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VELI POHJONEN

SELECTION OF SPECIES AND CLONES FOR BIOMASS WILLOW FORESTRY IN FINLAND

BIOMASSAN VILJELYYN SOPIVIEN PAJULAJIEN JA -KLOONIEN VALINTA SUOMESSA

THE SOCIETY OF FORESTRY IN FINLAND
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SELECTION OF SPECIES AND CLONES FOR BIOMASS WILLOW FORESTRY IN FINLAND

Biomassan viljelyyn sopivien pajulajien ja -kloonien valinta Suomessa

Veli Pohjonen

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Willow (*Salix* sp.) species and clones have been selected in Finland, originally for basket willow husbandry, since 1910s. Screening for biomass willows started in 1973 by the Foundation for Forest Tree Breeding. Biomass willow research for energy started in 1978. The objective of the study was, based on theoretical background, on historical record of Finnish willow research between 1910–1980 and on analysis of the Finnish biomass willow research of the 1980s, a further selection of exotic and indigenous willows for energy and chemicals.

Swedish selection of 63 exotics, mainly of *Salix viminalis* L. and *Salix burjatica* Nazarov, was screened in Kopparnäs willow research site in the southern coast of Finland, in 1983–1989. *S. viminalis* showed both high yield potential and good crop certainty. The yield variations in *S. burjatica* were big due to rust (*Melampsora* sp.) infection followed by lowered winter hardiness. Three recommendable *S. viminalis* clones for southern Finland were found: 78-0-183 (Sweden), E7888 (Somero, Finland) and 78-0-21 (Sweden).

Finnish indigenous species were screened based on collection (375 clones) in 1973–74 of the Foundation for Forest Tree Breeding and the Finnish 4H-organization (566 clones) in 1978–79. Test sites were Suomusjärvi, Nurmijärvi, Kannus and Haapavesi. *Salix myrsinifolia* Salisb. was most productive of the indigenous willows. Five recommendable clones were selected: E6631 Kullaa, K2322 Heinävesi, E6695 Hartola, V75 Mikkeli and V78 Loppi. The secondmost productive indigenous was *Salix phylicifolia* L., with most promising clones of E6682 Juva, V766 Pieksämäki and V754 Kuru.

Based on willow hybridization studies in the Finnish Forest Research Institute, a considerable additional selection effect, boosted by heterosis, was found from the progenies. Further intraspecific crossings of geographically distant clones of *S. myrsinifolia*, and selection from the progenies, are recommended.

Based on research results from 1910–1990 *Salix viminalis* is recommended for practical biomass forestry applications in the southernmost agroclimatic zone of Finland. *S. myrsinifolia* is recommended for further research and development in the other zones.

Pajulajeja ja -klooneja on kokeiltu ja valittu suomalaiseen viljelyyn 1910-luvulta lähtien, aluksi koripajun raaka-aineeksi. Biomassapajujen etsinnän käynnisti Metsänjalostussäätiö vuonna 1973. Energiapajujen valinta alkoi Metsäntutkimuslaitoksen PERA-projektin osana vuonna 1978. Tutkimuksessa valittiin biomassapajuja ja -klooneja suomalaiseen viljelyyn teoreettisen tarkastelun, 1910–1980 kertyneen kirjallisen aineiston ja 1980-luvun koetoiminnan perusteella.

Ruotsista saatiin vuonna 1983 Kopparnäsin kokeisiin 63 valittua vierasperäistä kloonia, etupäässä lajeja *Salix viminalis* L. ja *Salix burjatica* Nazarov. Vuosien 1983–89 kenttäkokeissa parhaat *S. viminalis* kloonit osoittautuivat viljelyvarmoiksi ja tasaisen satoisiksi. *S. burjatica* kloonien satovaihtelut olivat suuret, mahdollisesti ruostetautien (*Melampsora* sp.) ja niiden heikentämän talvenkestävyyden seurauksena. Kolmeksi, heti viljelyyn suositeltavaksi *S. viminalis* -klooniksi todettiin 78-0-183 (Ruotsi), E7888 (Somero) ja 78-0-21 (Ruotsi).

