundo donax* L.). It is resistant to a wide range of environmental stresses and can thus be grown on marginal lands that cannot support traditional food crops. Even though it has been reported that the introduction of biomass crops as an alternative to traditional food crops may improve the agricultural sector's economic situation, competition for land between food and non-food crops must be avoided. Giant reed (*Arundo donax* L.) is a perennial rhizomatous grass that has piqued the interest of bioethanol producers due to its high biomass yield in marginal land areas, high polysaccharide content, and low inhibitor levels in microbial fermentations. This chapter discusses various estimates from various studies as well as the potential contribution of giant reed to ecological and economic values.

**Key words:** Giant reed, perennial grass, bioenergy, sustainable, renewal energy

## Introduction

*Arundo donax* is a robust upright perennial grass that grows in tufts. The stems measure 3-5 cm thick, 30-60 cm long, and 2-6 cm wide, with tapered tips and hairy tufts at the base. The giant reed has a dense network of rhizomes that extends 5-30 cm beneath the soil surface. The stem is a hollow segmented culm that can branch and measures 1 cm to 4 cm in diameter. The thickness of the culm walls ranges from 2 mm to 7 mm, and the internodes can reach 30 cm in length. As one of the fastest growing plants, stems can grow up to 10 cm per day under ideal conditions. *Arundo donax* is a sustainable plant that reduces soil erosion, regulates water, grows quickly, uses few nutrients, and requires little primary energy. Furthermore, *Arundo donax* is a low-cost plant that creates local jobs and additional income for farmers because it is produced locally. Furthermore,

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because the plant tissues contain a high percentage of lignin, also known as wood fibers, this plant is resistant to salinity, humidity, and wind pressure. *Arundo donax* (Giant reed) is a robust erect perennial rhizomatous grass that can grow up to 9 m tall in ideal conditions (Komolwanich et al. 2014).

This species is thought to be indigenous to Eastern Asia and the Mediterranean region. However, it has been cultivated for thousands of years throughout Asia, Southern Europe, North Africa, and the Middle East, and has recently been widely planted in North and South America, as well as Australia (Polunin and Huxley 1987). *A. donax,* which originated in northern India and has spread globally throughout Mediterranean regions, has been planted for centuries as an erosion control and roof-thatching material, as well as feed and fodder for livestock (Dudley, 2000). Despite the fact that *A. donax* only reproduces vegetatively, it has greatly expanded its native range and is now classified as an invasive species throughout the United States' Sunbelt and Mediterranean regions worldwide. The characteristics that allow *A. donax* to invade and naturalize in marginal areas have piqued the interest of industrial engineers and agronomists specializing in biotechnologies, such as bioenergy production (Idris et al., 2012; Kausar et al., 2012). (Lewandowski et al., 2003). When compared to traditional energy crops, *A. donax* produces a high amount of biomass per surface unit; yield is affected by several factors, including plant age, pedo-climatic conditions, plant density, and agronomics, resulting in high variability in the literature. Plant production of more than 150 Mg Ha-1 (Giessow et al., 2011; Sharma et al., 1998; Spencer et sl., 2006) is very high and refers to wild fields in warmer climates (California and India); these data cannot be compared with those reported in Table 4, as they are cultivated fields, which are mostly located in temperate or Mediterranean climates.

Cultivation of *A. donax* is possible in almost all climatic regions, with the exception of colder climates; recently, researchers have been developing clones resistant to cold stress, allowing *A. donax* cultivation in colder climates (Pompeiano et al., 2013). The adaptability of *A. donax* makes it suitable for marginal and abandoned lands (Lewandowski et al., 2003), i.e., soils unsuitable for traditional agriculture. Nassi o di Nasso et al. (2013), for example, demonstrated competitive yields of *A. donax* (20 Mg Ha-1 DM) on a low fertility sandy soil. *A. donax* also demonstrated a high adaptability to soil with high macroelement content, such as N (Ambrose and Rundel, 2007) and P. (Williams et al., 2008). Economically, the high biomass yields offset both

plantation and water supply costs (Giessow et al., 2011) as well as herbicide treatments during the first crop year (Lewandowski et al., 2003). Soldatos et al. (2004) estimated a total cost of production for *A. donax* in Greece of approximately 1,200 € per cultivated Ha and 77 € per Mg dry matter produced. In comparison, the cost of cultivating Miscanthus was reported to be the same as that of *A. donax* per surface unit, but much higher when compared to the biomass unit (91 € $Mg^{-1}$ DM).

