Selection of *Salix Myrsinifolia* Clones for Biomass Forestry in Finland

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For biomass forestry in the inland parts of southern and central Finland, the obvious choice of willow species is *Salix myrsinifolia*. However, selection of clones of indigenous species has not yet been completed and more research and selection is needed. In the Piipsanneva old peatland trial, indigenous species of willow, mostly clones of *S. myrsinifolia* and *S. phylicifolia*, were compared in terms of biomass production, coppicing, height growth and diameter distributions. In this trial, the mean annual biomass production was not particularly high; more important results were attained in the ranking of clones. This trial strengthens the hypothesis that, over the long term, the biomass production of *S. myrsinifolia* is higher than that of *S. phylicifolia*. It was supposed that behind the highest yield there was a clone with uniform quality, one whose diameter distribution would be narrow and positively skewed. Comparisons of parameters of Weibull functions showed that the distributions of the best clones were wide, indicating that those clones use the whole growth space better than these with narrow distribution.

1 Introduction

1.1 *Salix Myrsinifolia* as a Short Rotation Tree

When willow clones are selected for biomass forestry in Finland, certain species can be recommended for southern Finland (Pohjonen 1991).

The most productive species in this zone are the exotic ones, especially *Salix viminalis* L. In northern Finland, however, exotic clones are susceptible to frost both in fields and in peatlands. Therefore, species recommendations and clone selection for the central and northern agroclimatic zones have not been completed. It has seemed that the indigenous species, *S. myrsinifolia* Salisb.

and *S. phylicifolia* L., are probably the best choices for this zone; and in long-term screening, *S. myrsinifolia* seems to grow better than *S. phylicifolia* (Pohjonen 1991).

S. myrsinifolia has not been widely used in biomass forestry, either in research or in practice. Pohjonen (1991) has suggested further testing of *S. myrsinifolia* as an energy plantation crop north of Salpausselkä. Southern regions, such as coastal Finland, should concentrate on growing productive exotic clones, like *S. viminalis*.

Salix myrsinifolia, which belongs to the subgenus *Vetrix*, the shrub willows, occurs over the boreal zone from Siberia to the northern temperate zone in central Europe and is found in both maritime and continental areas (Hämet-Ahti et al. 1989). In Finland *S. myrsinifolia* occurs throughout the country, but is most abundant in the southern and central parts (Hämet-Ahti *et al.* 1984). *S. myrsinifolia* and *S. phylicifolia*, which are closely related, hybridize easily forming the hybrid, *S. × tetrapla* Walker ex Sm. (Hämet-Ahti et al. 1984), which is rather common in Finland.

S. myrsinifolia is well adapted to the Finnish climate and is more winter tolerant than the exotics. Of the sprouts of one-year-old *S. myrsinifolia* clones, 80–100 % were alive at the time of the study of Lumme and Törmälä (1988), while the fast-growing exotic species suffered various degrees of frost damages.

Dry matter content was highest in the winter-tolerant *S. myrsinifolia* clones (43.2–53.1 %) compared to that of the exotic clones, which was considerably lower (Lumme and Törmälä 1988). The high dry matter content of the indigenous species may reflect an adaption to low winter temperatures, since low water content facilitates resistance to cold (Lumme and Törmälä 1988).

The pattern of biomass production in the *S. myrsinifolia* clones differs markedly from that in southern exotic willows. During the first growing season *S. myrsinifolia* clones insure sufficient root growth, with the result that first year shoot growth is weak. After coppicing, growth increases considerably during the next years (Lumme and Törmälä 1988). Exotic species are fast-growing already at the beginning, but they often suffer from cold weather in autumn (Ledin

et al. 1990). Their rate of photosynthesis declines only at the end of September, whereas indigenous clones become dormant by the beginning of September (Sievänen 1983).

The success of *S. myrsinifolia* in biomass trials has varied. In the first willow screening trial for biomass production in Finland (by the Foundation for Forest Tree Breeding) *S. myrsinifolia*, clone V75, was the second most productive indigenous species, next to *Salix pentandra* L. (Lepistö 1978). Since then *S. pentandra* has not succeeded as well as *S. myrsinifolia*.

In the study of Lumme and Törmälä (1988) the biomass production of one-year-old *S. myrsinifolia* clones remained much lower than that of the exotic species, but among the two-year-old sprouts only two clones were found in which biomass production was higher than in the control clone. These clones were *S. myrsinifolia* K2183 and K2242. In the Suomusjärvi trial of the Foundation for Forest Tree Breeding and in Kannus Clone Archive I, at the age of three the height growth results were best for the *S. myrsinifolia* clones, in Suomusjärvi even better than those for exotic species (Pohjonen 1991). In Suomusjärvi the best clone was V78 and in Kannus K2266 and K2264.

