Biomass and Bioenergy 93 (2016) 87–96

Contents lists available at ScienceDirect

Biomass and Bioenergy

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

Research paper

Influence of the agricultural management practices on the yield and quality of poplar biomass (a 9-year study)

M.J. Fernández*, R. Barro, J. Pérez, J. Losada, P. Ciria

Centro de Investigaciones Energéticas Medioambientales y Tecnológicas (CIEMAT), CEDER-CIEMAT (Energy Department, Biomass Unit), Autovía A-15, sal. 56, 42290 Lubia, Soria, Spain

A R T I C L E I N F O

Article history:
Received 6 April 2016
Received in revised form
20 June 2016
Accepted 24 June 2016

Keywords:
Biomass
Poplar
Yield
Quality
Composition
Combustion

A B S T R A C T

The aim of this work is to study the effect of different agricultural management on the yield and quality of two poplar biomass clones (AF2 and I-214 clones) in short rotation coppices (SRC), which were harvested using different alternatives (with and without cutting and sprouting after the first year), with two fertilisation doses and through three different 3-year rotation cycles. The plantation was established in 2006 in a marginal land at 1100 m above sea level in central-northern Spain. Yields were evaluated and biomass samples were analysed to determine the quality of the biomass for energy purposes. Biomass quality was estimated taking into account calorific value, volatile matter, ash content, carbon, nitrogen, sulphur and chlorine contents, as well as the chemical composition and melting behaviour of their ashes.

The highest yields, around 9 dry tons per hectare and year, were obtained in this marginal land during the first and second rotation cycles when plots received a supplementary fertilisation. Both clones (AF2 and I-214) provided similar yield and biomass quality. Plots where poplar was not harvested the first year (without cutting and sprouting after the first year) provided higher accumulated yields. Poplar biomass from SRC can be considered a suitable solid biofuel due to its appropriate ash melting behaviour and its low content of nitrogen (0.44 wt-%), sulphur (0.03 wt-%) and chlorine (around 0.01 wt-%). No important significance effect on the poplar quality can be found depending on the additional fertilisation. Poplar quality varied as a function of root/stem age.

1. Introduction

The biomass demand from non-food dedicated crops and agro-industrial residues is expected to increase in Europe due to the progressive development of the bioenergy and the bioeconomy [1,2]. The available agricultural surface could be partially dedicated to produce biomass for bioenergy and, in particular, the settlement of dedicated energy crops could offer new opportunities to current traditional agriculture in less-productive/non profitable agricultural areas.

Poplar is currently one of the most studied species worldwide as a potential source of solid biomass for combustion to generate heat and electricity. Some of the advantages reported of poplar in short rotation coppice (SRC) are: its high biomass and energy yields, its ecological interest and its comparatively low biomass production cost [3–5]. Nevertheless, relatively little information is available in the literature on the behaviour of the crop in SRC conditions in adverse pedoclimatic conditions, as those of many low productive or abandoned agricultural lands in southern EU countries.

The optimal selection of poplar clones, fertilisation rates and the harvest moment are crucial parameters to reduce the overall costs of the crop, not only the ones derived from biomass production, but also those associated with the combustion process, since the cited parameters could affect the biomass quality as a fuel [4–8], playing an important role in the appearance of slagging, fouling, corrosion or emission problems. Therefore, the crop management practices should be optimised and selected not only in terms of obtaining the highest biomass yields, but also taking into account the biomass quality properties in order to increase the efficiency of the thermal conversion plants and minimise the environmental impact. The literature is very scarce regarding the composition and quality of poplar biomass SRC as a function of crop management practises.

The international multipart standard ISO 17225 has recently set the fuel specifications and classes for particular trade forms of biomass, including pellets [9], briquettes [10] and wood chips [11], among others. The quality requirements regarding properties such

---

* Corresponding author.
E-mail address: miguel.fernandez@ciemat.es (M.J. Fernández).

http://dx.doi.org/10.1016/j.biombioe.2016.06.027

as ash, nitrogen, chlorine, sulphur or trace elements are clearly specified. These properties must be determined, particularly if biomass is used in small-scale applications, as some woody energy crops might exceed the standarised limits.

In the above context, this study offers valuable information about the yields and quality of the biomass obtained from two selected poplar clones grown under SRC in low productive agricultural areas with stringent pedoclimatic conditions. The effects that the number of harvests and the inorganic fertilisation dose have on the yield and fuel quality of the biomass obtained have also been determined for two poplar clones along three rotation cycles (9 years). The offered results are essential in the planning and decision-making processes for the eventual future commercial implementation of the studied energy crop as an alternative in low productive agricultural areas.

2. Materials and methods

2.1. Plantation establishment

The plantation was set in March 2006 using two poplar clones: I-214 and AF2 (*P. x canadensis* Moench → *P. deltoides* March *x P. nigra* L.). I-214 is the traditional clone utilised in the plywood industry in Spain due to the high yields it provides. It is used in this study as a reference clon because of its widespread cultivation in Mediterranean areas [12,13]. AF2 was specifically selected in Italy [14,15] for biomass production in short rotation conditions. It is a very productive clone, providing stable yields at a wide range of sites and under different coppicing managements [14].