Currently, the estimated costs to produce *A. donax* in Italy are around 700-1000 € $Ha^{-1}$ $y^{-1}$ (on average over ten years) and 13-20 € $Mg^{-1}$ DM (on average over ten years and 10,000 plant $Ha^{-1}$) in the Po Valley, North Italy (Arundo Italia s.r.l., 2013, personal communication). These investment costs are significantly lower than those reported for other energy crops grown in the same pedo-climatic region, such as corn, sorghum, rye, and triticale (1,187-2,136 € $Ha^{-1}$ $y^{-1}$) or crop rotations, such as triticale plus corn (3,346-2,903 € $Ha^{-1}$ $y^{-1}$). (Schievano et al., 2014). The difference in estimated costs between Italy and Greece can be explained by considering the lower yield and the need for irrigation in the Greek context (Soldatos et al., 2004), as opposed to Northern Italy. The high adaptability of *A. donax* to different pedo-climatic conditions, high biomass production, and plant tolerance to microelement concentrations in both soil and water suggest that this species could be used for phytodepuration. *A. donax*'s importance as a non-food crop is justified not only by its high biomass yields, low agronomic input, and low production costs, but also by its versatility. In fact, *A. donax* is used in the production of bioenergy/biofuels via biological fermentation, such as biogas (Ragaglini et al., 2014) and bio-ethanol (Jaradat, 2010), as well as direct biomass combustion (Dahl and Obernberger, 2004). Additional industrial applications and chemical compound extraction are well established (Tracy and DeLoach, 1998). This chapter is based on various studies of giant reed's ecological, economic, and potential applications.

**Sustainable material for architecture and interior design: *Arundo donax L.***

The *Arundo donax* is used in Egypt to build rural homes using a variety of passed-down methods. The Lattice, also referred to as Chebika, is the most well-liked building method and derives its name from the way the rods are connected. A linkage appears as an ornamental element during its construction. Because the plant is easily accessible nearby, each resident has the option to build their own home. A novice builder can finish the project quickly in a similar manner.

Cutting the reeds, allowing them to fully dry, gathering ten poles at a time in a beam, and tying them together with simple ropes to form the structure are the first steps in construction. The beams are arranged vertically, placed in batches, and fastened with the appropriate ropes.

The addition of a horizontal layer of beams and their connection to the vertical layer come next. The two parallel layers are then strengthened by the addition of a slanted layer of reed beams. The room measures 6 by 4 metres and is about 3 to 4 metres tall. Its height is six metres. These calculations take into account the portion of the wall that is built below ground level to support the building. Kites, woven baskets, and fences in Egypt are made from locally grown *Arundo donax*. The ancient Egyptians wrapped their dead in leaves and made fishing rods, walking sticks, and writing implements out of canes. Being a Mediterranean nation, Egypt is home to numerous locations where this plant can be found. The same methods used to build the walls can be used to build the ceiling, or you can layer single rods that are firmly connected to one another by strong, thin ropes. This is relevant, especially along the room's narrow side. Next, a second layer is added perpendicular to the first and parallel to the long side of the room. The ceiling is then held up by camphor-wooden poles.

**Table 1.** The presence of giant reed in certain governorates of Egypt.

| **Governorate** | **Places** |
|---|---|
| Cairo Qubba | Palace—Saffron Palace |
| Giza | Orman Park—Giza Zoo |
| Alexandria Sharqiya | Rural areas and slums |
| Gharbiyah | 13 shares – 15-karat – 95 acres |
| Dakahlia | Bridges, canals and banks |
| Monoufia | Bridges, canals and banks |
| Behera | Bridges, canals and banks |
| Qalyubiyah Fayoum | 100,000 Inch/Acre |
| Suez | Large areas cannot be counted |
| Port Said | Al Manzalah Lake |
| Matrouh | Trace amounts at Siwa Oasis |

**Source:** The center of progress and development of small industries, Ain Shams University

### *Arundo donax L.* as a raw material for thermochemical synthesis of materials and energy

Renewable energy has become more significant in recent years as a result of the declining availability of conventional fossil fuel resources, ongoing fossil fuel price increases, and rising atmospheric emissions of greenhouse gases. Since biomass is the only renewable source of carbon and can be converted into high-value chemicals, materials, and fuels using the right conversion

pathways, it is regarded as one of the most alluring and promising renewable energy sources. In contrast to other renewable energy sources that only produce heat, biomass is the only source that can be converted into liquid, solid, and gaseous fuel using two main conversion pathways, namely I biochemical and (ii) thermochemical (Chutia et al., 2013).

