Biomass and Bioenergy 92 (2016) 76–80

Contents lists available at ScienceDirect

Biomass and Bioenergy

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

Short communication

The effect of cutting back willow after one year of growth on biomass production over two harvest cycles

John M. Finnan*, Isabella Donnelly, Brendan Burke

Crops Research Department, Crops, Environment and Land Use Programme, Teagasc, Oak Park, Carlow, Ireland

A R T I C L E I N F O

Article history:
Received 25 February 2016
Received in revised form
18 May 2016
Accepted 10 June 2016
Available online 20 June 2016

Keywords:
Willow
Coppicing
Stem number
Stem diameter
Yield

A B S T R A C T

Trials were conducted on four separate but adjacent blocks of willow at a site near Carlow, Ireland in which willow, after one growing season, was either coppiced or left to grow. Each of the four randomised complete block design trials contained a different willow genotype (Endeavor, Resolution, Terra nova and Tordis). Coppicing had no adverse effect on stool mortality but significantly increased the number of stems per stool from 2.0 to 3.3. The average, median and maximum diameters of stems from non-coppiced stools were significantly greater than those of stems from coppiced stools. Biomass from non-coppiced treatments was significantly greater than that from coppiced treatments both one year after coppicing (4.3 Mg/ha [coppiced]; 9.3 Mg/ha [non-coppiced]) and two years after coppicing (12.6 Mg/ha [coppiced]; 20.8 Mg/ha [non-coppiced]). Both coppiced and non-coppiced treatments were harvested two years after coppicing and left to grow for an additional two years. After this two year period, there was no significant difference in stem numbers per stool, stem diameter and biomass yield between the coppiced and non-coppiced treatments. All willow genotypes responded in a similar way to coppicing. The results suggest that the omission of the coppicing operation after one year of growth may increase biomass yield at the first harvest without compromising yield at the second harvest.

1. Introduction

Willow species exhibit very high growth rates in their juvenile phase and are considered to be good candidate energy crops [1,2]. The exceptional growth rates of coppiced shoots and the regeneration of subsequent crops after repeated harvests in short cutting cycles is central to the short rotation management of biomass resources [3]. Willow has several characteristics which make it ideal for short rotation systems. One of the most important of these characteristics is its coppicing ability, an ability to resprout after multiple harvests [4,5]. Willow shoots are generally coppiced (cut back) after the first year of growth in order to achieve faster canopy development, coppicing removes apical dominance allowing the development of additional shoots from each stool [6–9]. Faster canopy development after coppicing has been suggested to be the result of a greater number of stems per unit area together with a faster growth rate due to an already established root system and carbon stored in stem bases, stump and roots [6]. It has also been suggested that the act of coppicing stimulates shoot growth by increasing moisture availability [9].

Coppicing after one year of growth is widely practised both in commercial plantations of willow [10,11] as well as in research work carried out in both Europe and North America [12–17]. Management guides for willow growers recommend that willow crops be coppiced in the winter following the first growing season [18–24]. The biomass is not generally harvested, being left on the ground. Some management guides, however, suggest that the coppicing operation can be optional. A management guide from the United Kingdom, for example, suggests that there may be a case for not coppicing if the crop has grown well in the first year [22] while a management guide produced in Sweden suggests that stems can be left to grow if they are strong and vigorous, are about the height of a man and number 2–3 per stool [21]. Although the practise of coppicing after one year of growth is very prevalent, there is little evidence of the practical benefits of the operation. It has not been proven that cutback results in higher biomass yields over the plantation lifetime even though the operation results in more shoots per stool [20]. A study conducted on three sites in the United States with a number of willow clones showed that cutting back (coppicing) provided no benefits in terms of canopy development

* Corresponding author.
E-mail address: John.finnan@teagasc.ie (J.M. Finnan).

http://dx.doi.org/10.1016/j.biombioe.2016.06.006
0961-9534/

or yield at the end of the first rotation [25]. Additionally, there is little evidence from closely related species to support the advantages of the coppicing operation. Biomass production from coppiced treatments of alder and poplar was found to be lower than that of non-coppiced treatments when both management systems were compared at a site in Scotland [26]. Field trials conducted in Belgium and France showed that poplar which was coppiced yielded less above ground volume after two and three years compared to poplar which was not coppiced although growth rates were higher in the coppiced system [27]. Given that the practise of coppicing willow after one year of growth is common although there is little evidence of the benefits of the practise, the objective of this study was to quantify the effect of coppicing on biomass production from a willow plantation over the first two harvests.

2. Materials & methods

2.1. Meteorological data

Meteorological parameters were measured throughout the study at a synoptic weather station sited within 100 m of the site and are presented in Table 1. The highest rainfall but the lowest mean temperature and solar radiation levels were recorded during the 2012 growing season. The lowest rainfall but the highest levels of solar radiation were recorded during the 2015 growing season. The highest mean temperature was recorded during the 2014 growing season.