S. myrsinifolia is a good material for hybridization. The good properties of indigenous clones, such as winter tolerance, can be combined with fast-growing exotic clones (Viherä-Aarnio 1989). Encouraging results have been attained by crossing clones of *S. myrsinifolia* with clones of distant origins. Compared with the parent clones, the yield of the best crossings has been much improved (Pohjonen 1991).

S. myrsinifolia can in the future also be utilized in ways other than as an energy plantation crop. *S. myrsinifolia* can be used, for example, in the pharmaceutical and chemical industries. Willows, especially the young leaves and shoots, contain flavonoids, tannin and phenolic glucosides, such as salicin, fragilin and salicortin. The amount of salicylates (salicin and its derivatives) varies considerably between willow species. *S. myrsinifolia* has been found to be much richer in salicin and in salicortin than the other indigenous species or some cultivated exotics (Julkunen-Tiitto 1989). Large-scale production of salicylates from *S. myrsinifolia* plantations may

prove feasible in the future, either as a main product or combined with other forms of biomass production (Pohjonen 1991).

1.2 Objective of the Study

In this study, the ranking of indigenous clones is examined according to the results of Piipsanneva Clone Archive II in Haapavesi. The biomass yields of the clones, however, are not the main purpose of the study even though the most interesting aspect is the priority list of the clones. The other objective is to clarify where the differences in biomass production might come from.

One hypothesis is that differences between clones are due to different diameter distributions. The objective of clone selection is not only to obtain as high biomass production as possible, even though the uniform quality of the clones gives the best results in biomass production. Uniform quality means here clones that are uniform in terms of their diameters, i.e. diameters that are distributed only on a few and the biggest diameter classes. It is assumed that behind high biomass production there is a quality clone which diameter distribution is positively skewed and it is not wide.

2 Material and Methods

2.1 Piipsanneva Clone Archive II

At Piipsanneva in Haapavesi (64°15' N, 24°25' E) Clone Archive II was set up in 1980 on an old peat production swamp. Clones for the Piipsanneva trial were based on screening and selection of an original 4H-collection in Kannus. Based on height growth, the 87 best clones from the original 4H-collection of 566 clones were selected for the Piipsanneva Clone Archive II.

On an old peatland area nine cuttings from each 87 clones were planted as five replicates. Most of the clones on the Piipsanneva trial were *Salix myrsinifolia* (35 %) and *S. phylicifolia* (38 %) clones. The species and clones used in the test are listed in Table 1. This list differs slightly from that of Pohjonen (1991), because the uni-

dentified and unclear clones were reidentified at the Department of Biology, University of Joensuu, in the summer of 1991. Some of these clones turned out to be *S. myrsinifolia*.

Since its establishment in 1980 the Piipsanneva trial has never been fertilized nor harvested and has been allowed to grow very old. In 1982 and 1983 the height of the best of seven clones was measured (Pohjonen 1991), but no other measurements were made until the spring of 1991, when the whole Clone Archive II was evaluated. Diameters of stems with a height of 110 cm were measured. From each stump a maximum of five stems were measured and the total number of stems from each stump was counted. After the evaluation, the stems were cut off. Based on the results for biomass production, the height growth and number of sprouts of the 20 clones with the best biomass production and two tallest clones determined by sight were measured in the autumn of 1991.

2.2 Biomass Estimation

The most common method for estimating biomass is the use of regression equations, and the most common forms are linear and nonlinear equations (Grow and Schlaegel 1988). For this study, a nonlinear regression equation (1) was chosen

$$Y = \alpha \cdot X^\beta \tag{1}$$

The commonly used independent variables in biomass equations are diameter at breast height (D) and total height (H). These two variables are usually combined into a single variable, D^2H (Grow and Schlaegel 1988, Verwijst 1991). However, in many experiments it has been found that the biomass of willows is not as dependent on shoot length as on diameter (e.g. Hytönen 1990, Nilsson 1982, Björklund and Ferm 1982). In this case only diameter at a height of 110 cm was used as an independent variable.

The coefficients of the equation was formed by regression analysis from other *S. myrsinifolia* data, which contained dry weights and diameters of different sized stems. Range of diameters was, however, equivalent in both data. With that bio-

Table 1. Species and clones in Piipsanneva trial.