Contrary to biochemical and biological processes, which favour particular biomass types and require pretreatment before processing, the thermochemical conversion process utilises the entire content of the biomass (Mosier et al., 2005). Pyrolysis is one of the most significant thermochemical conversion technologies because it produces a liquid fuel that can replace fuel oil in any static heating or electricity generation application. When biomass resources are far from where the energy is needed, the ability to store the liquid fuel produced by pyrolysis is advantageous. Only the pyrolysis process, which depends on process variables like heating rate, final temperature, vapor residence time, sweeping gas flow rate, and pyrolysis environment, can turn different types of biomasses into solid, liquid, and gaseous fuels (Bridgwater et al., 1999).

However, a requirement for the large-scale commercial use of any biofuel production process is the availability of inexpensive and high-quality non-edible feedstock (Chutia et al., 2013). It is clear from the literature that lignocellulosic biomass can be used to create cheap renewable liquid fuels called pyrolysis oils or bio-oils. Fast pyrolysis of biomass has been shown to be two to three times more affordable than gasification and fermentation-based biomass conversion technologies (Vispute et al., 2010). The cost of biomass fast pyrolysis oil was estimated by Wright et al. (2010) and NREL (USA) in 2013 at about $0.82 per litre. For standalone biomass-to-liquid fuel plants (pyrolysis, gasification, and biochemical) to produce fuels, Anex et al. (2010) estimated product value in the range of $2.00–5.50 per gallon ($0.53–1.45 per litre) gasoline equivalent, with pyrolysis having the lowest and biochemical having the highest value.

Numerous perennial grasses that frequently grow in a wild state are available all year long in India. These grasses are characterized as low input-high yielding biomass and can grow in a variety of climatic conditions. These grasses could provide bioenergy feedstock without having a negative impact on soil C stocks (Sarkhot et al., 2012). The use of various grass types for the pyrolysis process has already been documented in a number of literatures.

Switchgrass was investigated for conversion into gaseous and liquid fuel at temperatures between 600 and 1050 $^{o}$C by Boateng et al. in 2006.

According to Ruprekha Saikia et al the maximum bio-oil yield of 26.18% was achieved at a final temperature of 500 $^{o}$C and a heating rate of 40 $^{o}$C min$^{-1}$. It has a heating value of 24.70 MJ kg$^{-1}$ and an atomic H/C ratio of 1.79. The calorific value of the biochar produced under ideal circumstances is 24.21 MJ kg$^{-1}$, and it has a porous structure. It can be used as a liming material to correct soil acidity because it has a high pH. As a result, *A. donax* is a potential feedstock for pyrolytic conversion to energy and materials.

**Giant reed for selenium phytoremediation under changing climate**

Around the world, heavy metal contamination of soils and waters has been caused by anthropogenic development processes, such as mining and industrial activities, agricultural sectors, and urbanization sectors (Alloway 2013). This pollution poses a threat to ecosystem services, human health, and living things (Nsanganwimana et al. 2014). Soil is regarded as an essential component of Planet Earth's life support system because of its vital roles in terrestrial environments.

According to estimates, 44% of soils worldwide are moderately degraded, compared to nearly 25% of global soils that are highly degraded, primarily as a result of pesticides, radionuclides, metals and metalloids, persistent organic pollutants, etc. (Tripathi et al. 2015a). Additionally, it is reported that organic pollutants and heavy metals are co-contaminating more than 67% of the polluted areas (US EPA 2004). As a result, maintaining the functions of the agroecosystem depends on the sustainable management of these polluted soils (Tripathi et al. 2015a).

