FIBROUS ROOT FORMATION ON SELECTED SALIX TREE AND SHRUB CLONES

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SUMMARY

One clone each of *Salix fragilis* (PN 699), *S. alba* var. *vitellina* (PN 353) and *S. matsudana* (PN 227) were grown in the same high soil moisture conditions, along with five *S. matsudana x alba* hybrid clones, three clones of the shrub willow *S. purpurea*, and one hybrid shrub clone. After two seasons growth from 40cm wands, tops were harvested and air dried; while roots were washed, oven-dried and divided into fine and coarse grades.

Highly significant differences were found in stem growth and fibrous root production, and also between the ratios of fibrous root to stem mass, and ratios of fine to coarse root. The best stem growth occurred with the *S. matsudana x alba* clones, while the shrub willows showed less vigour and the hybrid *S. incana x daphnoides* 'Tiritea' performed poorly. Fibrous root production was highest with *S. fragilis* at 251g dry matter per plant, while the hybrid clones 'Adair'(NZ 1143) and 'Hiwinui' (NZ 1130) produced 15% less fibrous root but were not found to be significantly different. Of the shrub willows, the best vigour and fibrous root production was found with *S. purpurea* 'Irette" (PN 608). Although its fibrous root mass was only 65% that of *S. fragilis*, it produced 25% more than other clones of *S. purpurea*, such as 'Booth' (PN 249), and 60% more than *S. matsudana* (PN 227).

As suitable substitutes for *S. fragilis* in channel control work, 'Adair' and 'Hiwinui' are suggested, which offer the advantage of not congesting channels. The shrub clone 'Irette' is also suggested for use at higher planting densities (from cheaper propagation material) for the production of intensive root mats where large masses of tall stem material are undesirable. The suitability of hybrid tree willows for use in lower soil-moisture situations is considered, while 'Aokautere' and 'Moutere' are proposed as the best general purpose clones.

The hybridisation potential of *S. fragilis* is considered, for the introduction of bitter leaf and rough bark characteristics to the present line of hybrid tree willows.

INTRODUCTION

Following the distribution of several *Salix matsudana x alba* clones to Catchment Boards in the late 1970's and early 1980's, some soil conservators expressed concern that these hybrids appeared to produce an inadequate mat of fibrous root material, for scour resistance when planted on river channel margins. It was suggested that the species *S. fragilis* and *S. alba* var. *vitellina*, traditionally used by many Catchment Boards, were more suited to this role even though they tend to spread and congest channels. Preliminary trial work undertaken with 20cm cuttings grown for up to two seasons in saturated conditions indicated that certain hybrids compared favourably with *S. fragilis*. A more comprehensive trial was commenced in 1985, using both shrub and tree willows, to determine the extent of fibrous root production per clone, grown under identical high-moisture soil conditions.

MATERIALS AND METHODS

One clone each of *S. fragilis*, *S. alba* var. *vitellina* and *S. matsudana* were selected for comparison with five *S. matsudana x alba* clones, three clones of the shrub willow *S. purpurea*, and a hybrid shrub clone. Large planter bags (50 l) were filled with a potting mix of equal parts shredded bark, pumice sand, and washed river sand; plus 150 g of 9 month 'Osmocote', 10 g frittered trace elements and 300 g dolomite per 100 l of potting mix. Nursery pole soaking bays were used to simulate stream bank/ephemeral channel conditions, where the bags were placed on galvanised steel mesh tables which were 10 cm below the surface of flowing water. Each planter bag represented a plot, and two 40 cm wands were planted per plot, such that 3-5 cm of each wand was submerged in the permanent water table.

Roots emerging from planter bags by the end of the first season were harvested, dried and weighed; and at the end of the second season roots formed in open water were again collected and dried. The dominant stem was measured on each plant, and then all stems were cut and stored for three months air drying. Planter bags were cut open, roots were washed, oven dried and divided into fine and coarse grades. All root diameters equal to or greater than 2.0 mm were classified as coarse. Ratios were calculated between stem and root masses, and the masses of fine and coarse roots. Data was then subjected to analysis of variance.

Experimental Design - R.C.B., 3 replicates, 12 treatments, 2-wand plot: total, 72 plants.