Kotoperäiset lajit valittiin Metsänjalostussäätiön vuosien 1973–74 keräyksestä (375 kloonia) ja Suomen 4H-liiton ja Metsäntutkimuslaitoksen keräyskampanjasta vuosina 1978–1979 (566 kloonia). Satoisimmaksi lajiksi osoittautui mustuvapaju, *Salix myrsinifolia* Salisb. Viisi jatkotutkimuksiin ja käytännön viljelyyn suositeltavaa kloonia olivat E6631 Kullaa, K2322 Heinävesi, E6695 Hartola, V75 Mikkeli ja V78 Loppi. Toiseksi satoisin laji oli kiiltopaju, *Salix phylicifolia* L., jonka lupaavimmat kloonit olivat E6682 Juva, V766 Pieksämäki ja V754 Kuru.

Metsäntutkimuslaitoksen PERA-projektissa suoritettujen pajuristeytysten perusteella havaittiin, että pajulajien ja -kloonien valinta nopeutuu jos luonnon populaatioiden etsinnässä löytymätön hajonta tuodaan esiin suunnitelmallisilla risteytyksillä. Valitsemalla risteytysperheestä nopeakasvuisin klooni saadaan kotoperäisillä pajuilla nopeasti valintahyöty. Jos risteytyksiin valitaan lisäksi maantieteellisesti etäiset alkuperät, risteytysperheen hajontaa lisää populaation kasvuisammasa päässä F_1-sukupolvessa ilmenevä risteytyselinvoima (heterosis). Jatkotutkimuksissa kotoperäisten kloonien valintaa kannattaisi suorittaa maantieteellisesti etäisistä *Salix myrsinifolia × myrsinifolia* risteytyksistä.

Vuosien 1910–1990 pajunviljelyn tutkimusten perusteella biomassan viljelyyn sopivin laji Suomen eteläisimmällä maatalous-ilmatieteellisellä vyöhykkeellä on *S. viminalis*. Pohjoisemmilla vyöhykkeillä biomassapajujen viljelyn tutkimus- ja kehitystyötä tulisi jatkaa lajilla *S. myrsinifolia*.

Keywords: exotics, indigenous species, *Salicaceae*, *Salix viminalis*, *Salix myrsinifolia*, temperate zones, boreal zone, biomass production, heterosis, hybrids, taxonomy.
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Contents

1. INTRODUCTION 5
11. Willows and biomass 7
12. Willow species and clones 7
13. Hypotheses and objectives 7
2. PROBLEMATICS OF WILLOW SPECIES 8
21. *Salix* in the Plant Kingdom 8
22. Review on development of species concept with *Salix* 9
23. Hybrids: true, putative and artificial 9
231. Hybridomania 9
232. Hybrid inviability and breakdown 10
233. Artificial hybrids 11
234. Summary 12
24. Current species definitions 12
25. Number of willow species 13
26. Evolutionary background 13
3. REVIEW OF POTENTIAL SPECIES FOR BIOMASS WILLOW HUSBANDRY 15
31. *Salix alba* L. 15
32. *Salix burjatica* Nazarov 16
33. *Salix caprea* L. 16
34. *Salix cinerea* L. 17
35. *Salix daphnoides* Vill. 17
36. *Salix fragilis* L. 18
37. *Salix myrsinifolia* Salisb. 18
38. *Salix pentandra* L. 19
39. *Salix phylicifolia* L. 20
310. *Salix schwerinii* E. Wolf 20
311. *Salix triandra* L. 20
312. *Salix viminalis* L. 21
4. EARLY FINNISH SELECTIONS 23
41. Johnsson and Mäkinen 1910–13 23
42. Nordberg 1914–1930 23
43. Relander and Tapio 1949–1953 24
44. Foundation for Forest Tree Breeding 1973–1978 24
45. Pohjonen 1976–77 25
46. Summary for the end of 1970s 25
5. SELECTION OF BIOMASS WILLOWS IN THE 1980s 26
51. Material 26
511. Kopparnäs; exotics 26
512. Suomusjärvi and Nurmijärvi; exotics and indigenous 27
513. Kannus; indigenous 28
514. Hybridization and population studies 29
52. Results and discussion 30
521. Selection of exotics in Kopparnäs 30
522. Selection of exotics and indigenous in Suomusjärvi and Nurmijärvi 33
523. Selection of indigenous in Kannus 33
524. Selection from F1-progenies 37
53. Summary 39
54. Species recommendation 39
55. Further selection needs in Finland 40
REFERENCES 40
APPENDIX 44