In the earth's crust, selenium (Se) is a naturally occurring, solid material that is distributed widely but unevenly (0.05 mg kg$^{-1}$). It is also typically present in rocks and soils, where concentrations range from 0.05 to 1.50 mg kg-1 (Kabata-Pendias and Szteke 2015). Following are the average Se concentrations (mg kg-1) found in sandy soils across various nations: Slovakia scored a 0.10, followed by Lithuania and Poland at 0.14, Russia at 0.18, Finland at 0.21, Sweden at 0.23, the USA and Japan at 0.50, and a range of 0.8 to > 3.0 for the mean in different soils (Kabata-Pendias 2011).

A unique physiological trait of the giant reed (Arundo donax L.) allows it to quickly absorb and concentrate toxic chemicals from contaminated soils without significantly impairing its own

growth and development. Its ability to absorb contaminants like trace elements that are difficult to biodegrade makes it one of the most popular plants used as a trace element bio-accumulator, particularly via phytoremediation processes (Mirza et al. 2011). Consideration should be given to giant reed's promising role in Se phytoremediation more and more. The ability of giant reed to phytoremediate seleniferous soils has been the subject of some research studies (such as Dhillon and Dhillon 2014; Domokos-Szabolcsy et al. 2014;). Se tolerance was discovered to range between 20 and 50 mg $L^{-1}$ for the American (Blossom) and Hungarian (20SZ) ecotypes, respectively. Additionally, the findings demonstrate that giant reed clusters can accumulate red allotrope elemental selenium on a much smaller scale than selenate, but it is still available to them (Domokos-Szabolcsy et al. 2014).

**Potentials for giant reed (*Arundo donax* L.) growth and nutrient accumulation in various Egyptian habitats**

According to the macronutrient analysis, Canal Bank plants accumulated the most P (602.7 mg kg1) in their leaves, the most Mg (2890.6 mg /kg), and the least K (7180.5 mg /kg) in their below-ground components. Additionally, the aboveground leaves and stems of Nile Bank plants had the highest K and lowest Ca concentrations (17673.5 and 253.0 mg /kg), respectively. The underground portions of Drain Bank plants had the highest levels of N (44700.1 mg /kg) while the leaves and rhizomes of Railway plants had the lowest levels of N (3810.1 and 7919.5 mg /kg) and the highest levels of Ca (3810.1 and 7919.5 mg /kg).

The aboveground portions of Railway plants had the highest Fe and Cd concentrations (166.7 and 0.1 mg /kg), according to the analysis of trace metals in the various organs of *A. donax* from various habitats. Canal Bank plants had the highest Cd concentrations. While Nile Bank plants' stems had the lowest concentrations of Cu, Mn, and Zn (2.1, 2.8, and 2.0 mg kg1), Drain Bank plants' underground regions had the lowest Pb concentrations (2.0 mg kg1). In advanced plant research, such as the investigation of species distribution and abundance, biomass estimation is a crucial tool (Pine et al. 1989). The biomass of *A. donax* ranged from 1.7 kg m2 in Railways to 8.4 kg m2 in Drain Banks. This was higher than the biomass of P. australis, which was reported in Australia (9.5 kg m2; Hocking 1989) and Iraq (13.5 kg m2; Rezk and Edany 1981) but lower than that of Lake Burullus (5.4 kg m2; Eid and Shaltout 2014), the northern temperate zone, and other areas.

Similar studies on *A. donax* found that the biomass ranged from 2.3 to 13.7 kg/m2 in the Nile Delta (Eid et al. 2016), 1.5 kg/m2 in Germany (Bacher et al. 2001), 0.5 to 4.7 kg/m2 in Italy (Fagnano et al. 2015), 5.3 kg/m2 in Turkey (Gunes and Saygin € 1996), 2.3 to 17.2 kg/m2 in the United States (Sharma et al. 1998). In comparison to other regions, subtropical (including Egypt) and tropical regions have higher total aboveground biomass due to factors such as high solar irradiance, a long growing season, and favorable growth temperatures (Eid et al. 2012, 2016).