2.2. Trial design

A nested experimental design was used in which four adjacent but separate trials were established on blocks of willow located in the same field at the Teagasc research centre at Oak Park, Carlow, Ireland (52.86° N, 6.90° W). Each of the four willow blocks contained four double rows of a separate variety (Endeavor, Resolution, Terra nova and Tordis). A distance of 1.5 m separated each of the double rows while the distance between the individual rows in the double row was 0.75 m. The distance between plants in each double row was 0.6 m. Willow cuttings (16 cm in length) were planted on 31st May 2011 using a step planter (Salix Maskiner AB, Hedemore, Sweden) after the ground had been prepared by ploughing and power harrowing. The planted area was rolled immediately afterwards with a ring roller before a pre-emergence herbicide (Flexidor (isoxaben) 2 L/ha) and an insecticide (Clynch (chlorpyrifos) 3.3 L/ha) were applied. Additional weed control was carried out in August 2011 using an interrow rotavator. Soil pH in the experimental area exceeded 7 during the experiment while levels of Phosphorus and Potassium were both at the highest index levels [28]. At the start of 2012, herbicide was applied to the entire experimental area (4 L/ha Basta (glufosinate-ammonium) and 1.5 L/ha Falcon (propaquizafop)).

2.3. Treatment application

Randomised complete block experiments were laid out on the four double rows of each of the four trial areas. In each experiment, there were two treatments (coppiced and non-coppiced) and three replicates, plots measured 12 m in length. Coppiced plots were cut back using a finger bar mower (Agria-Werke gmbh, D-74219 Mockmuhl, Germany) on 13th February 2012. The average height of stems was 2 m at the time of coppicing. Non-coppiced plots were left to continue to grow.

Table 1
Meteorological data for each growing season (April to October).

	Mean temperature (°C)	Rainfall (mm)	Solar radiation (MJ/m^2/day)
2011	12.5	408.1	12.4
2012	11.9	574.3	12.0
2013	12.9	429.5	13.4
2014	13.4	496.2	13.6
2015	12.0	392.2	13.9

2.4. Measurements and harvesting

Early in 2013 (15th January), 14 stools, selected at random using random number tables [29], were harvested by chainsaw from one of the centre double rows in each plot. The biomass was weighed before a sample was taken for dry matter determination. Dry matter samples were chipped before being dried to constant weight.

All subsequent measurements and harvesting were conducted on the other centre double row in each plot. The number of productive stools in each plot were counted on 24th April 2013.

Early in 2014 (7th January), height, the number of living stems and stem diameter (60 cms height above ground; d60 cm) were determined on 14 stools selected at random using random number tables [29] from the centre row of each plot which was not harvested during 2013. These stools were subsequently harvested by chainsaw and weighed between 13th and 14th January 2014. Samples were taken for dry matter determination. The entire experimental area (both coppiced and non-coppiced plots) was harvested on 27th February 2014 by a self propelled harvester equipped with a specialised head for harvesting willow. Herbicide was applied to the entire area on 11th March 2014 (Basta, 2 L/ha) and 100 kg N/ha was applied to the entire area on 6th June 2014.

The number of living stems per stool was counted in early 2015 (25th February). In January 2016, fourteen stools were selected at random using random number tables [29] from the central double row of each plot, which was last harvested in January 2014. For each stool, the number of living stems was counted and the diameter of each stem at a height of 60 cms above ground (d60 cm) was measured. The fourteen stools in each plot were subsequently harvested and weighed on 13th January 2016. Stems from each plot were chipped and dry matter content was determined in the chipped sample.

The timeline of the cutback and harvesting operations is illustrated in Fig. 1 along with the shoot and root ages (SxRx) when each of these operations were carried out.

2.5. Statistics

Data from all four trials was combined and analysed by analysis of variance using the PROC GLM procedure in SAS (SAS/STAT V.9.4. 2012. SAS Inc. Cary, NC.). The analysis included two factors, treatment (coppiced; non-coppiced) and trial (Endeavor trial; Resolution trial; Terra nova trial; Tordis trial).

3. Results

3.1. Effects on stool numbers, height, stem numbers and diameters

Data on these parameters together with the plant age at the time of data collection is presented in Table 2. There was good establishment (percentage of cuttings producing shoots) in the experimental area (>94%). Coppicing had no significant effect on stool survival but significantly increased ($P < 0.001$) the number of stems per stool from 2.0 to 3.3. Two years after the coppicing operation, in January 2014, stems which grew from stools which had been coppiced (S2R3) had significantly ($P < 0.0001$) smaller