Abbreviations

ACU	*Salix daphnoides* subsp. *acutifolia* (Willd.) Blytt & O. C. Dahl	Parai	Parainen
ALB	*Salix alba* L.	PEN	*Salix pentandra* L.
BUR	*Salix burjatica* Nazarov	Pertu	Pertunmaa
CAP	*Salix caprea* L.	PHY	*Salix phylicifolia* L.
DAP	*Salix daphnoides* subsp. *daphnoides* Vill.	POL	*Salix triandra* L. × *S. viminalis* L. 'Polyphylla'
Denma	Denmark	PUR	*Salix purpurea* L.
FRA	*Salix fragilis* L.	Reisj	Resijärvi
Halsu	Halsua	Ruots	Ruotsinkylä
Harto	Hartola	Ruove	Ruovesi
Heino	Heinola	SAL	*Salix* sp. (unidentified)
HYB	Hybrid	Sievi	Sievi
Iloma	Ilomantsi	Somer	Somero
Janak	Janakkala	Suone	Suonenjoki
Jyvas	Jyväskylä	Swede	Sweden
Kanga	Kangasniemi	Tammi	Tammisaari
Karja	Karjaa	TET	*Salix* × *tetrapla* Walker ex Sm.
Karko	Kärkölä	Toysa	Töysä
Kulla	Kullaa	TRI	*Salix triandra* L.
Lieto	Lieto	Ullav	Ullava
Liper	Liperi	Ulvil	Ulvila
Mikke	Mikkeli	Vaasa	Vaasa
MYR	*Salix myrsinifolia* Salisb.	VIM	*Salix viminalis* L.
Palka	Pälkäne		

Preface

Since 1973, when Professor Paavo Yli-Vakkuri from the Department of Silviculture, University of Helsinki, suggested initiation of screening study into possible species for Finnish short rotation forestry, I have been helped and inspired by several persons involved in biomass willow research. The early phases took place in the Arctic Circle Experiment Station of the Research Centre for Agriculture in Finland, Hyytiälä Research Station of the University of Helsinki and the Research Institute for Northern Finland of the University of Oulu.

Professor Gustaf Sirén has been in many ways a moderator of the selection of biomass willows besides in Sweden, also in Finland. He was behind the selection of the original clones for Kopparnäs trial in Inkoo. Discussions with him during 1983–1991 have been of great help in matters of exotic species and clones for the southernmost Finland. Planning sessions with Mr. Esko Jaatinen and Mr. Lars Wessman, of the Imatran Voima Ltd, have also been helpful. Ms. Maisa Viljanen from the University of Joensuu has measured all the Kopparnäs trials with accuracy and patience.

Selection of indigenous biomass willows was mainly done in the Kannus Forest Research Station of the Finnish Forest Research Institute. Since 1978 it was part of the PERA-project of the Institute. The Chairman of the project, Professor Olavi Huikari, encouraged in many ways implementation this part of the project. He also originated the mass collection of willow clones in cooperation with the Finnish 4H-clubs.

