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Effect of species and management on root development in SRC willow

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Abstract

Root excavations were carried out for a clone of two willow species *Salix schwerinii* ‘Kinuyanagi’ and *S. viminalis* ‘Gigantea’ to investigate the root response to management strategies; coppicing and siting.
The two species, grown in short rotation coppice willow trials in New Zealand, differed in root extension and coarse and fine root distribution. *Salix viminalis* ‘Gigantea’ roots occupied a greater volume of soil than did roots of *S. schwerinii* ‘Kinuyanagi’ at stool age 3 years. Coppicing reduced fine root length and mass in both species. Coarse root response following coppicing differed between species. Siting of plantings may disadvantage growth where depth of soil and slope reduce soil available water. Knowledge of rooting characteristics of Short Rotation Coppice (SRC) willow species can contribute to understanding of species performance in changing environments, especially moisture deficit conditions, and choice of clone in marginal environments.

Introduction

Published studies on Short Rotation Crop SRC willow have reported above ground responses such as stool height, number of stems, stem diameter, dry matter (DM) production; and to a variety of conditions such as soil, climate, irrigation, fertilisation, planting density, and phenology (Christersson 2005, Labreque and Teodorescu 2005, VandeWalle *et al*. 2007, Weih 2009). However, it is unclear whether the above ground data have been influenced by plant behaviours below ground. Below ground responses are rarely reported. Crow and Houston (2004) reported that the maximum size of root produced in SRC poplar and willow (a range of species) were influenced by rotation length, species and stool location within a block. Martin and Stephens (2007) reported for three year old *Salix viminalis* grown in lysimeters that water stress did not change root dry mass but did result in a different distribution of roots in the soil profile, with stressed plants having more root at depths below 0.2 m and down to below 0.6 m.

S. schwerinii ‘Kinuyanagi’ is a vigorous clone, producing thick stems which can branch heavily at the nodes. *S. viminalis* “Gigantea’ is a well-performed clone also, generally carrying less leaf area than ‘Kinuyanagi’, growing a greater number of thinner stems off the cuttings with minimal side branches. This study investigated root development of these two clones in a non-irrigated SRC trial planted in a volcanic ash soil near Taupo, New Zealand, and in an SRC non-irrigated nursery in a sedimentary soil in Northland, New Zealand.

In their first year of growth from cuttings at the trial in Taupo, both species suffered retarded growth from water shortage. Many more ‘Kinuyanagi’ than ‘Gigantea’ cuttings died. “Gigantea’ responded to water stress by shedding leaves, but ‘Kinuyanagi’ did not. This partly explained differences in survival. We hypothesised that under soil water limitation differences in the root system may also contribute to ‘Kinuyanagi’ showing more stress than ‘Gigantea’.

Methods

Description of the sites

Rotokawa and Hauhungaroa are both located on the volcanic plateau near Taupo. The soil type at both locations is a volcanic ash. Rotokawa is a terraced, relatively flat site had been converted from pine forest in to dairy pasture just two years before the trial started. The levelling of the land to establish pasture had redistributed the topsoil unevenly and this influenced water storage. Hauhungaroa is a sloped site varying from steep to gentle. The Northland site (near Whangarei) includes both flat and sloped terrain. The soil type is clay overlaying limestone bedrock.

Excavations

The following excavations of the root systems of the two SRC willow clones *Salix schwerinii* 'Kinuyanagi' and *S. viminalis* 'Gigantea' were carried out at the three trial locations.

a. Rotokawa: (i) Three uncoppiced stools of each clone were excavated from the water stressed part of the trial to test the hypothesis that root differences may explain greater stool mortality in the clone *Salix schwerinii* 'Kinuyanagi' test our hypothesis in relation to water stress, (ii) Three coppiced stools and three uncoppiced stools (both aged three years) of equivalent size that had shown no effect of water stress were excavated to determine the effect of coppicing on root development. These stools were coppiced after the first growing season.
b. Hauhungaroa: Three coppiced stools and three uncoppiced stools (aged four years) of *S. viminalis* 'Gigantea', and three coppiced stools of *Salix schwerinii* 'Kinuyanagi' were excavated. These stools were coppiced after the third growing season.
c. Whangarei: Three stools of both species were excavated from three positions; the steep part of the slope, the gentler part of the slope, and the flat at the base of the slope.

