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Effects of mechanical planting on establishment and early growth of willow

Stina Edelfeldt*, Theo Verwijst, Anneli Lundkvist, Johannes Forkman

Department of Crop Production Ecology, Swedish University of Agricultural Sciences, P.O. Box 7043, SE-750 07 Uppsala, Sweden

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ABSTRACT

Commercial willow planting is mostly performed by machines, using long rods which are automatically pressed in the soil and cut. This procedure exerts a large mechanical impact on the cuttings, and may lead to damage, especially when planted in compacted soils. We studied cuttings and early growth performance of willow (in terms of produced shoot biomass, shoot height, leaf area, and number of shoots per cutting) after machine planting, in comparison to manually prepared and planted cuttings. To isolate the effect of mechanical planting from the effects of field variation after planting, we dug out cuttings from five different clones directly after machine planting in well prepared and compacted soil respectively and grew them under controlled conditions, together with a manually prepared control. We found that undamaged cuttings had a better growth performance than visibly damaged cuttings. Planting by machine on compacted soil resulted in a relatively large number of cuttings landing on the soil surface, instead of being planted vertically in the soil. Soil compaction and machine planting interacted with cutting dimensions, the poorer performance of thinner cuttings being more pronounced in compacted soil. To obtain a faster and more even establishment of willows, we recommend thorough soil cultivation prior to planting, further development of planting machines to minimize damage to cuttings at planting, and the use of cuttings with a diameter of at least 10–11 mm.

1. Introduction

Establishment costs for short rotation willow coppice decreased substantially during the initial phase of commercialization in Sweden [1]. This was mainly achieved by mechanisation of planting, employing equipment which, in one process, cuts willow rods (1.8–2.4 m long) into cuttings and then plants them. These cuttings are around 18–20 cm long, and the cutting is pressed down into the prepared soil so that only 1–2 cm protrudes above soil surface. This is believed to provide the cutting with good soil contact, thereby minimizing the risk of drying out [2]. However, this mechanical planting procedure may lead to damage to the cuttings which, in turn, may affect establishment and early growth of plants in a willow stand. Good establishment in terms of high survival and vigorous growth is known to be positively related to the yield levels during consecutive cutting cycles [3], and hence of relevance for the profitability of willow cultivation. Low variability in plant size following establishment is also important, because an early variation in willow plant size gives rise to a size hierarchy, which is preserved below ground over harvest [4]. This hierarchy enlarges over time and leads to mortality and gaps in the stands [5,6], thereby resulting in production losses during consecutive harvests [7] and in the need for prolonged weed control.

* *Corresponding author*. Tel.: +46 18672311; fax: +46 18672890.
E-mail addresses: stina.edelfeldt@slu.se, nyaka@bredband.net (S. Edelfeldt).
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Several studies have addressed damage by machinery on willow during harvest. Stool survival and subsequent growth are known to be correlated to the type and extent of damage done by the harvester [8]. Sennerby-Forsse [8] noted the occurrence of bark damage inflicted by the harvest machine, which may destroy dormant buds and may force resprouting from other stool areas, often at or below ground level. In addition, damage to the bark may disturb the transport system in the phloem and thereby decrease the plant's resistance to attacks by pathogens [8]. Souch [9] showed that mechanical damage to stools by machines at harvest resulted in large and significant effects on plant growth, with fewer stems and less biomass produced. The decrease in stems was due to a reduction in the number of buds. This effect was larger in newly established stands. A similar result was obtained by Hytönen [10] who found negative effects of simulated harvest damage on survival, height and biomass production in a young *Salix Aquatica* plantation, while older plantations showed no such effects.