The practical assistance of Mr. Esa Heino, Mr. Taisto Jaakola and Mr. Kaarlo Sirviö of the Kannus Forest Research Station, who took care of the 4H-cooperation, and subsequently established the clonal archives, has been essential in order to finally compile the data for study. Mr. Jyrki Hytönen supervised the willow research in Kannus from the mid 1980s. He kindly also delivered part of the screening data to be used in this study.

Fruitful discussions have also been held with Ms. Kirsi Elo who originally planned the willow hybridization study under the PERA-project, and with Ms. Anneli Viherä-Aarnio who completed the hybridization programme.

Professor Leena Hämet-Ahti has gone through the list of willow species, subspecies and cultivars, with valuable corrections and comments.

I wish to express my gratitude to all the above mentioned persons, willow enthusiasts, without help of whom the selection would not have been possible.

Joensuu, 17. 9. 1991

Veli Pohjonen

1. Introduction

11. Willows and biomass

Willows (*Salix* sp.) have a long-standing history as arable crops in Europe. Willow husbandry has its roots in the art of basket making, dating back to times of Plinius (23–79 A.D.) and Columella (died around 50 A.D.). Roman scholars developed an advanced discipline for willow husbandry including selection of species and optimization of cultivation practices, but all their innovations were to be forgotten for centuries (Makkonen 1975).

Systematic screening of suitable species and clones for basket willow husbandry was developed in mid 1800s in Germany by Reuter (Tapio 1965) and Krahe (1886). Organized work led into remarkable collections; Nordberg (1928) for instance mentions about an archive of 800 willow clones at a silvicultural station near Munich. Selection from such collections, connected with high demand of productive clones for basket willow husbandry, led early into commercial cultivars, besides in Germany also elsewhere in Europe. Stott (1956) has summarized such development from the British angle.

In Finland the first attempts to initiate basket willow husbandry date in the 1880s (Flinta 1881). Screening of species and clones was started in

1910 by L. Mäkinen and J. W. Johnsson (Mäkinen 1913, Nordberg 1914). A remarkable effort in developing Finnish willow husbandry, with first documented species and clone trials, was made between 1914–1930 by S. Nordberg (Nordberg 1919, 1923, 1928, 1930). The last serious research into basket willow husbandry in Finland was carried out by E. Tapio (née Relander) between 1950–53 (Relander 1950, 1951a, 1951b, 1952, Tapio 1953).

Despite considerable inputs in research and development, basket willow husbandry in Finland never advanced into practical farming. In the older days the obstacle was the import of cheaper and more flexible raw materials, like basket willow from East Europe and rattan (*Calamus acanthospathus* Griff) from Far East. Later, synthetic materials largely replaced willows in basket industry, in Finland and everywhere in Europe alike. Fundamental reviews of the potential and history of the Finnish basket willow husbandry have been given by Nordberg (1928) and Tapio (1965).

The concepts of *biomass*, *biomass for energy* and *biomass willows* are offsprings of the 1960s and the 1970s following the developments of the International Biological Programme (e.g. Cooper 1975) and the two energy crises of the 1970s. The new association between renewable natural resources, energy and chemicals (Abelson 1982) was early combined with willow husbandry. This happened notably in Sweden, already from 1970s onwards (Sirén et al. 1974, Sirén 1981, Ledin et al. 1990). Consequently, it provided a new focus for selection and genetic improvement in willows (Zsuffa et al. 1984).

The early research and development into basket willows has been of prime importance for biomass willow husbandry. Productive basket willow is high yielding also in terms of dry matter. The early screening of basket willows followed the same general principles that were to be followed when screening the willows for biomass. The remnant collections for old basket willow husbandry, like the Long Ashton collection in Britain (Stott 1984), could therefore immediately deliver suitable clones, even commercial cultivars, for biomass willow husbandry.

The Finnish research into biomass willows has its origin in 1953. R. E. Serlachius from the Finnish forest industry and R. Sarvas from the Finnish Forest Research Institute arranged an import of 5000 cuttings of *Salix burjatica* Nazarov 'Aquatica No 56' from Denmark. The cuttings were planted in field trials of the Forest Research Institute (Hagman 1976, Pohjonen 1987).