Treatments - Twelve clones as follows:

1. *Salix fragillis* (PN 699)
2. *Salix alba* var. *vitellina* (PN 353)
3. *Salix matsudana* (PN 227)
4. *Salix matsudana x alba* 'Aokautere' (NZ 1002)
5. *Salix matsudana x alba* 'Hiwinui' (NZ 1130)
6. *Salix matsudana x alba* 'Adair' (NZ 1143)
7. *Salix matsudana x alba* 'Wairakei' (NZ 1149)
8. *Salix matsudana x alba* 'Moutere' (NZ 1184)
9. *Salix purpurea* 'Booth' (PN 249)
10. *Salix purpurea* 'Holland' (PN 605)
11. *Salix purpurea* 'Irette' (PN 608)
12. *Salix incana x daphnoides* 'Tiritea' (NZ 1012)

RESULTS

The means calculated for stem growth, root dry matter production and associated ratios, are presented in Table 1.

Table 1. Stem growth and root production, Fibrous root formation trial

Clone ~~(m)~~	Mean Ht. ~~(kg)~~ (m)	Mean Stem D'Wt. ~~(g)~~ (kg)	Dry Weight Root Fine (g)	Total (g)	Fine Root: Stem Ratio	Total Root: Stem Ratio	Fine: Coarse Root Ratio
PN 699	2.8	0.64	251	396	0.40	0.63	1.79
PN 353	3.2	0.47	172	292	0.35	0.60	2.13
PN 227	3.4	0.57	102	148	0.18	0.26	2.35
Aokautere NZ 1002	4.0	0.89	200	329	0.22	0.37	1.58
Hiwinui NZ 1130	3.9	0.86	212	309	0.24	0.35	2.51
Adair NZ 1143	4.2	0.80	213	305	0.26	0.38	2.52
Wairakei NZ 1149	3.9	0.86	193	294	0.23	0.34	1.96
Moutere NZ 1184	3.5	0.78	187	298	0.24	0.38	1.77
Booth PN 249	2.6	0.39	131	213	0.34	0.54	1.64
Holland PN 605	2.6	0.46	146	211	0.35	0.50	2.24
Irette PN 608	3.1	0.45	164	235	0.37	0.53	2.30
Tiritea NZ 1012	1.8	0.15	43	75	0.28	0.49	1.51
SE mean	0.18	0.135	15.1	27.5	0.034	0.047	0.333
Signif.	**	**	**	**	*	**	**
C.V.%	9	38	15	18	20	18	18

N.B. * - denotes means are significantly different at the 0.05 level;
** - denotes means are significantly different at the 0.01 level.

Table 2. Stem height and Dry weight Rankings

Height			Dry Weight	
Clone	Mean (m)		Clone	Mean (kg)	
NZ 1143	4.2	a	NZ 1002	0.89	a
NZ 1002	4.1	a	NZ 1149	0.86	a b
NZ 1149	3.9	a b	NZ 1130	0.86	a b
NZ 1130	3.9	a b	NZ 1143	0.80	a b
NZ 1184	3.5	a b c	NZ 1184	0.78	a b c
PN 227	3.4	b c d	PN 699	0.64	b c d
PN 353	3.2	b c d	PN 227	0.57	c d e
PN 608	3.1	c d	PN 353	0.47	d e
PN 699	2.8	c d	PN 605	0.46	d e
PN 605	2.6	d	PN 608	0.45	d e
PN 249	2.6	d	PN 249	0.39	e
NZ 1012	1.8	e	NZ 1012	0.15	f

N.B. means with the same letter are not significantly different at the 0.05 level.

Highly significant differences in stem growth and fibrous root production were found, as well as a significant difference between the ratios of fibrous root mass to stem weight. The tallest stems were produced by the *S. matsudana x alba* hybrids, while the shrub willows produced shorter but more profuse stem growth, and the shrub hybrid 'Tiritea' (NZ 1012) showed poor vigour. Differences in stem production were more apparent when air-dried weights were compared, and the ranked means for height and dry weight are presented in Table 2.

Table 3. Ranked means, Fine root Dry weight.

Clone	Dry Weight (g)	
PN 699	251	a
NZ 1143	213	a b
NZ 1130	212	a b
NZ 1002	200	a b c
NZ 1149	193	a b c
NZ 1184	187	b c d
PN 353	172	b c d
PN 608	164	b c d
PN 605	146	c d
PN 249	131	d
PN 227	102	d e
NZ 1012	43	e

N.B. means with the same letter are not significantly different at the 0.05 level.

