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First *vs.* second rotation of a poplar short rotation coppice: Above-ground biomass productivity and shoot dynamics

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ABSTRACT

Within the global search for renewable energy sources, woody biomass from short rotation coppice (SRC) cultures is a valuable option. So far there is a shortage of large-scale field yield data to support stakeholders. We investigated an operational-scale SRC plantation (POPFULL) with 12 poplar genotypes in Flanders during its first two biennial rotations. By inventorying shoot numbers and diameters, combined with allometric relationships, productivity related data were derived after each growing season. We observed significant variation in biomass yield and productivity-related characteristics among the 12 poplar genotypes, of which two recently selected. Genotype Hees (*Populus deltoides* × *Populus nigra*) and Skado (*Populus trichocarpa* × *Populus maximowiczii*, selected in 2005) reached the highest productivity among genotypes, i.e. 16 Mg ha^{-1} y^{-1} of dry matter (DM) yield in the second rotation, which was more than double than the poorest performing genotype Brandaris (a pure *P. nigra*). However, with many small shoots genotype Hees had a different growth strategy than Skado that resprouted with few, thicker and higher shoots. Biomass production increased from a plantation average of 4.04 Mg ha^{-1} y^{-1} of DM in the first (establishment) rotation to 12.24 Mg ha^{-1} y^{-1} in the second rotation. Mean height growth raised from 2.08 m y^{-1} during the first rotation to 2.99 m y^{-1} during the second rotation. The influence of the first coppicing on tree mortality was negligible. Monitoring of subsequent rotations over the plantations' lifetime – which counts for SRC bioenergy cultures in general – is essential to evaluate productivity in the long term.

1. Introduction

Short rotation coppice (SRC) cultures can be a potential option to meet the increasing demand for woody biomass as a renewable energy source [1–3]. Despite the fact that the amount of research on SRC plantations is increasing, data on the productivity are so far rather scarce and limited to small experimental-scale plantations. Studies have shown that small-scale plantations tend to overestimate biomass production values [4–6]. As Searle and Malins [5] concluded when reviewing energy crop yields, more realistic yield data from

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commercial-scale SRC fields are needed for stakeholders to set targets for the support of bioenergy.

The success of an SRC plantation largely depends on its sustainability and biomass yield, which is on its turn for a major part dependent on the choice of the genotypic materials next to management practices and site conditions [7–9]. To decrease cultivation risks as diseases, insects or pests, it is necessary to use a sufficiently broad genetic diversity among the planted genotypes. At the same time it is important to examine how much genetic variation is available in particular traits in order to determine the selection efficiency of a certain trait in future breeding and selection programs [10,11]. The advantage of the genetic variation is often challenged by the demand of industry for uniform biomass quality (e.g. importance of shoot or stem size for harvesting; wood quality for processing). Therefore, more comparative data are needed for different genotypes, especially for the more recently produced genotypes, and over different rotations under larger scale operational conditions. It has already been shown that weed control during the establishment year is of crucial importance in SRC plantations, regardless of genotypes or site conditions [12–14]. Besides weed problems, diseases as rust infections are a common cause of tree mortality [15]. Nearly all poplars (*Populus* spp.) and all willow species (*Salix* spp.) – both in the *Salicaceae* family – have vigorous regrowth after coppicing [16,17]. Poplars resprout after coppicing with 5–25 shoots per coppiced tree. Due to self-thinning, the number of sprouted shoots reduces with up to 75% within the first growth year. Shoot mortality occurs mostly among the smallest shoots, in favor of the largest shoots whose dominance increases. From a scientific point of view (understanding shoot population dynamics, biomass productivity determinants) as well from an applied perspective (yield, uniformity in size of shoots to be harvested) the changes between different rotations in biomass productivity and in shoot dynamics need to be examined in more detail.