The first Finnish baseline study into the potential of biomass willows was carried out by Malmivaara et al. (1971). The field trials were initiated in 1973 (Pohjonen 1974, 1985). The Foundation of Forest Tree Breeding started a countrywide collection of biomass willow species and clones also in 1973 (Lepistö 1978).

The early interest behind the potential biomass production was in acquiring more raw material for pulp industry. Especially in the beginning of the 1970s, based on rising demand for pulp and paper, it was calculated that the conventional supply of long rotation pulp wood would not suffice for long. Later in the 1970s cultivation and utilization of willows became a part of a larger research project into production and utilization of short rotation wood (Pohjonen 1977, Hakkila et al. 1979).

The early studies of the 1970s revealed that biomass willows have a considerable yield potential if cultivated in fertile arable lands, and if as intensive methods are used as are standard with agricultural practices. An early finding was the superiority of some exotic willows over the indigenous species as biomass producers (Pohjonen 1974, 1977, Lepistö 1978). The most promising exotics were the osier and its relatives (*Salix viminalis* L., *Salix burjatica* Nazarov and *Salix × dasyclados* Wimm., see also Tapio 1965).

A boom of biomass willow research took place in the turn of 1970s into 1980s. Intensive research into biomass for energy was initiated in Sweden (Sirén 1983), Great Britain (Mclain 1983), Ireland (Neenan 1983) and Canada (Zsuffa 1982). In Finland the biomass willow research became part of the PERA-project (PERA – wood as a source of energy) (Energiametsätoimikunnan ... 1979, Hakkila 1985).

As the topics of willow husbandry were still rather unexplored the biomass willow research concentrated first in widening the genetic diversity of the germplasm. Massive collections and selections of species and clones were initiated in Sweden (Ager et al. 1986) as well as in Finland (Heino and Pohjonen 1981).

There was a remarkable difference in the Swedish and Finnish willow screening objectives. The Swedish screening programme concentrated in the exotics, the Finnish one in the indigenous species. The importance of species diversity in general, and clonal diversity especially, were understood in both programmes. Ecological theories did not favor establishing the biomass willow husbandry totally as monoclonal plantations.

As the potential cultivation areas are somewhat more northern in Finland than in Sweden, it was felt that the reliance on exotic clones only would be on an uncertain basis. Based on the basket willow husbandry the winter hardiness of the productive exotics, like *Salix viminalis* was already known to be poor in Central Finland.

At the end of 1970s the Finnish indigenous willows were poorly studied by their cultivation characteristics. In general, for instance based on the screening of 1970s (Lepistö 1978), the exotics (especially *Salix burjatica* 'Aquatica') seemed to have far higher yield potential than the indigenous species. Compared to exotics also the cultivation characteristics of indigenous species, for instance the ability to root as cuttings, seemed uncertain. The only reliable species in this respect was *Salix triandra* L. (Siira et al. 1981).

Based on the experience of the basket willow husbandry and the field research in 1970s the development of biomass willow husbandry in Finland diverged in 1979 into two lines: (i) cultivation studies with existing exotic species complemented by further screening of imported Swedish germplasm and (ii) collection and screening for indigenous species complemented with breeding for combined productivity and winter hardiness.

12. Willow species and clones

When Linné in 1753 established his 29 willow species, he made a note in his systematics that the willow species are extremely difficult ("Species huius generis difficillime extricantur", Skvortsov 1968). The difficulty of the systematics has prevailed in the willow research since Linné's days. Unclear boundaries between species, introduction of subspecies, varieties, forms, populations and clones, has confused the willow researchers as well as farmers involved in willow husbandry. Opinions about number of willow species have varied between Linné's 29 and Gandoger's over 1600 (Skvortsov 1968). Still more confusing has been the inclusion of spontaneous hybrids in the willow systematics.

