EARLY GROWTH OF *SALIX MATSUDANA* x *ALBA* HYBRIDS

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ABSTRACT

The early growth from cuttings of 51 **Salix matsudana** × **alba** hybrids was compared with that of their parents in a two-year clonal test. From measurements of growth rates and foliation date, estimates of clonal differences, clonal repeatabilities and clonal and phenotypic correlations between characters were made.

Many of the hybrids were considerably faster growing than their parents, in some cases more than 100% for diameter and 30% for height over the higher parent at age two years. There was substantial variation between clone means and clonal repeatabilities were moderate to high.

There were high correlations between first and second year diameters, as well as between first and second year heights of trees grown from cuttings. Ortet height and diameter at two years showed some correlation with first and second year height and diameter of the cuttings. There was no correlation between diameter (first and second years) and foliation date. These hybrids appear promising for soil conservation and river protection planting.

INTRODUCTION

Tree willows are used extensively throughout New Zealand for river protection planting and the control of erosion on unstable hill country. The two main species used in the past were *Salix fragilis* (crack willow) and *S. alba* var. *vitellina* (golden willow). These species have proven to be unsuitable for New Zealand conditions, owing to their relatively slow growth, brittleness of branches and poor form.

Recently, a number of clones of *S. alba* and one clone of *S. matsudana* were made available by the Plant Materials Centre of the Ministry of Works and Development. These are of considerably better form and faster growing than those clones used previously. *Salix matsudana* is indigenous in China, where it is planted extensively for protection forestry (Richardson, 1966). The single clone introduced to New Zealand is now used extensively by Catchment Boards and the Lands and Survey Department for soil conservation planting in New Zealand. The clones of *S. alba* were introduced from Italy and although these have proven less adapted to New Zealand conditions than *S. matsudana,* they grow rapidly under suitable conditions.

As part of the willow improvement programme at the Plant Materials Centre, hybrids were produced between these two species. Many of these hybrids showed considerably faster early growth than either parent. This paper reports on the early growth of cuttings of these hybrids, up to two years from setting.

MATERIALS AND METHODS

The experiment included 51 hybrid clones, which were ramets taken in 1973 from the largest of 385 two-year-old seedlings. They all had a single clone of *S. matsudana* as the female parent. The male parent of 28 clones was *S. alba* 'I-2/59' and of 17 clones, *S. alba* 'I-4/59'. The remaining six clones originated from open-pollinated *S. matsudana,* growing in close proximity to a number of *S. alba* clones, and although the individual male parents are not known they were, from the morphology of the hybrid offspring, almost certainly *S. alba* clones. For comparison, the experiment also included ramets of the parent clones. The test was carried out at the Plant Materials Centre nursery at Aokautere, near Palmerston North on a Manawatu sandy loam soil type. Cuttings from the hybrid clones were taken from one-year-old trees which themselves had been grown from cuttings taken from two-year seedlings. Cuttings of the parent clones were taken from five-year-old stools which had been cut back annually. All cuttings were of ripened first year shoot wood, and were 25 cm long and 1.0 to 1.5 cm in diameter. Six cuttings of each clone were set in August 1974 at a spacing of 1 m × 0.6 m in a randomised complete block layout, with two tree plots and three replicates. The trial was surrounded by a single guard row of *S. matsudana.* The site was spray-irrigated twice each growing season and kept free of weeds by cultivation.

Measurements of height and diameter were made in April 1975, and April 1976, at the end of the first and second growing seasons respectively. Height was measured with a pole to the nearest decimetre and diameter was measured at 1.4 m above ground to the nearest millimetre. Foliation date was recorded at the beginning of the second season, as the number of days after 1 August when the first leaf tips of vegetative buds appeared. Ortet height and diameter had been recorded at age two years in June 1973.

Analysis of Results

The analysis was carried out by the method of unweighted means. Some ramets were discarded owing to deaths or leader damage, but in no case did both ramets of a plot need to be discarded. Expected mean squares and cross-products, and details of calculations are given in Table 1.

RESULTS AND DISCUSSION

A summary of the results is set out in Table 2 and the percentage increase in the growth of the hybrids over the high parent in Table 3.

Many of the hybrid clones were substantially faster growing than the parent clones over the two growing seasons of the experiment, in some cases over 100% for diameter and 30% for height over the high parent. The "family" means also showed a considerable superiority (n.b. these are not true family means as only ramets of the largest seedlings of the families were included).

The superiority of the hybrids with regard to height and diameter was of a similar order in both the first and second seasons, except for those clones with *S. alba* 'I-4/59' as the male parent. This parent clone showed a substantial increase in height growth rate during the second season although there was no corresponding increase in diameter growth rate. It is possible that the initial rooting and take-off of this clone is slower than that of the hybrids, but subsequent growth rate, in height anyway, may be equal to that of the hybrids.

