BIOMASS AND BIOENERGY 70 (2014) 392–399

Available online at www.sciencedirect.com

ScienceDirect

http://www.elsevier.com/locate/biombioe

Energy characterisation of herbaceous biomasses irrigated with marginal waters

Giovanni Molari [a,*], Mirco Milani [b], Attilio Toscano [b], Maurizio Borin [c], Giuseppe Taglioli [a], Giulia Villani [a], Demetrio Antonio Zema [d]

[a] DISTAL, University of Bologna, Via G. Fanin 50, 40127 Bologna, Italy
[b] DiGeSA, University of Catania, Via S. Sofia 100, 95123 Catania, Italy
[c] DAFNAE, University of Padova, Viale dell'Università 16, 35020 Legnaro, PD, Italy
[d] DiSTAfA, University of Reggio Calabria, Via Feo di Vito, 89122 Reggio Calabria, Italy

ARTICLE INFO

Article history:
Received 23 March 2014
Received in revised form
10 July 2014
Accepted 12 September 2014
Available online 1 October 2014

Keywords:
Renewable energy
Arundo donax (L.)
Typha latifolia (L.)
Phragmites australis (Cav.) Trin. ex Strudel
Lythrum salicaria (L.)
Heating value

ABSTRACT

The paper reports the results of a research program aiming to evaluate the agronomic, and energy sustainability of the biomass production by perennial non-food herbaceous crops irrigated with different kinds of marginal waters. In four different sites (Bologna, Padova, Reggio Calabria, and Catania) the same four species (*Arundo*, *Typha*, *Phragmites*, and *Lythrum*), usually tested without irrigation, were planted and monitored during 2008–2010. The results show that a planting density of 10 m^{-2} is necessary to obtain a maximum dry yield levels already from the second year of transplanting. The maximum productivity was obtained with *Arundo* (close to 100 Mg ha^{-1} y^{-1} in Bologna and 86 Mg ha^{-1} y^{-1} in Padova, 50–60 Mg ha^{-1} y^{-1} in the southern locations). *Lythrum* productivity ranged from 5.2 to 9.2 Mg ha^{-1} y^{-1} in all the RUs, with the exception of Reggio Calabria. *Typha* (around 10 Mg ha^{-1} y^{-1} at the third year) and *Phragmites* (5–8 Mg ha^{-1} y^{-1}) gave significant production only in the northern locations. The HHVs were close to 15.5 MJ kg^{-1} for *Phragmites* (except for Catania and Reggio Calabria with 20.0 MJ kg^{-1}) 18.0 MJ kg^{-1} for the *Arundo* (except for Catania with 20.0 MJ kg^{-1}), 18.5 MJ kg^{-1} for the *Typha* and *Lythrum* (except for Catania with 20.0 MJ kg^{-1}).

1. Introduction

Biomass energy production will increase in the next years as a consequence of the Kyoto Protocol, which has the main goal to reduce greenhouse gases [1], and because of the opportunity to increase the relatively low profits of agricultural and forest sectors through the development of renewable energy [2]. In this context, a large scale introduction of biomass energy could contribute to a socially, environmental and economically sustainable development [3,4]. The cultivation of energy crops was also suggested by the European Biofuels Technology Platform [5] that indicated them as crops with specific traits that allow their use as an energy vector. Therefore it is necessary to adopt extensive cultivation systems, using vigorous high productive perennial plants, characterised by limited soil management such as planting and related tillage [6], high yield potential and high contents of lignin and cellulose [7].

* *Corresponding author*. Tel.: +39 051 2096191; fax: +39 051 2096178.
E-mail address: giovanni.molari@unibo.it (G. Molari).
http://dx.doi.org/10.1016/j.biombioe.2014.09.009
0961-9534/

Biomass irrigation is generally necessary to achieve high productivity in particular in summer crops. In this context, treated wastewater reused (or marginal water used) for energy crops irrigation combines different advantages. Water fertilising properties decrease the demand for synthetic fertilisers and contribute to the reduction of nutrients loading in rivers; this practice increases the available agricultural water resources and it may lower treatment costs [8]. In the Mediterranean zones, characterised by a chronic water resource shortage, the wastewater reused for irrigation is necessary [9,10]. However the wastewater irrigation reuse raises concerns such as soil and crop contamination by pathogens and thus public health issues. As a consequence, these practices have to be regulated according to wastewater reuse norms, but unfortunately at present, there is no an European legislation on this theme. Therefore the water reuse approaches are very different for each country. An other factor that negatively affects the diffusion of wastewater reuse practice is strictly economic: wastewater treatment plants are often far from the irrigation areas. This implies the construction of distribution systems that represents the principal cost of most water reuse projects. Despite this, the use of treatment wastewater in irrigation would represent a clear added value in Southern Europe as highlighted by the WFD [11].