The primary pathway for trace elements in plants is thought to be the root (Kumar et al. 2006). The present study found that *A. donax*'s belowground organs had the highest concentrations of Cd, Fe, and Mn. This is consistent with other studies that have found that trace metals are largely retained in these organs (e.g., Bonanno 2013). The presence of an iron plaque around the root may be the cause of the high concentration of Fe found in the underground organs of *A. donax*. Wetland plants' roots frequently exhibit iron plaques, which may be important in wetlands designed to detoxify pollutants and purify water (Wang and Peverly 1996). Through the co-precipitation or adsorption of toxic metals, this plaque may shield the root from trace-metal toxicity (Eid 2012). Wetland plants may have a tolerance mechanism that involves the translocation of excess metals into old leaves just before their shedding and the sequestration of metals in tissues or cellular compartments (such as central vacuoles) that are insensitive to them (Vymazal et al. 2007). Additionally, compared to canal and drain banks, trace metal accumulation was lower in railway and roadside plants. Roadside trace-metal concentrations in developed areas are higher than those in underdeveloped areas, according to Saeedi et al. (2009).

### *Arundo donax* water use and photosynthetic responses to drought and elevated $CO_2$

Lloyd L. Nackley et al. carried out an experiment with close-topped CO2 chambers to investigate the interactions between increased CO2 and low water on the growth and physiology of the leaves of *A. donax*. Strong linear relationships between "total water use" and "oven-dry biomass growth per plant" were found in the analysis of whole-plant WUE (Fig. 2) for both the ambient CO2 treatment group (R2 = 0.99) and the high CO2 treatment group (R2 = 0.94). *A. donax* produced 12.5 g L1 of dry biomass when atmospheric CO2 was doubled as opposed to 6.5 g L1 at ambient $CO_2$. These findings imply that water use and *A. donax* growth are closely related. The statistically significant interaction between CO2 and water use (p 0.05) suggests that

improvements in WUE can be attributed to the CO2 treatment. An ANOVA revealed that the $CO_2$ treatment significantly influenced growth (p 0.05).

The outcomes of this study offer the first linear models for calculating whole plant WUE as well as clear predictions of the physiological effects that will most likely occur as $CO_2$ levels in the atmosphere rise. According to data on gas exchange and carbon isotopes, *A. donax* transpires at a relatively high rate, which means it will require more water than many $C_3$ and $C_4$ biomass feedstocks. The results of this study are important because they represent the first published work regarding *A. donax* WUE or stress tolerance at various CO2 levels, even though it is obvious that more research must be done to fully understand how this species will react to climate change and how these outcomes will manifest in situ. In order to better understand the effects of *A. donax* cultivation as a biomass feedstock and to inform sustainable management of this species' effects on water resources, this study aims to address these issues.

**Phytoremediation potentials of Giant reed**

Heavy metal pollution has emerged as one of the most serious environmental problems that affect human health as a result of rapid urbanization and industrialization (Zhao et al., 2018). More than 30,000 tons of Cr and 800,000 tons of Pb have been released into the environment globally over the last five decades (Yang et al., 2018). The air, water, and human health are all impacted by heavy metal pollution, which also has a significant effect on crop yield and quality. A large number of them are cytotoxic, carcinogenic, and mutagenic, and are toxic even at low concentrations. The maximum tolerable intake for As, Cd, Pb, and Cr has been established as 2, 1, 6.03, and 3.32 g/kg body weight/day, respectively, by the Joint Committee of the World Health Organization (WHO) and Food and Agriculture Organization (FAO) on Food Additives (JCEFA) (Dubey et al., 2018). Excessive amounts of heavy metals can pose health risks, such as lung damage, kidney damage, proteinuria, allergy, and amalgam disease if Hg concentrations in whole blood reach 10 g/L, 2) kidney function can be impacted by dietary Cd intake of 0.01 mg/kg/day, 3) renal function can be impacted by Ni intake of 5 mg/kg/day from contaminated food, etc. (Rai et al., 2019). By negatively affecting a variety of plant physiological and molecular activities, heavy metal accumulation on soil can result in a direct or indirect reduction in plant growth (Tiwari and Lata, 2018).