TABLE 1 – Expected mean squares and cross-products for clonal test; repeatability and correlation calculations.

Source of variation	Expected mean squares	Expected mean cross-products
Between clones	$\frac{V_w}{1.81} + V_{rc} + 3V_c$	$\frac{Cov_w}{1.81} + Cov_{rc} + 3Cov_c$
Within clones	$\frac{V_w}{1.81} + V_{rc}$	$\frac{Cov_w}{1.81} + Cov_{rc}$
Within plot	V_w	Cov_w

Where V_c = variance between clones; V_w = variance within plots;
V_{rc} = variance due to replicate x clone interaction
Cov_c = between-clones covariance for a pair of characters

Clonal repeatability $R_c = \frac{V_c}{V_c + V_{rc} + V_w}$

Repeatability of clone means $R_{\bar{c}} = \frac{V_c}{V_c + V_{rc}/3 + V_w/5.43}$

Clonal correlation coefficient $r_c = \frac{COV_{xy}}{\sqrt{V_{c_x} \cdot V_{c_y}}}$

Phenotypic correlation coefficient $r_p = \frac{COV_{c_{xy}} + COV_{rc_{xy}} + COV_{w_{xy}}}{\sqrt{(V_{c_x} + V_{rc} + V_{w_x}) \cdot (V_{c_y} + V_{rc_y} + V_{w_y})}}$

The clonal repeatabilities were highly significant for all characters measured, and were greater after the second season than after the first. The repeatability of clone means was high (≥ 0.67) for all characters.

The phenotypic and clonal correlations are given in Table 4. Height and diameter were highly correlated in both the first and second seasons. There were significant ($P < 0.5$) although very imperfect correlations of one- and two-year diameter with ortet diameter at two years, and one-year height with ortet height at two years, indicating that growth rates of seedlings give some indication of what may be expected from cuttings.

However these results, together with the clonal repeatabilities, indicate that selection should preferably be delayed until after two years' growth from cuttings.

Even though clones differed widely in foliation date (range of 41 days), there was no correlation between this and diameter growth. This differs from the result obtained

TABLE 2—Summary of clonal means, variance components and clonal repeatabilities

Clone	Age 1 year		Age 2 years		
	dbh (cm)	height (m)	dbh (cm)	height (m)	foliation date (1)
Parent clones:					
matsudana	1.1	2.8	2.0	4.1	9.5
alba cl. 'I-2/59'	1.0	2.8	2.2	4.5	21.5
alba cl. 'I-4/59'	1.5	3.2	2.7	5.6	31.5
"Family" means					
matsudana × **alba** cl. 'I-2/59'	1.7	3.5	3.0	5.4	15.7
matsudana × **alba** cl. 'I-4/59'	2.1	3.9	3.8	5.9	20.3
matsudana (open-pollinated)	2.1	3.9	3.9	5.8	17.6
Best clones of each family					
matsudana × **alba** cl. 'I-2/59'	2.0	3.7	4.5	5.9	2.3
matsudana × **alba** cl. 'I-4/59'	2.6	4.6	5.7	6.7	26.5
matsudana (open-pollinated)	2.3	4.1	4.5	6.1	17.2
Overall mean (all clones)	1.8	3.7	3.5	5.6	23.7
Range of clone means	1.0-2.6	2.7-4.6	1.4-5.7	3.3-6.7	2.3-41.3
V_c	0.091	0.100	0.450	0.214	32.8
V_{rc}	0.076	0.097	0.228	0.163	4.7
V_w	0.102	0.084	0.130	0.078	0.91
Clonal repeatability R_c	0.338***	0.356***	0.557***	0.470***	0.854***
Repeatability of clone means	0.673***	0.677***	0.818***	0.757***	0.950***
LSD ($P < 0.05$)	0.58	0.61	0.88	0.73	3.7
Coefficients of variation (a)	0.051	0.027	0.129	0.038	1.38
(b)	0.042	0.026	0.065	0.029	0.198
(c)	0.057	0.023	0.037	0.014	0.038

(1) days after 1 August. *** $P < 0.001$

(a) clonal, $V_c \div \bar{x}$; (b) interaction, $V_{rc} \div \bar{x}$; (c) within-plot, $V_w \div \bar{x}$, where $\bar{x}$ = overall mean

TABLE 3—Percentage superiority in growth of hybrids over the high parent*

Clone	Age 1 year dbh	Age 1 year height	Age 2 years dbh	Age 2 years height
"Family" means				
matsudana × **alba** cl. 'I-2/59'	55	25	36	20
matsudana × **alba** cl. 'I-4/59'	40	22	41	5
matsudana (open pollinated)	91	39	95	41
Best clones of each family				
matsudana × **alba** 'I-2/59'	82	32	105	31
matsudana × **alba** 'I-4/59'	73	44	111	20
matsudana (open pollinated)	109	46	125	49

* In the case of **matsudana** (open pollinated), the percentage superiority over **S. matsudana** is given.