Clone	Species	Origin	Clone	Species	Origin	Clone	Species	Origin
E6630	phy	Mouhijärvi	K2210	phy	Ylihärmä	E6698	myr	Anttola
K2264	myr	Liperi	K2120	phy	Veteli	E6699	myr	Anttola
K2266	myr	Liperi	E6680	myr	Hartola	K2220	phy	Kuortane
E6634	phy	Kullaa	E6800	myr	Orimattila	K2221	phy	Kuortane
K2151	S. ssp	Närpiö	E6681	myr	Juva	K2224	tet	Pielavesi
K2152	myr	Närpiö	E6806	myr	Kärkölä	E6714	myr	Pertunmaa
K2158	myr	Töysä	K2276	phy	Heinävesi	E6717	phy	Pertunmaa
E6637	tet	Juva	E6684	phy	Kuru	P6184	phy	Siikajoki
E6639	tet	Juva	E6813	myr	Mäntsälä	P6185	phy	Siikajoki
E6779	myr	Asikkala	E6690	vim	Eurajoki	K2225	myr	Rääkkylä
K2183	myr	Vaasa	E7313	S. ssp	Mouhijärvi	K2233	phy	Kuortane
K2107	phy	Sievi	K2216	phy	Lappajärvi	P6188	phy	Liminka
K2188	myr	Närpiö	K2217	phy	Lappajärvi	E6730	myr	Tuulos
K2190	tet	Kristiin.k	K2218	phy	Lappajärvi	E6731	*	Tuulos
K2191	tet	Närpiö	K2386	S. ssp	Juva	K2236	phy	Laihia
K2192	tet	Närpiö	E6820	capr	Jokioinen	K2239	myr	Viitasaari
K2193	tet	Närpiö	E6821	**	Jokioinen	K2242	myr	Suonenjoki
K2194	myr	Närpiö	E6824	phy	Jokioinen	K2244	myr	Suonenjoki
K2281	phy	Kristiin.k	E6825	phy	Jokioinen	K2245	myr	Suonenjoki
K2274	phy	Heinävesi	E6826	phy	Rautjärvi	K2248	myr	Suonenjoki
K2196	*	Maalahti	E6828	myr	Rautjärvi	K2250	cin	Laihia
K2202	tet	Töysä	E6829	myr	Rautjärvi	E6744	phy	Padasjoki
E6789	myr	Asikkala	E6831	myr	Rautjärvi	P6193	S. ssp	Kuhmo
E6791	vim	Hausjärvi	E6750	phy	Lammi	P6286	phy	Simo
K2204	capr	Kuortane	E6845	phy	Parikkala	E6745	phy	Eura
E6672	phy	Humppila	E6847	tet	Parikkala	E6842	myr	Loppi
E6795	*	Heinolan mlk	K2257	myr	Äänekoski	E6748	myr	Lammi
K2207	phy	Ylihärmä	P6195	phy	Kuhmo	K2146	S. ssp	Kaustinen
P6198	phy	Vaala	K2385	S. ssp	Maalahti	K2259	phy	Lappajärvi

* = myr × phy × cin   ** = phy × cin

capr = *S. caprea*   cin = *S. cinerea*   myr = *S. myrsinifolia*
tet = *S. tetrapla*   vim = *S. viminalis*   phy = *S. phylicifolia*

mass equation (1) each measured diameter was converted to dry biomass. From these results, the biomass production of each stump was calculated and after that the mean biomass production of the stump in each replicate. The numbers of dead stumps and of stems were also surveyed. Differences in biomass production, number of stems and number of dead stumps for each clone were tested statistically using one-way analysis of variance, Tukey's HSD-test and correlation analysis.

2.3 Weibull-Functions in Diameter Distributions of Willows

To examine the supposed differences of diameter distributions, frequency distribution histograms of stem size and Weibull distribution function were formed.

A complete Weibull function contains three parameters: location parameter a, scale parameter b and shape parameter c (Bailey and Dell 1973). The Weibull function is commonly used to describe diameter distributions. It is very flex-

ible, and differently shaped distributions can be formed with it (Kangas et al. 1990). In this study a two-parameter Weibull density function (2) was chosen. A form of the probability density function of the two-parameter Weibull is described by Bailey and Dell (1973):

$$f(x) = (c/b)(x/b)^{c-1}\exp\{-(x/b)^c\}$$
$$x \geq 0, b > 0, c > 0 \tag{2}$$

The advantages of using a two-parameter function are that the demand for stand information is reduced and the parameters of the two-parameter formulation can be recovered using a simple numerical method (Eriksson and Sallnäs 1987). In a two-parameter function it can be assumed that the minimum diameter is zero.