Similar to harvest damage to stools, direct damages to cuttings at planting could result in fewer buds, a decreased ability to take up water and nutrients, and an increased susceptibility to desiccation and pathogens. While studies targeting the effects of machine planting on subsequent growth thus far are lacking, practical field experience suggests that thinner cuttings may be damaged more frequently in the planting process. For commercial planting material a minimum diameter of about 8–9 mm has been recommended [11]. Both cutting size [12–15] and soil factors [16–19] are known to affect early willow performance, in terms of survival and early growth. Positive effects of cutting size are generally attributed to the size of the carbohydrate pool available for allocation to roots and shoots [20], while positive effects of soil on growth and survival are attributed to water holding capacity and nutrient supply. Dry and compacted top soils are a well known problem in crop production. The pressure exerted by machinery used on willow plantations may lead to soil compaction [21], resulting in a mechanical impedance of root growth and a reduced uptake of water and nutrients from the soil [22,23]. Once the root system is well established, these effects have been shown to be relatively small in willow [9,24,25]. However, some negative effects have been found during the first year, when the root system is shallow and the roots are young and more susceptible to compaction damage [9]. In addition, soil compaction before planting, or planting in a hard soil type may also cause direct damage on the cuttings when they are pushed into the soil by the planting machine.

The aim of this study was to assess and quantify effects of machine planting on sprouting and growth of shoots. To be able to separate the effects of planting in soils with different degrees of compaction from the possible effects of those soils on actual growth, and to decrease effects of field variation, we designed an experiment in which cuttings, after machine planting in two differently prepared soils, were transferred to a standard soil. Four main hypotheses have been formulated. A higher relative performance in the following hypotheses is expressed as higher survival, higher production of biomass, a larger leaf area, a higher number of shoots and a greater maximum shoot height for each cutting. Our hypotheses are that:

1) Cuttings planted in compacted soil will be more damaged than cuttings planted in non-compacted soil.
2) Damaged cuttings will have a lower performance than undamaged cuttings.
3) Cuttings planted in compacted soil will have a lower performance than cuttings planted in non-compacted soil, which in turn will have a lower performance than the control.
4) The relative performance will be dependent on clone and cutting size.

2. Material and methods

2.1. Cutting preparation and measurements

From a field plantation at Ultuna, close to Uppsala, Sweden (59° 48'N, 17°39'E), about 60 one-year old undamaged shoots (rods) with a base diameter of about 9–10 mm or larger were collected from each of the clones Tora (*Salix schwerinii* x *Salix viminalis*), Jorr (*Salix viminalis*), Olof (*Salix viminalis* x (*Salix schwerinii* x *Salix viminalis*)), Sven (*Salix viminalis* x (*Salix schwerinii* x *Salix viminalis*)), and Gudrun (*Salix dasyclados*) on March 16 2009 and placed in a freezer at −5 °C. On May 11, the rods were taken out of the freezer and a 5 cm long part of the base of each rod was removed to standardize the effects of drying, moulds and other kinds of storage damage. For each of the clones, 16 rods were randomly assigned to each of the three treatments, the first being a control, comprising solely manual preparation of cuttings. The second and third treatments were designated for non-compacted and compacted soil, respectively. On May 12, the rods for the non-compacted and compacted treatments were planted commercially with a Wood Pecker 601 at the Lindberg farm in Bälinge, in a conventionally prepared clay soil (autumn ploughing and harrowing a few days prior to planting). Immediately before planting, the soil of the compacted treatment was homogenously compacted in a single run by the tractor carrying the planting implement to create harder soil conditions. The resulting top soil penetration resistance range was estimated to resemble the one encountered in poorly prepared seed beds in spring, after autumn ploughing. The rods were planted by clone, with the rods for each clone planted in a random order. Directly after planting, the first 8 cuttings from each rod (counting from rod base) from the non-compacted and compacted treatments were dug out manually. Any other cuttings were discarded. The orientation of each cutting, i.e. if it was either stuck properly in the ground or lay on it, was noted. The cuttings were transported to the laboratory and placed in a cold store at 3 °C for 1–3 days (depending on clone) before planting in boxes. In the non-compacted and compacted treatments, cutting lengths were measured and the existence of major machine planting damage (broken, split, and partly debarked) noted for each of the cuttings. Cuttings with none or only minor damages (smaller scratches or dents) were considered to be normal. In the control treatment, cutting length was calculated for each clone from the average length of the machine processed cuttings and cut manually. Base diameter and fresh weight