TABLE 4—Clonal and phenotypic correlation coefficients

Characters	Phenotypic (r_p)	Clonal (r_c)
1 year diameter with 1 year height	0.934 ***	0.922 ***
2 year diameter with 2 year height	0.790 ***	0.954 ***
1 year diameter with 2 year diameter	0.755 ***	0.924 ***
I year height with 2 year height	0.786 ***	0.841 ***
1 year diameter with seedling ortet diameter	0.258 *	—
2 year diameter with seedling ortet diameter	0.237 *	—
1 year height with seedling ortet height	0.319 *	—
2 year height with seedling ortet height	0.183 NS	—
Foliation date with 1 year diameter	0.169 NS	0.253 NS
Foliation date with 2 year diameter	0.118 NS	0.169 NS

NS — not significant. $P > 0.05$
* — $P < 0.05$
*** — $P < 0.001$

by Wilcox and Farmer (1966), who found a highly significant correlation between foliation date and size for juvenile growth of *Populus deltoides* in Mississippi. This may possibly be explained by the relatively slow growth of poplars and willows early in the season in New Zealand, rapid growth not occurring until mid-summer.

There was much less variation between clones in the date of growth cessation and leaf fall than in foliation date, and these small differences would not be expected to have any significant effect on growth.

The significantly greater early vigour of the hybrids over the parent clones may indicate the presence of heterosis in this particular species combination. However,

several other factors which could also account for this difference in vigour must be considered.

The relatively close spacing of the ramets raises the question of whether the more vigorous hybrids had suppressed the slower growing parent clones, especially during the second season. This may have occurred to a limited extent. It would be expected that had there been any significant suppression of growth, the coefficients of variation for height and diameter might be greater in the second season than in the first. Clonal and interaction coefficients of variation for diameter in particular were somewhat higher in the second season (Table 2) indicating that competition effects may have biased the clonal performances towards the end of the trial. However, the performance of ramets of the parent *S. matsudana* within the trial was similar to those in the guard row where competition effects were much less, indicating any bias in favour of the hybrids to be minimal.

In this test the growth of cuttings from 2-year-old hybrid seedlings which had been repropagated once was compared with the growth of cuttings from pollarded stools of much older clones which had been repropagated many times, possibly from older trees. Thus the comparison of genotypes may not be completely valid, especially if clonal aging or "maturation" affects the growth rates of plants grown from cuttings, as occurs in some other species, e.g. radiata pine (Sweet and Wells, 1974). The effect of clonal maturation on growth has not been considered a problem in *Salix* (or the closely related genus *Populus*) in the past, and it is perhaps for this reason there has been little investigation of this effect in these genera. Although it is well known that cuttings of *Populus* species taken directly from older trees have a much lower rooting ability and thence early growth than those taken from juvenile plants (e.g. Farmer, 1966), unlike most other species, high rooting ability can be regained by interposing a clonal generation (Wright, 1962) or by pollarding and taking cuttings from the regrowth. A similar principle possibly applies with respect to growth in the longer term, as cuttings taken from pollarded stools consistently produce vigorous plants (FAO, 1958). There have been no reports of any obvious decline in vigour of clones repropagated in this way.

The increased vigour of the hybrids may be specific to conditions such as those of the test site. Elsewhere, e.g. in the natural environment of the parent clones, the results might well have been quite different. Selection within natural populations of the parent species would possibly produce clones with growth rates equal to those of the hybrids, as has been found with *Populus deltoides* × *nigra* (Muhle Larson, 1970). However, if such clones were used as parents in a breeding programme, hybrids with even faster early growth rates than those reported here might well result.

Although no rating was given for stem straightness, many of the hybrids were considerably better in this respect than the parent clones, particularly the *S. alba* parents. This could offset any possible superiority in the later growth of *S. alba* 'I-4/59'.

From the immediate practical aspect, these tree willow hybrids appear promising as a replacement for *S. fragilis,* which is still used extensively for river protection planting, and to supplement the use of *S. matsudana* and *Populus* species for soil conservation planting in general. Many more willows will need to be planted for soil conserva-

tion than in the past, owing to a shortage of poplars resistant to the leaf rusts, *Melampsora larici-populina* and *M. medusae* which arrived in New Zealand in 1973 (van Kraayenoord *et al.*, 1974).

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