Fibrous root production was greatest for *S. fragilis* while the hybrid tree clones 'Adair' (NZ 1143) and 'Hiwinui' (1130) produced 15% less fibrous root, and 'Aokautere' (NZ 1002) and 'Wairakei' (NZ 1149) produced around 22% less, but all fell within the same significance grouping (see Table 3). The *S. purpurea* clone 'Irette' (PN 608) was the best shrub willow, producing 25% more fine root than other clones of the same species, and 60% more than *S.*

matsudana (PN 227). The hybrid tree clones generally produced twice as much fine root as *S. matsudana.*

When ratios of fibrous root mass to stem weight were compared, *S. fragilis* again dominated, yielding a root mass equivalent of at least 40% of its (air dried) stem production, followed closely by 'Irette' at 37%. These figures should be regarded as conservative estimates, because complete oven drying of stems would have produced ratios nearer to 50% with these clones. Generally the shrub clones outperformed the tree species in this respect with the best hybrid, 'Adair', yielding 26%, down to 'Aokautere' at 22%. When means for this variable were ranked, an even gradation of four broad significance groups emerged, smoothing the differences between clones.

Table 4. Ranked means, Fine root to Stem ratios.

Clone	Fine Rt:Stem mass	
PN 699	0.40	a
PN 608	0.37	a b
PN 353	0.35	a b c
PN 605	0.35	a b c
PN 249	0.34	a b c
NZ 1012	0.28	a b c d
NZ 1143	0.26	a b c d
NZ 1130	0.24	b c d
NZ 1184	0.24	b c d
NZ 1149	0.23	c d
NZ 1002	0.22	d
PN 227	0.18	d

N.B. means with the same letter are not significantly different at the 0.05 level.

Total root production appeared to broadly reflect that of fine root production, but ratios of fine to coarse root (total root minus fine) showed greater variation than anticipated, with *S. fragilis* displaying a relatively high proportion of coarse root, and *S. matsudana* (PN 227) a relatively high proportion of fine root. The two broad significance groupings that emerged however, tended to minimise differences, even though findings ranged from 50% more fine root mass than coarse for 'Tiritea' (NZ 1012), to 150% more for 'Adair' (NZ 1143).

Table 5. Ranked means, Fine to Coarse root ratios.

Clone	Fine:Coarse Rt	
NZ 1143	2.52	a
NZ 1130	2.51	a
PN 227	2.35	a b
PN 608	2.30	a b
PN 605	2.24	a b
PN 353	2.13	a b
NZ 1149	1.96	a b
PN 699	1.79	a b
NZ 1184	1.77	a b
PN 249	1.64	b
NZ 1002	1.58	b
NZ 1012	1.51	b

N.B. means with the same letter are not significantly different at the 0.05 level.

DISCUSSION

In spite of a number of overlapping significance groups amongst the variables analysed, preferential clones are clearly identifiable. 'Adair' and 'Hiwinui' were not found to be significantly different from *S. fragilis*, even though they did not produce an equal amount of fine root. Compared with *S. fragilis* however, these clones have better form, are not brittle or female (which leads to channel congestion), and are more manageable in pole nurseries. Of the shrub willows, 'Irette' displayed the most potential. While certain tree clones outperformed it in terms of fine root production per plant, the ease and cheapness of propagating this clone from 1.0m stakes allows for high planting densities which more than compensate. Its high root to stem ratio make it suitable for deployment in situations where a mass of tall stem material is considered undesirable or unmanageable.

While few significant differences tended to be found within certain groups of clones, those with top ranking are of most interest. It should be remembered that this trial was limited to two seasons growth, and with time progressive differences in growth and development would become more apparent. Also, in practice different types of planting stock are used - 2.5 or 3.0m poles for tree species and wands or stakes (up to 1.2m) for shrub species. In the first few seasons of establishment, it is likely that shrub species produce relatively dense localised root masses while tree species produce more extensive systems.

Salix fragilis, while having disadvantages for channel work, has obvious potential for crossing with the hybrid tree clones to develop more desirable characteristics, such as upright narrow crown form. It offers other desirable traits - bitter, possum resistant foliage and rough, stock resistant bark - as well as high fibrous root production. During his 1987 European tour, Mr Bob Hathaway selected 10 bitter clones of *S. fragilis* for inclusion in the willow breeding programme, but high quarantine charges have so far prevented their importation. Meanwhile, potential exists in local varieties, particularly in some South Island river systems.