A total of 800 unrooted 25-cm long poplar cuttings were planted manually at a density of 33,333 plants/ha (1 m × 0.30 m spacing). An experimental trial with a split-plot design with four replications was used. Each replicate subplot consisted in 25 cuttings of the same genotype, resulting in square experimental units in which the 9 central cuttings were monitored in order to avoid the border effect (Fig. 1).

The SRC poplar plantation was located in the Spanish province of Soria. The plantation site is situated at 41°36′ N and 2°30′ W, at an altitude of about 1100 m above sea level. The climatic conditions are Mediterranean continental, with a free frost period only between May and September. In general, winter months in the area are cold, with mean temperatures around 3–4 °C, minimum temperatures falling below 0 °C, frequent frosts (89 days per year) and occasional snows (25 snowing days per year). Summers at this site are fairly hot, with mean temperatures around 20 °C and maximum temperatures well above 30 °C (see Table 1). Annual pluviometry averages about 500 mm. It is important to note that irrigation was applied according to crop requirements and weather conditions. Plots were drip irrigated during the dry months (from May to September). Altogether, it could be considered the plantation area is established in a marginal climatic zone for the cultivation of poplar.

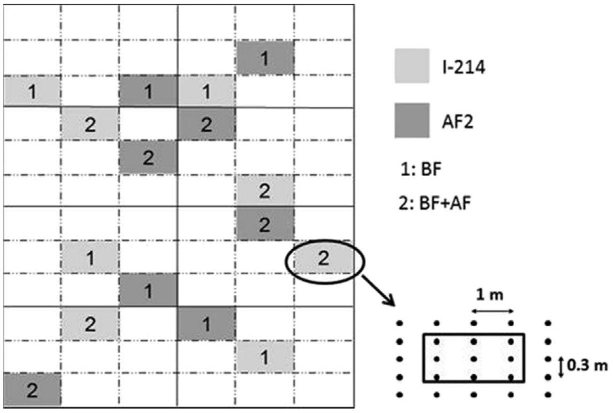

Fig. 1. Experimental plot for each harvest alternative. BF: basic fertilisation. AF: additional fertilisation.

The soil at the experimental site had a sandy texture, with 86% sand, slit and clay less than 10%, low organic matter (0.6%), and low contents of available P (6.6 ppm) and K (61 ppm). This soil was considered poor, light and with good drainage.

To estimate biomass yields, 36 trees per condition (9 trees per replication) were cut at the end of 2008, 2011 and 2014 (3 rotation cycles). Plants were severed at the ground line (10 cm above the soil level) after litterfall, and the weight of the aerial biomass (stems and branches) was recorded. Trees were cut following (Fig. 2) two different harvesting schemes (A and B). In half of the plots (harvesting alternative A), nine trees were additionally cut at the end of 2006, when they were 1-year old, to evaluate whether this additional cut would boost crop productivity during the following years. Table 2 can be also consulted for a better comprehension of the codes used. The first letter and number indicates the age of the root in years, whereas the second part of the code indicates the age of the stem. In alternative A, poplar trees were cut at the end of the first year (biomass R1S1: trees with a 1-year old root and a 1-year old stem). This same plantation was cut again two years after sprouting (biomass R3S2: trees with a 3-year old root and a 2-year old stem). In contrast, trees of alternative B were cut only once in the first rotation cycle (3-year old). Two more 3-year rotation cycles were evaluated in both plantations (A and B).

A scheme of the applied fertilisation as a function of the harvest alternative and root/stem age is shown in Table 3. Before planting and additionally in 2007 and 2009, NPK fertilisation (8-15-15) was applied at a dose of 600 kg ha^{-1} (basic fertilisation, BF). Each year (2006, 2007, 2009 and 2013), half of the trees in all plots received additional fertilisation (AF) with NPK (12-12-17), elements (6% S and 1.2% Mg), and microelements (0.1% Fe, 0.02% B and 0.01% Zn), at 800 kg ha^{-1}. The amount of nutrients applied as base fertilisation (BF) was calculated taking into account the extractions expected by the crop according to our own previous studies [16]. As the soil where the plantation was established can be considered a poor soil, additional fertilisation (AF) was applied to half the plot in order not to limit the potential biomass production. Taking into account sustainability criteria, N, P, and K applications decreased as trees aged (Table 3) because these nutrients are supposed to be partially supplied when poplar leaves fall and decompose [17].

Deltamethryn 2.5 w/v-% was applied at the beginning of each vegetative period for beetle (*Melasoma populi*) control.

2.2. Sampling and analytical methods

Biomass quality was determined by analysing three whole trees (stem and branches) per experimental condition. Every tree was selected randomly, and was completely chipped and milled. After grinding, homogenisation, dividing and drying, a representative analytical biomass sample was obtained, following the European standard of sample preparation EN 14780. Analytical tests were performed in the Laboratory of Biomass Characterisation of CEDER-CIEMAT.

The determination of moisture, ash, volatile matter, chlorine (Cl), sulphur (S), carbon (C), hydrogen (H), nitrogen (N) and calorific value were carried out following European standards for Solid Biofuels developed by the Technical Committee CEN/TC 335. Moisture content was determined by drying the biomass in an oven at 105 °C to constant weight, following the European standard EN 14774-2. Volatile matter and ash content were determined