The parameters of the Weibull diameter distributions were tested statistically. First, the level of fit was tested with the Kolmogorov-Smirnov test. For example, Eriksson and Sallnäs (1987) have used the Kolmogorov-Smirnov test to examine the level of fit of Weibull functions. With a small sample, as in this study, the Kolmogorov-Smirnov measure (K_s) is more efficient than, e.g. the χ^2 measure, which also uses information about the order of the observations (Ranta et al. 1989). After the Kolmogorov-Smirnov test, the parameters were tested with one-way analysis of variance and in pairs with Tukey's HSD-test.

2.4 Sprouting

After the stems were cut at the height of 10 cm in the spring of 1991, the height of the one-year-old sprouts was measured in the autumn of the same year. Only the 20 clones with the best biomass production and the two clones with the best height growth determined by sight were measured. Of the nine stumps, the first three were chosen systematically to be measured, and all the sprouts of the stump were counted. Coppicing capacity was examined by determining the dominant height, mean height and number of sprouts. Differences between clones were tested by analysis of variance, and the correlation between these variables and the biomass production of the previous generation was also examined.

3 Results

3.1 Biomass Production of the Clones

The equation used for estimating the biomass of the clones was a nonlinear regression equation. The form of the equation was:

$$Y = 3.0456 \cdot X^{1.8120}$$
$$Y = \text{biomass (g)}, X = d_{1.1} \text{ (mm)}$$
$$R^2 = 0.934, F = 531^{***} \tag{3}$$

The form of the regression equation and the dispersion of the observations can be seen in Fig. 1. Results of the regression analysis are presented in Table 2.

On average, the biomass production of all 87 clones varied between 290 and 5720 g/stump (mean annual increment 26–520 g/stump/a). The average biomass production of the best 20 clones over rotation is presented in Fig. 2. According to the analysis of variance, the biomass production differed statistically significantly between clones (Table 3). The clones which had a biomass production over rotation of under 1000 g were considered to be unimportant and were excluded
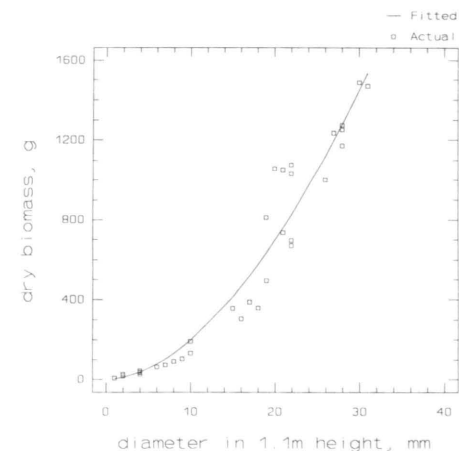

Fig. 1. Regression equation of *Salix myrsinifolia* clones for estimating biomass production. $Y = 3.0456 \cdot X^{1.812}$, $R^2 = 0.934$, $F = 531^{***}$.

Table 2. Parameter estimates, t-values significance and mean square (mm) of the biomass equation.

	Estimate	t-value	MS
α	3.0456	2.1052***	1.4467
ß	1.8120	12.6635***	0.1431

from Tukey's HSD-test. According to Tukey's HSD-test, the group of best clones from among the 78 clones cannot be determined accurately.

3.2 Number of Stems and Stump Mortality

The number of stems in the clones differed significantly, varying on average from three to eight stems per stump (Fig. 3). There was no significant correlation between biomass production and number of stems (Table 4).

Stump mortality did not differ statistically significantly between clones, although the mortality rate of the stumps varied from 7 to 47 % (Fig. 4). Most of the variation originated from differences between replicates. Stump mortality and biomass production did not correlate with each other (Table 4), nor was biomass production dependent on number of living stumps.

Correlation analysis between the number of stems and the mortality rate of stumps indicated that these variables did not correlate with each other. It could have been supposed that if the

Table 3. The results of analysis of variance.

Analysis	Source of variance	df	Mean square	F
Biomass	clones	86	6938587.1	
	repl.	384	1789131.4	3.878***
Parameter c	clones	19	1.40	
	repl.	80	1.06	1.325
Parameter b	clones	19	38.07	
	repl.	80	11.93	3.192***
Mean height	clones	21	1352.99	
	repl.	88	740.90	1.826*
Dominant height	clones	21	1053.77	
	repl.	88	441.35	2.388**
Sprouts	clones	21	199.89	
	repl.	88	84.01	2.379***
Stems	clones	19	8.59	
	repl.	80	3.33	2.577**
Dead stumps	clones	19	571.76	
	repl.	80	364.46	1.569

stump mortality was high, the number of stems would have been correspondingly high. The living stumps would have grown more stems and in this way would have utilized the growth space better. The correlation between the death-rate of stumps and the height growth was also analyzed. It was assumed, that after felling in the spring of 1991, stump mortality did not increase during the growth period.