Indeed, if there is only one species of *Populus* (*P. tremula* L.) in Finland, why are there 21 species of *Salix* (Hämet-Ahti et al. 1989) in the same geographical area? Why are there such difficulties in the systematics with *Salix*, while the genus *Populus* is relatively distinct, even worldwide? And both genera are believed to have evolved rather parallelly from the same ancient parents (Dorn 1976).

The genus *Salix* is agreed to be taxonomically one of the most complex genera in the Plant Kingdom (e. g. Argus 1973). Its antiquity, wide distribution, perennial habit, polyploidy, ability to hybridize, wide ecological amplitude and morphological plasticity all contribute to the difficulties encountered in the taxonomical, ecological and evolutionary studies of willows (Julkunen-Tiitto 1989).

The problematics in specifying the willow species can — besides the definition of species itself — be attributed to three main issues: (i) *Salix* is one of the youngest broad-leaved genera in the timeframe of the plant evolution, (ii) true hybrids between willows do exist, (iii) willows have the modality of insect-pollination which has geographically limited the exchange of genes and thus created numerous local populations.

A close resemblance of nearby willow species makes the collection of the germplasm complicated. The researchers, however, have learned to live with the complications by stressing the importance of clones and proper clone selection. According to this approach the separation of species and finding their correct names are irrelevant. A properly marked, registered and described clone is the basic unit for practical plantation applications. But — without knowing the background of different clones in the systematics, the clone selection and willow breeding work unefficiently and at random (Pohjonen 1987).

It is a central research problem in the species selection for biomass willows to understand what is species, what is a natural hybrid, what is actually a putative hybrid, and what are the possibilities to introduce productive artificial hybrids between the agreed species.

13. Hypotheses and objectives

Selection of species for biomass willow husbandry must base on understanding of the ecological, evolutionary and hybridization principles within this genus. First, the species concept with willows must be agreed upon: what are the willow species, how did they evolve, what are their evolutionary relationships? Second is the hybridization: how do the willow species hybridize, how do the F1- and F_2-generation be-have in terms of biomass production? The output of such reasoning is the frame within which the species and clone selection must operate.

The frame leads into the following hypotheses:

- Species selection based on evolutionary and ecological theory will give better selection of new species and clones.
- The yield differences between exotic and indigenous species are diminished or levelled out with proper clonal selection. Over a long run, the better crop certainty (Kallinen et al. 1976) of indigenous species compensates for the temporal high yields of the exotics.
- Artificial crossings of geographically isolated indigenous species reveal the population variation. Clonal selection from such families increases the selection efficiency.

Related to these hypotheses, the objective of this study is the selection of suitable exotic and indigenous willow species and clones for practical applications in the Finnish biomass willow forestry. The selection is to be based on a theoretical background, on the historical record of Finnish research into basket and biomass willows between 1910–1980 and on an analysis of the Finnish biomass willow research of the 1980s including exotic collections, indigenous collections and artificial hybridizations.

2. Problematics of willow species

21. Salix in the Plant Kingdom

The willows, *Salix*, belong to the family *Salicaceae* which forms part of the order *Salicaceae* of the group *Amentiflorae*. The *Amentiflorae* fall within the subclass *Monochlamydae* of the class *Dicotyledonae*, subdivision *Angiospermae*, division *Phanerogamae*.

The family of *Salicaceae* consists of three genera: *Salix* L., *Populus* L. and *Chosenia* Nakai. The genus *Salix* is further divided into three subgenera: *Salix*, *Vetrix* and *Chamaetia*. In the subgenus *Salix* there are 6 sections, in *Vetrix* 15 sections and in *Chamaetia* 5 sections.