According to recent research, the following heavy metals (loids) had the highest soil concentrations: Maximum concentrations of As were 11–34 mg/kg, Cd–21.84 mg/kg, Cu–16–713 mg/kg, Ni–25–740 mg/kg, Pb–25–2025 mg/kg, and Zn–25–3,925 mg/kg (O'Connor et al., 2018). However, the majority of plants do not have a high tolerance for safe levels of heavy metals. The following are guidelines for safe levels of some heavy metals: Cd between 3 and 6 mg/kg, Cu between 135 and 270 mg/kg, Pb between 250 and 500 mg/kg, Zn between 300 and 600 mg/kg, and Ni between 75 and 150 mg/kg (Nagajyoti et al., 2010). Heavy metals have a detrimental effect on plant growth, biomass, and photosynthesis at high concentrations, which jeopardizes the sustainability of food production (Etesami, 2018). Heavy metals harm both plants and people as a result of this. The removal of heavy metal pollution has become a source of concern recently. As of now, a number of effective methods, including chemical precipitation, adsorption, ion exchange, reverse osmosis, phytoremediation, bioremediation, membrane technology, and electrochemical treatment, have been reviewed for the removal of heavy metals (Dixit et al., 2015).

Recently, the buildup of heavy metals by giant reed has drawn increasing attention from a variety of scientific and engineering fields and has become a hotspot for research (Borso et al., 2018; Coppa et al., 2020; Delplace et al., 2020). Giant reed has the potential to absorb a variety of metals from the environment, including Pb, Cd, Mo, As, Zn, Cu, Ni, Co, Fe, Mn, Cr, Hg, and Al (Miao et al., 2012; Delplace et al., 2020; Danelli et al., 2021). It is a viable candidate for the phytoremediation of soil contaminated with Zn and/or Cr (Li et al., 2014). When compared to biomass from non-contaminated soils, biomass from Zn and Cr contaminated soils had higher ash content and Zn/Cr content (Barbosa et al., 2013; Barbosa et al., 2015). According to Pu et al. (2017), giant reed's photosynthetic system was not harmed despite the oxidative stress involved in the mechanism of Cd toxicity associated with the high Cd transport. The examined parameters, including stem height and diameter, number of nodes, fresh and dry leaf weight, and net photosynthesis (Pn), were unaffected when giant reed was grown on surface soil and irrigated with mixed heavy metal solutions of Cd (II) and Ni (II) (Papazoglou et al., 2005).

Water purification is made easy with giant reed. Wang et al. (2008) tested the removal efficiency of chemical oxygen demand (COD), total nitrogen (TN), and total phosphorus (TP) in rural domestic sewage by seven kinds of aquatic plants (*Arundo donax, Triarrhena sacchariflora, Acorus calamus, Phragmites communis, Iris pseudacorus, Lythrum salicaria, and Sagittaria*

*trifolia*), and the result shows that giant reed has the strongest purification ability. Total suspended solids (TSS) are removed from the water more quickly by giant reed than by some aquatic plants (Toscano et al., 2015). According to a previous study, giant reed planted in gravel-based constructed wetlands (CWs) can remove up to nearly 100% of Escherichia coli (E. coli) and is a better option for E. coli removal than Pennisetum purpureum Schumach (Fidele and Audra, 2020). (Idris et al., 2012a). According to studies by Leto et al. (2013), Jesus et al. (2017), and Pu et al. (2018), giant reed can effectively treat a variety of polluted waters by removing organic pollutants, macronutrients, microorganisms, and heavy metals (Liao et al., 2017).

**Table** Types and locations of giant reed accumulating heavy metals.

| Metal type | Concentration organs | Highest concentration organ | Lowest concentration organ | References |
|---|---|---|---|---|
| Hg | Root, stem, leaf | Root | Leaf | Cristaldi et al. (2020) |
| Cd | Root, stem, leaf | Root | Stem | Guo and Miao (2010) |
| Cu | Root, stem, leaf | Root | Stem | Han and Wang (2007) |
| Pb | Root, stem, leaf | Root | Stem | Guo and Miao (2010) |
| Fe | Root, stem, leaf | Root | Stem | Castaldi et al. (2018) |
| Ni | Root, stem, leaf | Root | Stem | Bonanno (2012), Mabhungu et al. (2019) |
| Al | Root, stem, leaf | Root | Stem | |
| As | Root, stem, leaf | Root | Stem | |
| Cr | Root, stem, leaf | Root | Stem | |
| Mn | Root, stem, leaf | Root | Stem | |
| Zn | Root, stem, leaf | Root | Stem | |