Table 4. The correlation coefficients between the variables. Significance: *** = 0.001, ** = 0.01, * = 0.5.

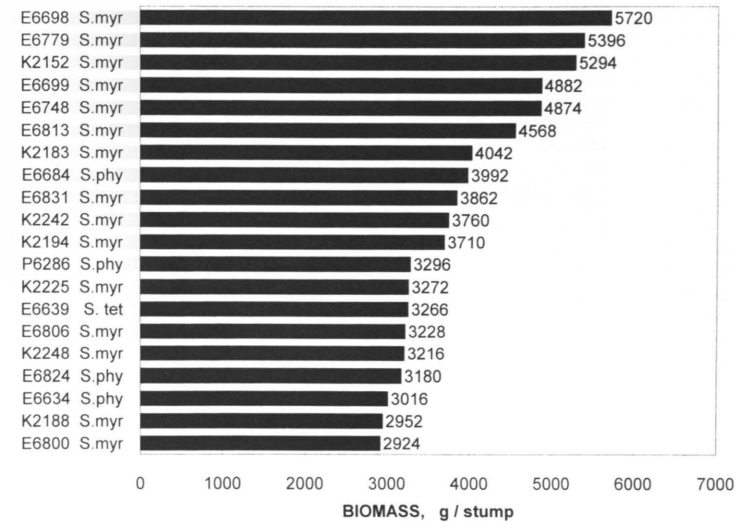|	Mean height	Dominant height	Stems	Sprouts	Dead stumps
Mean height					
Dominant height	0.6349***				
Stems/stump	−0.0890	−0.0282			
Sprouts/ stump	0.5415***	0.6002***	−0.0591		
Dead stumps	−0.5740***	−0.4011***	0.1495	−0.2009*	
Biomass	0.1934*	−0.0584	−0.0368	−0.1144	0.0507

Fig. 2. Average biomass production per stump of the best 20 clones over 11 years rotation, g/stump.
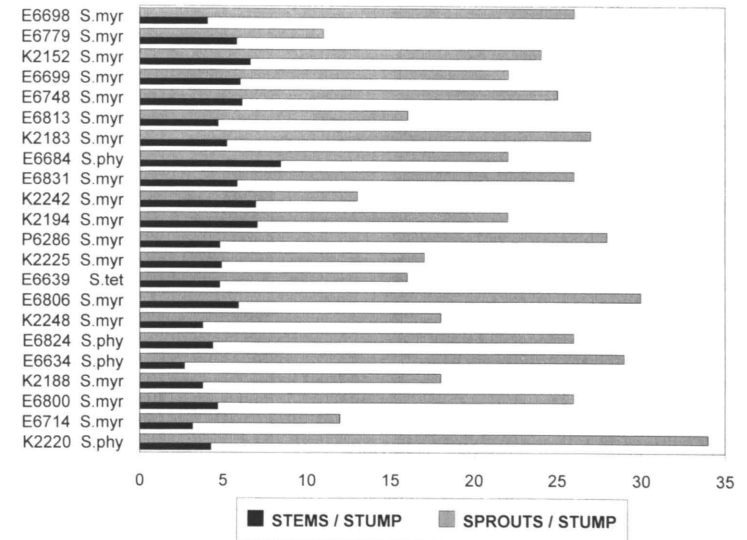