Measurements

Stem number and length were recorded for the excavated stools and the intact roots were bagged, stored at 5°C and processed in the laboratory. Roots were separated into coarse (≥ 2mm diameter) and fine (<2mm diameter) roots, their length measured and then dried at 70°C for five days to constant weight. Photos of typical examples were taken for each species and management scenario (Figure 1).

Figure 1: Root system of non-coppiced and coppiced *S. viminalis* 'Gigantea' (top photos) and *S. schwerinii* 'Kinuyanagi' (bottom photos) stools aged three years.

Where the data allowed analysis for significance was carried out using ANOVA. Data between the three sites are not compared since the site conditions (topography, soil type, previous land use, rainfall, management) varied considerably.

Results and Discussion

Root development: the Species Effect.

Table 1 Observational root differences for two SRC willow clones *S. schwerinii* 'Kinuyanagi' and *S. viminalis* 'Gigantea'.

S. schwerinii 'Kinuyanagi'	*S. viminalis* 'Gigantea'
thicker shorter coarse roots	Thinner longer coarse roots
greater number and mass of fine roots (<2 mm diameter)	Smaller number and mass of fine roots
Shorter lateral roots	Much longer lateral roots
Shallower rooting	Deeper rooting
Roots occupied a smaller soil volume	Roots occupied a greater soil volume

Excavation of the root systems revealed important differences in root development of the two clones (Table 1, Figure 1) that could contribute to the difference in survival under water stress in their first growing season. In a pot trial under well-watered conditions 'Kinuyanagi' allocated 16-21% less biomass to roots than three other willow species (*S. lasiandra, S. lasiolepis, S. matsudana × alba*) and 85-148% more biomass to leaf. Leaf:root biomass allocation was highest in 'Kinuyanagi'. It was the only species with nil survival under severe soil water deficit (McIvor *et al*. 2005).

Though 'Kinuyanagi' roots occupied relatively less soil volume, for uncoppiced stools 'Kinuyanagi' coarse root length was 1.6x that of 'Gigantea' and coarse root DM 1.7x (Table 2). Fine (<2mm diameter) root DM averaged 18% in 'Kinuyanagi' and 9.6% in 'Gigantea', and fine root length in 'Kinuyanagi' exceeded that in 'Gigantea' by a factor of 10 (240.8 m compared with 23.3 m). The difference in absorptive area is huge. While we did not measure root biomass as a proportion of total biomass in this study Grogan and Matthews (2002) used a value of 0.25 for annual allocation of biomass production to root growth in their modelling of SRC willow carbon sequestration which is on the high side of pot values measured by McIvor *et al*. (2005). A published value for *S. viminalis* could not be sourced. However it is likely that there is considerable variation between SRC willow species and clones commonly used in commercial production.

Root development: the Management Effect.

Coarse root response to coppicing

Coppiced 'Gigantea' had greater coarse root length (RL) than uncoppiced 'Gigantea'. Coppicing appeared to also stimulate root extension in 'Gigantea'. This was true both when the stools were coppiced following the first growing season and following the third growing season. Root mass (DM) was lower for 3 year stools though higher for the 4 year stools (Table 2). However the differences were not significant. Coppicing 'Kinuyanagi' resulted in lower values for root length and root mass.

Table 2 Above and below ground measurements for two SRC willow clones *S. schwerinii* 'Kinuyanagi' and *S. viminalis* 'Gigantea' with/without coppicing (N=3) at two stool ages. Values given for coarse root data are means and SD. Different letters in each column indicate significance at p=0.05.