Among the various biomass conversion technologies, direct combustion represents the most reliable for thermal energy production [12]. Starting from several research activities on lignocellulosic material in the seventies and eighties [13–15], current research is oriented towards the direct combustion of vegetal biomasses and their residues [16,17].

In this context the paper reports the results of the experimental activities carried out in the first three years of an Italian National Research Project. The goal of the paper is the evaluation of the agronomic, and energy sustainability of biomass production by non-food crops irrigated with different kinds of marginal waters maintaining the soil moisture close to the field capacity. In particular the results are focalised on biomass production and heating values of *Arundo donax* (L.), *Phragmites australis* (Cav.) Trin. ex Strudel, *Lythrum salicaria* (L.) and *Typha latifolia* (L.).

2. Materials and methods

2.1. Description of the experimental plants

The experiments were conducted in 2008–2010 by four research units (RUs) located in Northern (Bologna and Padova) and Southern (Catania and Reggio Calabria) Italy. Each research unit tested four herbaceous species (*A. donax* (L.) in the following *Arundo*, *P. australis* (Cav.) Trin. ex Strudel in the following *Phragmites*, *L. salicaria* (L.) in the following *Lythrum* and *T. latifolia* (L.) in the following *Typha*) in their own experimental fields characterised by different climatic conditions, wastewater treatments and methods of irrigation used. The different water and irrigation methods have been selected with respect to the main availability and practice of the different units [18]. Each RU planted one of the four species in its own larger plot (ranging from 60 to 480 m^2) and the other ones in the smaller plots (ranging from 9 to 60 m^2) with three repetitions. The different plot dimensions were justified with the different goals of the project not fully reported in this paper.

2.1.1. Bologna

The experimental field was placed in the farm of the University of Bologna in Cadriano (44°33′N, 11°24′E, 25 m a.s.l.). The *Lythrum* was planted in a plot of 60 m^2 while for the others herbaceous species a randomised block design with three replications was used (each plot of 9 m^2). All the species were planted in May 2008 with a density of 10 plants m^{-2}.

2.1.2. Padova

The trial was carried out in the experimental farm of the University of Padova at Legnaro (45°38′N, 11°40′E, 10 m a.s.l.). The *Phragmites* was planted in a block of 3.300 m^2 and the others species in nine plots of 9 m^2 each, with three replications for each species. The plants were transplanted in the same period and with the same density as in Bologna.

2.1.3. Catania

The experiment was conducted in an open field located at S. Michele di Ganzaria (37°81′N, 14°82′E, 350 m a.s.l.). *Arundo* was transplanted on an area of 480 m^2 divided in three plots of 150 m^2 each. *Phragmites* was planted in three plots of 9 m^2 each while *Lythrum* and *Typha* where cultivated in two different areas, of 30 m^2 each, divided in three plots of 10 m^2 each. All plants were transplanted in July 2008 with a density of 4 plants m^{-2}. Different plant density with respect to the other RUs has been adopted to define the better plant density.

2.1.4. Reggio Calabria

The experimental plan was set up, in September 2008, in a marginal area of the municipality of S.Lorenzo (38°00′N, 15°49′E, 70 m a.s.l.) with a density of transplanting of 6 rhizomes m^{-2}. *Typha* was cultivated in a plot of 300 m^2, divided in three plots (100 m^2 size). *Arundo* and *Phragmites* was planted in two blocks, of 60 m^2 each, divided in three plots (20 m^2 size).

2.2. Climatic conditions

The RUs located in the north of Italy are characterised by a humid continental climate while the RUs located in the south of Italy are subjected to a Mediterranean semiarid climate. In the three years of the experiments the temperature was characterised by similar average monthly values during the summer in the four RUs while during the winter period the lowest monthly value was registered in Bologna with a difference of more than 5 °C with respect to Catania and Reggio Calabria (Fig. 1).

2.3. Soils

The soils of the different RUs were analysed with reference to texture [19] and to chemical and physical characteristics [20] taking a sample in the first 0.30 m. The soil was Silty-Clay Loam in Bologna, Silt-Loam in Padova, Clay in Catania, and Sandy-Loam in Reggio Calabria. The characteristics, reported in Table 1, show a higher concentration of sand in Reggio Calabria, silt in Bologna and Padova, clay in Bologna and