Fig. 3. The number of stems per stump before coppicing and number of sprouts per stump of the best 20 clones in terms of biomass production and two tallest clones determined by sight.
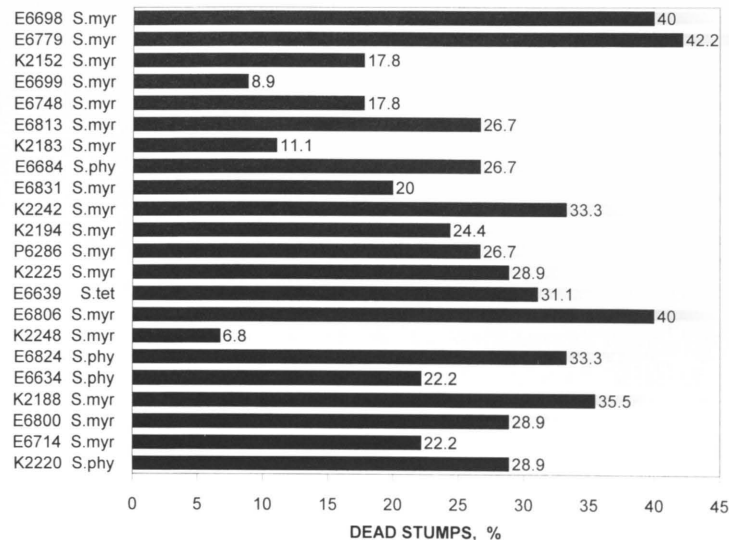
Fig. 4. The number of dead stumps of the best 20 clones in terms of biomass production.
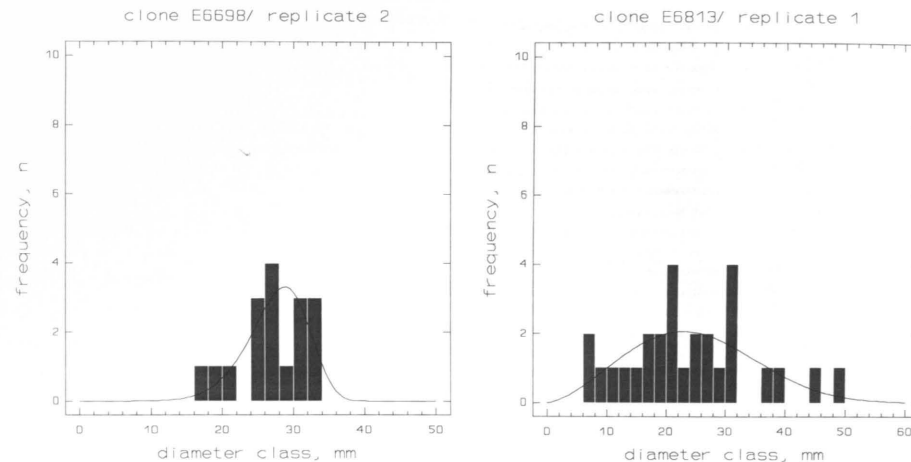

Fig. 5. (a) Example of positive skewed Weibull distribution. Parameter c = 7.7058. **(b)** Example of negative skewed Weibull distribution. Parameter c = 2.5463.

3.3 Weibull Diameter Distributions

Weibull functions and diameter frequency histograms were formed for the 20 clones with the best biomass production. According to the Kolmogorov-Smirnov test, all the cumulative distribution functions supported the hypothesis. Parameters were then tested by one-way analysis of variance (Table 3). The mean values of parameter b varied between 16.5488 and 25.8556 and those of parameter c between 3.6339 and 5.4255 (Table 5). Differences between clones in shape parameter c were not statistically significant. Most of the total variance was derived from differences between replicates.

In all clones parameter c > 3.6, which means that, on average, diameter distributions of the all clones were positively skewed. Figs. 5a and 5b are examples of positively and negatively skewed diameter distributions. Generally, no distinct trend between parameters and biomass production could be found; all kinds of combinations occurred.

Table 5. Mean values for parameter b and c of the best 20 clones in terms of biomass production.

	Clone	Parameter b	Parameter c
1.	E6698	25.8556	4.5986
2.	E6779	24.7813	4.1591
3.	K2152	22.2844	4.2663
4.	E6699	22.1498	3.8235
5.	E6748	22.9953	4.2334
6.	E6813	23.8760	3.6339
7.	K2183	21.8487	4.8116
8.	E6684	16.5188	4.5656
9.	E6831	20.6390	3.7105
10.	K2242	16.7901	4.4460
11.	P6286	20.3202	4.2423
12.	K2194	16.8012	4.8823
13.	K2225	20.4332	3.7105
14.	E6639	21.4402	4.6060
15.	E6806	18.0818	4.5704
16.	K2248	23.6220	4.3230
17.	E6824	21.8590	5.4755
18.	E6634	15.5097	5.1381
19.	K2188	20.3811	4.0572
20.	E6800	19.6245	4.8486

3.4 Height Growth and Coppicing

There were considerable differences between clones in height growth. The tallest sprouts were over two meters and the shortest 30–40 cm high. The mean height of the best clones (K2248, E6699) were about one meter (Fig. 6). The mean height of the clones did not differ significantly. Most of the variation originated from differences between replicates.

The dominant height of the clones varied between 130 and 182 cm (Fig. 6). According to analysis of variance, the dominant height differed significantly between clones.

Analysis of variance indicated differences between clones in sprouting capacity. Clone K2220 had the most sprouts (34/stump) and clone E6779 had the least (11/stump) (Fig. 3). The biomass production of the previous generation and the number of sprouts did not correlate with each other, whereas the number of sprouts correlated positively with both mean height and with dominant height (Table 4). The more sprouts a stump had, the longer the sprouts were.

