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Size matters? – The diverging influence of cutting length on growth and allometry of two Salicaceae clones

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ABSTRACT

Short rotation coppices (SRC) are often established by inserting cuttings vertically into the soil. Longer cuttings are generally regarded as superior to establish plants on stress-prone sites. However, knowledge about above- and belowground biomass production, plant allometry and root characteristic of clones established through different lengths of cuttings is scarce.

The experiment was performed with 2 common SRC clones (*Populus* clone Max 4, *Salix* clone Inger) and 2 cutting length (20 cm and 40 cm). Above- and belowground biomass and leaf and root morphology were determined after one growing season. Longer cuttings produce more biomass but have a diverging influence on the shoot:root allocation of both clones. Long cuttings of *Populus* cl. Max produce more aboveground biomass, mostly leaves, than 20 cm cuttings, while 40 cm *Salix* cl. Inger cuttings have more fine roots. Leaf and root morphology are only marginally influenced by cutting length.

Choosing longer *Populus* cl. Max cuttings might not be a good strategy when considering SRC establishment on more stress-prone sites, since their larger above-ground biomass will e.g. increase transpirational demand. Because of the lower shoot:root ratio, longer *Salix* cl. Inger cuttings seem to be more suitable to establish SRC on fields with (partially) restricted water and nutrient supply than shorter cuttings. Thus, planting difficulties and higher costs of longer cuttings may be offset by higher survival and greater aboveground productivity only in some clones. In the future, optimal cutting lengths must be evaluated not only for different environmental conditions but also for different SRC species/clones.

1. Introduction

Intensively managed, short-rotation tree plantations have the potential to partially offset the increasing demand for wood and wood products, can be used for phytoremediation approaches and as riparian buffer zones, and are a source for bioenergy feedstock [1–3]. Short rotation coppices (SRC) are common in some European countries, although still rare compared to the volume of the entire European agricultural sector, and are becoming increasingly important in the United States and world-wide as bioenergy demands turn to woody biomass. Compared to annual agricultural products, biomass from perennial woody crops in SRC has several environmental

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advantages such as a higher retention of nitrogen, a more positive impact on soil ecology and biodiversity, and the potential to sequester significant amounts of carbon above and belowground [4].

Poplars (*Populus* spp.) and willows (*Salix* spp.) are fast-growing and high-yielding tree species which are managed and regenerated as SRC. *Populus* spp. is widely planted in Europe and regarded most promising for biofuel production; the area cultivated by *Salix* spp., one of the most widely planted second generation bioenergy crops in Europe, is expected to increase greatly in the next decades [4–6]. Intensive breeding programs resulted in great numbers of clones with high production rates [7,8]. Indeed, nearly all fast-growing clones perform well under regular maintenance, including site preparation, weed and pest control, fertilisation and irrigation. Aboveground growth and productivity get the majority of attention during breeding but survival and regeneration ability are other important selection criteria [9,10]; low survival rates decrease stand yield, and replanting to mitigate low survival is costly. The environmental benefits of SRC are most pronounced if maintained extensively, i.e. with low fertigation regimes. Furthermore, due to competition with agricultural areas, short-rotation plantations are often established on marginal land with unfavourable edaphic and climatic conditions. The minimum maintenance and the site conditions can result in excess stress levels, especially during plant establishment, and will thus lower yield and survival rates of SRC. In addition, fast-growing hybrids have been found to be more sensitive to nutrient and water stress than slower-growing natural clones [11]. While it has been realised that clones need to be assessed in regard to their resistance to abiotic stress such as prolonged drought periods [12], information about the root system development of different clones is still relatively scarce. The ability to rapidly produce adventitious roots during the establishment phase is thought to be a key for the success of SRC plantations. For example, Pallardy and Kozlowski [13], using fast growing clones of deciduous species, showed that greater root weight per leaf area and increased root elongation rates resulted in greater carbon assimilation and thus greater long-term biomass production. In general, plants respond to reduced water/nutrient supply by either structural acclimation (e.g., reduced leaf:root area ratio) or physiological acclimation (e.g., increased water/nutrient use efficiency), or combinations of both. Thus, a well-developed root system in relation to the (transpiring) surface area/aboveground biomass is imperative to improve the ability of both cuttings and transplanted seedlings to mitigate drought stress and to cope with scarce nutrient supply [13,14].