In 2010 an operational-scale SRC plantation for bioenergy purposes was established with 12 poplar genotypes in Flanders. The plantation was studied during the first (single-stem) biennial rotation and the second biennial rotation after coppice (2010–2014). This study is part of an ambitious large-scale project (POPFULL [18]) aiming to make a full greenhouse gas balance and to investigate the economic and energetic efficiency of a SRC culture with poplar. Within the context of the POPFULL project, the objectives of this study were: (i) to quantify the biomass production of the plantation during both rotations; (ii) to determine the impact of coppicing on productivity and related productivity characteristics; and (iii) to study the variation among the 12 poplar genotypes over the four years and to assess the first yield data of a number of recently (2005) selected and released poplar genotypes.

2. Materials & methods

2.1. Site description and plant material

The POPFULL SRC site is located in Lochristi, Belgium (51°06′44″ N, 3°51′02″ E). The climate is temperate oceanic with a long-term mean annual temperature and precipitation of 9.5 °C and 726 mm, respectively (Royal Meteorological Institute of Belgium [19]). According to the Belgian soil classification the site is part of the sandy region with poor natural drainage [20]. The groundwater table fluctuates throughout the year between 0 cm and −140 cm below ground level, being on average 100 cm higher during winter than during summer [21,22]. The 18.4 ha site was a former agricultural area consisting of croplands (62%) and extensively grazed pasture (38%). An area of 14.5 ha (excluding the headlands that remained unplanted) was planted on 7–10 April 2010 with 12 selected and commercially available poplar and three willow genotypes. The poplar genotypes represented different species and interspecific hybrids of *Populus deltoides* Bartr. (ex Marsh.), *Populus maximowiczii* Henry, *Populus nigra* L., and *Populus trichocarpa* Torr. & Gray (ex Hook.). The present study focuses on the poplar genotypes only; details on the origin and the parentage of the 12 genotypes are shown in Table 1.

Six of the 12 genotypes were bred by and obtained from the Institute for Nature and Forestry Research in Geraardsbergen (Belgium). Genotype Robusta originates from an open-pollinated *P. deltoides* tree, first commercialized by the nursery Simon-Louis Frères (Metz, France). The other five genotypes were bred by "De Dorschkamp" Research Institute for Forestry and Landscape Planning in Wageningen (The Netherlands) and, as Robusta, obtained from the Propagation Nurseries in Zeewolde (The Netherlands). Preceding the planting, soil preparation included ploughing (40–70 cm depth), tilling and the application of a pre-emergent herbicide treatment. Using an agricultural leek planting machine, the 25-cm-long dormant and unrooted cuttings were planted in a double-row planting scheme with alternating inter-row distances of 0.75 m and 1.50 m and a distance of 1.10 m between trees within the rows, corresponding to a tree density of about 8000 ha^{-1}. The plantation was designed in large (0.16–0.61 ha) monoclonal blocks of eight double rows wide that covered the two types of former land use (cropland and pasture). The minimum of two and maximum of four replicated blocks of each genotype, with row lengths varying from 90 m to 340 m, were based on the available number of cuttings and on the spatial configuration of the site.

During the first months after planting intensive weed control – mechanical, chemical and manual – was applied to decrease competition for light and nutrients (details in Ref. [12]). Otherwise, plantation management was extensive, without fertilization or irrigation. After two years of growth (2010 and 2011), i.e. at the end of rotation 1 (R1), the plantation was harvested for the first time on 2–3 February 2012 with commercially available SRC harvesters (described in Ref. [23]). From then on, trees continued to grow as a coppice culture with multiple shoots per stool in the following biennial rotation, i.e. rotation 2 (R2). The second harvest took place on 18–20 February 2014, partly manually and partly by mechanical SRC harvesters (described in Ref. [24]).

2.2. Shoot diameter and mortality

Tree mortality, number of shoots per tree and shoot diameter were assessed as the main productivity characteristics in winter – during the dormant stage – at the end of each growing season (GS). For reasons of spatial