4 Discussion

Piipsanneva Clone Archive II, which was older than most of the similar trials, was an exceptional trial. As a forgotten, old trial without tending and fertilization, the Piipsanneva experiment can be seen as a good example of the capacity of indigenous willow species to adopt to prevailing conditions. As a controlled trial with fertilizer input and other treatments, the results from Piipsanneva would surely have been different.

In the Piipsanneva trial there were about as many *S. myrsinifolia* clones as *S. phylicifolia* clones, and 10 % of the clones were crossings between these two species. In the final results the *S. myrsinifolia* clones were more successful than the *S. phylicifolia* clones. Of the 20 best clones in terms of biomass production, 75 % were *S. myrsinifolia* clones; and only one *S. phylicifolia* clone was among the ten best clones. As Pohjonen (1991) indicated, in the long-term screening *S. myrsinifolia* seems to be superior to *S. phylicifolia*.

Comparisons between the origin of the clones indicated that the best clones were mostly from southern Finland. Of the best 20 clones, 60 %
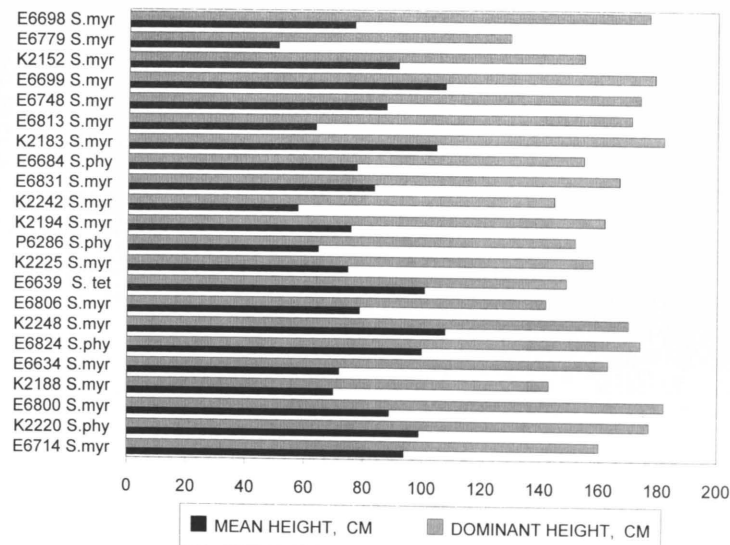
Fig. 6. The mean height and the dominant height of the best 20 clones in terms of biomass production and two tallest clones determined by sight, cm.

originated from southern Finland, 35 % from central Finland and 5 % from northern Finland; whereas of all clones in the trial, 44 % were of southern Finnish origin, 48 % from central Finland and 7 % from northern Finland. All together, the clones that originated from southern Finland succeeded well at the latitude of Haapavesi. Thus southern indigenous clones may be the right choice for energy plantation forestry in central and northern Finland.

There are some restrictions on the use of general biomass equations for estimating tree biomass. For example, large differences in site and stand characteristics may result in poor biomass estimates. The range of tree size should also vary within the data that has been used to form the equation (Crow and Schlaegel 1988). In addition, it is better to make a biomass equation from one's own data. In this study own data was not available, because no stem samples had been taken from Piipsanneva for determination of dry biomass. Therefore other data with dry weights and diameters of different sized *S. myrsinifolia* stems was used to form regression equation. This

trial and the Piipsanneva trial were not quite equal; for example, the willows in this trial were younger than those in Piipsanneva. According to Hytönen (1990), when only diameter was used as an independent variable, the values for the exponent and the constant of the regression equations were relatively stable for willows of different ages.

Due to the large variation between replicates, there were no distinct differences between clones in terms of biomass production. But from among these 87 clones can be separated a group of poor clones, which had a biomass production of under one kilogram over the whole rotation. The biomass production, i.e. the mean annual increment, of the five best clones were: E6698 520 g, E6779 491 g, K2152 481 g, E6699 444 g and E6748 415 g/stump/a. In the Lumme and Törmälä study (1988), the biomass production of the best *S. myrsinifolia* clone K2183 was about 492 g/stump/a.