For the development of intensive fibrous root mats, those clones displaying a high ratio of fine to coarse root, as well as high fine root production, offer the most potential. *Salix fragilis*, 'Adair', 'Wairakei', and 'Aokautere' all meet this criteria, while the relatively large stems produced by the hybrid clones offer suitable anchorage for additional river control works, and a source of heavy sash material for felling on river banks where extra wave lap/scour protection is required.

It was noticeable during the washing of roots that clones which produced high fine root to stem mass ratios - namely *S. fragilis* and those of *S. purpurea* - displayed a very even distribution of fine material in their root systems. This was less apparent with other clones which, in field situations, often appear to develop fibrous (feeder) root masses off the end of larger (explorer) roots at varying distances from the tree, depending mainly on local soil moisture. It might be presumed that those clones which displayed lower fine to coarse root ratios are more prone to clustered development of fine roots, although this was not clearly discernible under the trial conditions where root growth was both confined and subject to a high water table.

Meanwhile some soil conservators have remarked on the more reliable establishment and growth of *S. matsudana* (PN 227) on drier sites. The high ratio of fine to coarse root PN 227 displayed suggests that a high proportion of feeder roots allows more effective capture of soil moisture, while its comparatively low root mass relative to stem production indicates it is an efficient water user. This is not entirely in agreement however, with field trial findings. A drought tolerance trial of tree willows (hybrid, *S. matsudana* and *S. alba clones*) near Gisborne found that after two years, the best survival (100%) occurred with *S. matsudana x alba* 'Tongoio' (NZ 1040) and 'Moutere' (NZ 1184), followed by 'Aokautere' at 89%, and then *S. matsudana* (PN 227) at 82%. The worst survival rate for a *S. matsudana* clone was 60% (PN 675), and the worst for a *S. matsudana x alba* clone was 55% (NZ 1240). 'Adair' and 'Hiwinui' were not included in this trial. The best growth was found with 'Tongoio' and *S. matsudana* (PN 227) at 3.7 m and 3.6 m respectively, followed by 'Aokuatere at 3.5 m (Continuing). Meanwhile, a clone trial planted on a moderately dry site near Pohangina produced trees of 'Aokautere' at a mean height of 5.7 m after two years, compared with *S. matsudana* (PN 227) at 5.2 m, 'Hiwinui' at 4.8 m, and 'Moutere' at 4.5 m. No 'Adair' was available for this trial, and all the above clones gave 100% survival (Continuing).

Field experience elsewhere indicates that the drought tolerance of 'Adair' and 'Hiwinui' is limited (S. Braakfsma, *pers. comm.*). Their high fine to coarse root ratio suggests extra feeding capability, but relative to *S. matsudana* this is moderated somewhat by their slightly higher ratios of root to stem mass, implying that they may not utilise available water as efficiently as PN 227. Drought tolerance could in fact be a more innate characteristic where stomatal response is geared more to plant water status than atmospheric conditions. Further clonal studies of water use, with heat pulse techniques perhaps, would provide a more comprehensive examination of this aspect.

CONCLUSION

For channel control planting, the results of this trial indicate that 'Adair', 'Hiwinui' and 'Irette' are all satisfactory, if not better, substitutes for *S. fragilis*; and even the widely distributed clone 'Aokautere' would be well suited to channel control work, ahead of *S. matsudana* (PN 227) for example. For hillside planting also, 'Adair' and 'Hiwinui' may establish and perform as well as PN 227, but until the water demand of these clones is clearly defined 'Moutere' and 'Aokautere' - which represent a balancing of desirable fine:coarse and root:stem ratios - would appear to be the most competent all-rounders. Generally, willows are planted on river banks or hillslopes to provide a root mat capable of resisting channel incision, and are consequently deployed along drainage lines which are unlikely to dry off to the same extent as surrounding terrain. Drought tolerance therefore, is of most concern only when a unique combination of factors occurs i.e. an upper slope ephemeral channel on light soils or poorly consolidated parent material, subject to a Summer minimum/Winter maximum rainfall with a distinct probability of high intensity rainfall. For the space planting of open faces, *Poplus* species are usually more suitable.

Salix fragilis has emerged as a prime candidate for incorporation in the Willow Breeding Programme, to impart improved stock and possum resistance, as well as enhanced fibrous root production. Hopefully, suitable material will be available within the next year, from local if not overseas sources, for crossing with existing clones.