The root systems of woody species and SRC clones vary often per se in terms of shoot:root ratios, root biomass and root morphology [15–17]. In addition, previous studies found that planting methods, pre-planting treatments and properties of cuttings can influence the root development of short-rotation species and are thus playing a critical role in improving plant establishment. For example, soaking *Populus* spp. or *Salix* spp. cuttings in water before planting stimulates the development of root primordia and changes the shoot:root ratios [18–20]. In addition, position in the stool and the diameter of cuttings can affect the rooting ability [21–24], with larger diameter or longer cuttings resulting in better survival and growth [23,25–27]. Thus, it is surprising that information on the influence of cutting size on root development, and information on the root system development of common SRC clones in general, is scarce.

This study evaluates if the lengths of cuttings has an influence on plant development of two common SRC clones of the genera *Populus* and *Salix* during the first growing season. In detail, this study will answer the following questions: i) Does the size of cuttings influence the above- and below-ground biomass production of two modern SRC clones? and (ii) Does the cutting length influence the root:shoot allocation in regard to biomass and surface area, and the leaf and root morphology?

2. Material and methods

2.1. Plant material and study design

In late March 2012, dormant cuttings of the poplar clone Max 4 (*Populus maximovizcii* × *P. nigra*) and the willow clone Inger (*Salix triandra* × *S. viminialis*) were collected (Probstdorfer Saatzucht, Vienna, Austria). Both clones are commonly used in Europe to establish SRC [28]. The cuttings were stored at −2 °C for maximum of 28 days; after delivery, cuttings were stored at 4 °C and wrapped in moist tissues for 14 days until planting took place. Two different cutting lengths were used in the experiment, 20 cm (subsequently also named "short cuttings") and 40 cm ("long cuttings"). The 20 cm long cuttings were made by parting long cuttings into halves. At the day of planting (DAP 0), average diameter and fresh weight of each cutting were determined (Table A.1).

The experiment was designed as 2 × 2 factorial, with 2 clones (*Populus*, *Salix*) and 2 cutting length (20 cm and 40 cm). Unrooted cuttings were planted (15.05.2012) in 25 l containers (diameter: 35 cm, height: 30 cm) filled with homogenised soil (stagnosol) from the vicinity. One cutting was planted per container; 80% of the cuttings' length, i.e. approx. 16 cm and 32 cm, respectively, was inserted into the soil. Per clone, 7 short and 8 long cuttings were planted. The soil had a pH(H_2O) of 8.0 ± 0.03 and pH($CaCl_2$) of 7.3 ± 0.01, a C:N ratio of 17.3 ± 0.6 and a $CaCO_3$ content of 32 ± 4 mg g^{-1} (Mean ± SE, $n = 4$). Total C and N concentrations were measured with a CN analyser (SC 444, LECO, St. Joseph, MI, USA) and total $CaCO_3$ contents were determined by Scheibler (gasometrical) analysis. Information on soil nutrient contents, determined by inductively coupled plasma atomic emission spectroscopy (ICP-OES Optima 3000 XL, Perkin–Elmer, Waltham, MA, USA), can be found in Table A.2. Containers were arranged randomly in three rows of 10 plants each. Subsequently, plants were grown for a period of 19 weeks at the BOKU Forestry Experimental Garden "Knödelhütte" in Vienna (290 m a.s.l.; N 48°13′ E 16°14′) under natural climatic conditions. The average air temperature during the experimental period (May to September 2012) was 15–20 °C with a total of 300 mm of precipitation. In periods without rain, containers were irrigated with tap water to full capacity twice a week. Because no leaf wilting was observed, it can be assumed that water supply was sufficient during the whole experimental period.