As far as growth conditions are concerned, height growth was surprisingly good in the first year after coppicing. The old roots had obvious-

ly remained vigorous, and therefore height growth and coppicing were intensive. For example, the dominant height of the one-year-old shoots of the best clone (K2183) was 182 cm in 1991; the dominant height of the same clone was 150 cm at the age of three years in 1982 (Pohjonen 1991). In the study of Lumme and Törmälä (1988) height growth of the best *S. myrsinifolia* clone attained 148 cm in one year (two-year-old roots), and in Kannus Clone Archive I the mean height of the best *S. myrsinifolia* clones in two-year-old stems (5 to 6-year-old roots) was about 140 cm (Pohjonen 1991). In the Piipsanneva trial the mean height of the best clones was already 108 cm in the first year after coppicing (11-year-old roots).

If we compare these results of biomass production in 1991 and the height growth results of the four-year-old stems from the year 1983 (Pohjonen 1991), we find that the five best clones in terms of dominant height in 1983 (K2248, E6813, K2242, K2183 and E6699) are among the 20 best clones in biomass production in 1991. Clones K2248, E6699 and K2183 were also the three best clones in terms of mean height in the autumn of 1991.

The ranking of the clones according to height growth is quite different from the ranking for biomass production. The best clones in terms of biomass production were not the best in height growth. Biomass production did not correlate significantly with either mean height or dominant height. These results give no reason to suppose, however, that the sprouts of the best clones in terms of biomass production would also grow better at the beginning of the next generation.

According to Ferm and Kauppi (1990) stump mortality, vigor of the roots and shoot-root relations also affect growth of the next generation; and the old stumps give the poorest sprouting results. In this study lack of fertilization and the old stumps did not seem to affect coppicing negatively. The number of the sprouts, on average 11–34 sprouts/stump, was high. According to Hytönen (1990), the mean height and the number of sprouts express sprouting capacity poorly, because the height distribution of young sprouts is skewed. There are many short sprouts and the number of sprouts decreases rapidly during the first growing season. Therefore dominant height and stump mortality would be better descriptive

variables.

The effect of length of rotation cycle is not well known, but it is supposed that a longer rotation cycle gives better coppicing results and higher yields (Ferm and Kauppi 1990, Nilsson and Ericsson 1986). In the studies of Wright (1987) and Willebrand et al.(1993) the short rotation cycles (1–2 years) did not produce better results than rotation of four years or longer.

Competition and fertilization increase stump mortality (Ferm and Kauppi 1990). In the Piipsanneva trial, however, there was no fertilizer input. Stump mortality varied between 7 % and 42 %; on average, 27 % of the stumps were dead. In this study the stump mortality was highest in the two best clones in terms of biomass production (E6698 and E6779), but no distinct relation was found between biomass production and stump mortality.

In scale parameter b the clones differed statistically significantly. The two most productive clones (E6698 and E6779) attained the highest values for parameter b. The diameter distributions of these clones were not concentrated on only a few diameter class; on the contrary, these distributions were wide, a result that was in contradiction to the hypothesis. The mean values of parameter b indicated that the best clones had generally higher values in the scale parameter than the poorer clones did.

The shape parameter of the distributions varied considerably between replicates and no obvious connection between biomass production and parameter c were detected. The skewness hypothesis, according to which clones with high yield would be positively skewed, was not confirmed here. For all clones the Weibull-distributions were, on average, positively skewed (c > 3.6). Most of the diameters were between 10 and 30 mm, and very small diameters (4–9 mm) were rare. Skewness of plant size distribution is common in even-aged monocultures, as a consequence of competition (Weiner and Thomas 1986, Ford 1975).

No similarities were found between the shape parameter and biomass production. The most productive clones were not particularly positively skewed nor were the poorest clones the most negatively skewed. If the parameter examination had included all clones of the trial, some more

distinctive differences between clones might have appeared.

There was no connection between parameters b and c; these two parameters did not seem to affect each other. On the other hand, values of parameter b differed significantly between clones. The best clones in terms of biomass production had the highest values for parameter b. Their diameter distributions were wide, whereas the diameter distributions of poorer clones were narrow. Contrary to the hypothesis, behind the high yield there were diameters in all diameter classes, not a concentration into a few diameter classes. This gives reason to assume that in an older, even-aged willow population utilization of the whole growth space gives the best result. Clones that have a wide diameter distribution may be able to utilize the three-dimensional space better.

Pohjonen (1991) recommends five *S. myrsinifolia* clones (E6631, K2322, E6695, V75 and V78) for further experiments and for energy wood plantations. According to the Piipsanneva trial, to this list could be added the five best clones in terms of biomass production (E6698, E6779, K2152, E6699 and E6748) and the three best clones in terms of height growth (K2183, K2248 and E6800). In further tests, comparisons between clones both on mineral soil and on peatlands would be interesting, and further trials should concentrate on comparing these best clones from different trials.

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