**Source:** Deng Zhang et al. 2021

## Giant Reed as Biofuel Input

*Arundo donax* is a crucial component of biofuel production that is frequently examined in various studies (see Table 3). The grass biomass must be pre-treated in order to produce bioethanol effectively. This should also be taken into account when evaluating the life-cycle energy balance, as this stage of production requires the most energy. In contrast to this presumption, Stichnothe et al. emphasize that more advancements are needed because the biomass pre-treatment technology currently used for fermentation is not cost-competitive with the conventional sugar-based technologies. However, the biomass of *Arundo donax* that had been chemically and enzymatically pre-treated and used in a multistage biorefinery approach was more sustainable (from an energy

perspective) than the lignocellulose biorefinery's most popular feedstock (e.g., corn stover, switchgrass). Consequently, giant reed is an excellent choice for supplying sustainable biorefineries.

The preferred characteristics of a biomass feedstock depend on the end use for bioenergy production. There are various specifications for the heating value, ash content, moisture content, sugar yield, digestibility, and other properties of the feedstock for each conversion technology, such as combustion, gasification, pyrolysis, fermentation, and anaerobic digestion (AD). Because minor elements have an impact on gas emissions, water discharge, and the disposal of solid waste, factors like the content of minor elements like nitrogen, Sulphur, and chloride should also be taken into account. High-cellulose feedstocks are preferred for the biological conversion of energy crops to ethanol, butanol, methane, or hydrogen. Microbes in AD can use a wider range of organic compounds, including hemicellulose, extractives, lipids, and proteins, but the lignin primarily remains intact. Some microbial species can also use hemicellulose for the production of ethanol.

**Table 3.** Summary of biofuel-related studies.

| Study | Topic | Country | Method | Results |
|---|---|---|---|---|
| Mohapatra et al. (2017) | Second generation biofuel production | Global | Review of literature | For effective bioethanol production the pre-treatment of the grass biomass is required. |
| Liguori et al. (2016) | Second generation biofuel production | Global | Review of literature | For biofuel production, the biomass of giant reed requires pre-treatment which is the most energetic intensive part of the production |
| Stichnothe et al. (2016) | Biomass pretreatment for fermentation | Global | Theoretical modelling | Currently the biomass pre-treatment technology available for fermentation of giant reed is not cost competitive |
| Villegas et al. (2018) | Pre-treatment of *Arundo donax* for biorefineries | Italy | Mixed | Chemically and enzymatically pre-treated biomass of *Arundo donax* consumed by a multistage biorefinery approach was more sustainable than the most common feedstock of the lignocellulose biorefinery |
| Accardi et al. (2015) | Second generation bioethanol production | Italy | Theoretical modelling | 1. Giant reed is one of the most promising biomass production candidates 2.Giant reed's moisture content and the holocellulosic–lignin ratio is in favour of bioethanol |

| | | | | |
|---|---|---|---|---|
| | | | | production |
| Sgroiet al. (2015a) | Biogas production | Italy | Theoretical modelling | Under Mediterranean circumstances giant reed is a promising solution for feeding biogas plants. |
| Sgroi et al. (2015b) | Biogas production | Italy | Theoretical modelling | In profitability terms, plant size of 300 kW is the most beneficial for producing bioenergy from *Arundo donax* |
| Fengmin and Mingquan (2011) | Effects of binder content and biomass content on properties of biomass briquetting | China | Field experiment | Giant reed-based briquette has better calorific value than the reed based |

**Source:** Attila Jámbor et al. 2019

## Conclusion

*A. donax* is a herbaceous, quickly growing, and high yielding, low input grass. It has existed in the Mediterranean basin for countless years and is well suited to subtropical and warm temperate regions. The enormous amount of biomass that giant reed produces, along with its potential for heavy metal remediation, carbon sequestration, and many other ecosystem services, make it an ecologically and economically valuable resource. Giant reed, a perennial biomass crop, would also have the benefit of spreading out the cost of planting over the course of its productive cycle (one annual harvest for 10-15 years), resulting in a more favorable energy output/input ratio than annual grasses. This chapter is majorly focused on the various estimates of giant reed in reference to ecological and economic value.

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