Clone	Stool age yr	Coppice	Number of Stems	RL (≥ 2 mm dia.) m	DM (≥ 2 mm dia.) g	Longest root m
Gigantea	3	Year 1	7.7 ± 1.5 a	10.42 ± 2.67	119 ± 46	1.62 ± 0.25 a
	3	No	3.0 ± 1.0 b	8.47 ± 2.07	152 ± 25	1.11 ± 0.33 ab
Kinu-yanagi	3	Year 1	8.7 ± 2.5 a	11.05 ± 3.02	137 ± 108	0.67 ± 0.14 b
	3	No	2.3 ± 1.2 b	13.73 ± 4.65	260 ± 126	1.22 ± 0.62 ab
Gigantea	4	Year 3	15.0 ± 2.6 a	12.07 ± 1.17 b	356± 106	3.74 ± 1.32 a
	4	No	6.0 ± 1.7 b	7.54 ± 1.78 c	238 ± 114	1.55 ± 0.36 b
Kinu-yanagi	4	Year 3	6.3 ± 1.2 b	16.18 ± 2.05 a	336 ± 87	1.42 ± 0.30 b
	4	No	No data	No data	No data	No data

Fine root response to coppicing
Fine root length of 'Kinuyanagi' was 10-14 times that of 'Gigantea', and fine root mass 3-4 times (Table 3).

The ratio of root length (m) to root mass (g) was 1.5 for 'Gigantea' and 5 for 'Kinuyanagi', i.e. "Kinuyanagi' fine roots were thinner than 'Gigantea' fine roots. Coppicing reduced fine root length and fine root mass by a factor of 4. Coppicing resulted in a reduction of 'Gigantea' fine root mass from 9.6% of total DM to 3.5%, and for 'Kinuyanagi fine root mass reduced from 18% to 12% of total DM. Coppicing increased stem number. Coppicing would be expected to shift resources from roots into new stems. If this is so, then stool deaths could increase for some clones (particularly 'Kinuyanagi' because of its more compact rooting system) if the plantation experiences water stress in the year following coppicing.

Table 3 Effect of coppicing on fine root (<2 mm diameter) length and mass for two SRC willow clones *S. schwerinii* 'Kinuyanagi' and *S. viminalis* 'Gigantea', at two stool ages (N=3).

Clone	**Stool age yr**	**Coppiced**	**Fine RL m mean SD**	**Fine DM g mean SD**
Gigantea	3	Year 1	6.11 ± 3.33.	4.2 ± 2.3
Gigantea	3	no	23.30 ± 4.63	15.9 ± 3.2
Kinuyanagi	3	Year 1	85.9 ± 16.7	16.9 ± 3.3
Kinuyanagi	3	no	240.8 ± 107.7	47.5 ± 21.2
Gigantea	4	Year 3	not measured	not measured
Gigantea	4	no	not measured	not measured
Kinuyanagi	4	Year 3	106.0 ± 25.5	20.9 ± 4.7
Kinuyanagi	4	no	not measured	not measured

Conclusions

The two SRC willow species *S viminalis* 'Gigantea' and *S. schwerinii* 'Kinuyanagi' differed in root extension and coarse and fine root allocation. The roots of *S viminalis* 'Gigantea' occupied a greater volume of soil than did roots of *S. schwerinii* 'Kinuyanagi' at stool age 3 year. This is interpreted as a species difference, but it could be enhanced by water stress (Martin and Stephens 2007). *S. schwerinii* 'Kinuyanagi' could be vulnerable to death during the establishment year if it experiences water stress conditions because its high fine root mass could deplete soil water quickly and limited soil volume occupation limits the available water supply.
S. schwerinii 'Kinuyanagi' should be a more efficient gatherer of soil resources when the resources are plentiful (sufficient close to the stool). *S. viminalis* 'Gigantea' should be a more efficient gatherer of soil resources when they are scarce.

Coppicing reduced fine root length and mass in both clones. Coarse root response following coppicing differed between species and sites. In the more uniform environment at Rotokawa there was considerable reduction in coarse root biomass in both species, whereas coarse root length increased in 'Gigantea' and decreased in 'Kinuyanagi' following coppicing. Allocation of resources to production of new stems is considered to be at the expense of root biomass.

Knowledge of rooting characteristics of SRC willow clones can contribute to understanding of clone performance in changing environments, and the choice of clone in marginal environments.

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