Subgenus *Salix*, tree willows, can grow to tall trees between 10 and 35 meters high. In evolutionary timing they are the oldest willows. They are usually found by the sides of rivers, mostly in lowlands and in warm temperate countries, for instance in the valleys of the Italian Po, Balkanese Danube and Argentinan Parana rivers. They produce natural stands of timber trees, often in association with poplars. If grown as coppice they usually produce relatively few shoots per stool (less than 10) and may need cutting cycles of 5–10 years or more to optimize their biomass yields. In this respect they are similar to poplars; also taxonomically tree willows are nearer to poplars than the evolutionary younger shrub willows of *Vetrix*.

In the subgenus *Vetrix* the willows grow normally from 2 to 10 meters high. They are of little value as timber trees but they can produce substantial amounts of woody biomass. They are adapted to a large amplitude of ecological conditions, some of which are dry. They range across the north temperate regions of the world into the colder areas of Scandinavia, Siberia and Canada. As coppiced they produce a plenty of shoots per stool, often 20–30. The yields are maximised with short rotation cycles of about 5 years (Stott 1984). The species of the subgenus *Vetrix* might be the most appropriate ones in starting the breeding programmes for biomass willows.

The subgenus *Chamaetia*, the dwarf willows, has no immediate potential as biomass willows. As they are the youngest in the evolutionary timing some of them may, however, have some special use as source material for breeding.

Systematically the position of *Salix* in the Plant Kingdom seems clear. The difference between *Populus* and *Salix* is distinct. The rare intermediate genus with a single species (*Chosenia bracteosa* Trautv.) is of scientific interest only and does not pose any species definition problems.

The difficulties in systematics lie inside the subgenera. There is a remarkable natural variation within willows species. Usually a particular willow consists of several distinct groups or populations. Depending on the degree of morphological or geographical variation the within species variants are is grouped up to 6 levels (taxons): i) subspecies, ii) varieties, iii) forms, iv) populations, v) clones and vi) cultivars.

Species, subspecies and forms are named following common rules. For breeding purposes a population can be given a population number like R-53-075 for *Salix burjatica* 'Aquatica No 56' (Hagman 1976), or in the case of a selected individual from a population, a clone number like E7888 for *Salix viminalis* clone collected from Somero.

A cultivational or commercial taxon has been used with willows for long: the cultivar (cv.), for instance 'Regalis' for *Salix viminalis* L. 'Regalis'. Cultivars are recognized of the natural populations by morphological or other clear trait which also is conserved in the propagation. The cultivar name is usually more vernacular than the plain clone number. The classification rules for cultivars have been internationally adopted (Bricknell et al. 1980).

From the plant husbandry point of view it is most confusing how the various ranks between species and clones are designated, and how they can be kept distinct. The use of the taxonomy loses therefore its content when willows are taken for cultivation, away from their geographical distribution and ecological environment. The ultimate aim of the plant husbandry is to operate with cultivars. All the taxons between cultivar and species seem unnecessary in that context.

22. Review on development of species concept with *Salix*

The concept of species with willows has a clear historical development. Linné with his 29 willow species had a rigid species concept: species are fundamental units which do not easily change or hybridize. Linné was the first to follow the typological species concept (Mayr 1970).

A departure from Linné's standards and ideas is, however, noted already at the end of the 1700s. Characteristic for the new period is the striving for the maximum disclosure of the diversity of willow species. In those times a morphological distinction was usually simultaneously interpreted as a taxonomic distinction. Investigations of morphological differences in herbarium specimen led into a mass description of new willow species.

The amount of species began to multiply with an incredible speed. In 1804 already 45 willow species were given by Smith. In 1806 Willdenov numbers a global total of 116 species. Toward 1828, according to Koch's calculation, 182 species of willows had been described, 165 of them European. And in 1835 Hooker reported 71 species for the British isles alone (Skvortsov 1968; Skvortsov himself accepts only 19 species for the British isles).

The extreme in the willow systematics is Gandogers's 28-volume 'Flora of Europe' from 1890, in which more than 1600 willow species are given for Europe, 1576 of them established by Gandoger himself. For instance *Salix caprea* was divided into 76 species. Later, however, not a single one of the 1576 names proposed by Gandoger did get any nomenclatural right (Skvortsov 1968).

All willow researchers in the 1800s did not accept the mass description of new species. Already in 1825, based on observations of willows in nature, Koch emphasized the presence of a wide range of variability. In a review of European willows he reduced the number to 48. Other opponents were Tausch and Kerner. It was, however, Wimmer who in 1866 completed the consolidation and clarification of willow species. Wimmer subjected the number of European species to further reduction of 34 (Skvortsov 1968; Skvortsov himself accepts 58 European species).

Simultaneously with the sharp increase in the number of species, number of varieties began to disappear; there is not a single one for all of the 116 species in Willdenov; they are absent from Smith as well.

23. Hybrids: true, putative and artificial

231. Hybridomania

The early proposals to reduce the number of *Salix* species were complemented by designating hybrid status for the specimen which earlier might have been granted a generic rank. In a way naming hybrids got the same magnitude as naming pure species earlier. Skvortsov (1968) calls this period hybridomania.

The existence of spontaneous willow hybrids was first proposed by Scopoli in 1760. About one hundred years later Kerner, Wimmer and particularly Wichura verified the existence of natural hybrids and the comparative ease of obtaining various artificial hybrids.

Wimmer demonstrated in 1866 the hybrid nature of a large number of willow forms that had previously been recognized as pure species. In his "Salicales Europaeae" he describes 57 hybrids. He is of the opinion that the number of willows species in Europe is small but numerous hybrids do exist. He ascertained once and for all that each species is polymorphic and there exists a wide possibility of hybrid combinations.

The last prominent willow systematist in the period of hybridomania was Swedish Floderus. He pointed out that pure species are rare on the arctic territories of Novaja Zemlja, Greenland and Kamchatka, partly also in northern Scandinavia, while simultaneously hybrids predominate.

The strength of hybridomania was boosted by field observations of putative hybrids and the artificial hybridization studies of Nilsson (1918). They led botanists to the view that willows hybridize extensively in the nature and more or less freely with each other. Discussions on this period have been given besides Skvortsov (1968) also Du Rietz (1930), Argus (1974) and Meikle (1975).

The opinions about spontaneous hybridization between willow species started to change in the late 1800s. Swiss Buser was the first who was sharply against the hybridomania. He was also the first who noticed that the closest species do not hybridize most easily; on the contrary, particularly frequent are hybrids between species of the various sections (Skvortsov 1968). Striking are especially the hybrids between the small dwarf shrubs of the sections *Retusae* or *Chamaetia* in the subgenus *Chamaetia* and the tall representatives of the sections *Arbuscella*, *Lanatae* or *Villosae* in the subgenus *Vetrix*.

Wichura (1865), who was originally in favor of spontaneous hybridization, slowered later himself the hybridomania by establishing that willow hybrids do exist but they are by no means possible between every species. Wichura made also the first attempt to quantify the phenomenon of the natural hybridization. He estimated that the most common hybrids in the nature, such as *Salix purpurea* × *viminalis* or *Salix aurita* × *repens* are found at ratio of one to 300–500 in relation to their parental species, while for instance *Salix triandra* × *viminalis* (interesting from willow husbandry point of view) occurs only in ratio of one to 50'000.

Wichura (1865) also pointed out that often the hybrids have a poor viability and a reduced fertility. Consequently the adaptation of the hybrids to the growing conditions is worse than with the parent species. Therefore the spontaneous hybrids do not have good prospects in nature.

In the more recent research Skvortsov (1968) and Argus (1973, 1974), who have wide ranging taxonomical experience with willows of Eurasia and North America, agree that willows do not hybridize indiscriminately. The hybrid swarms are not as common as once assumed. The natural interspecific hybridization has less to do with intraspecific variation than was commonly held.

What was behind hybridomania, why has the role of hybrids in willows been so strongly overrated? Skvortsov (1968) points out three reasons. First, the typological species definition prevailed since Linné's days, with strict concentration on morphological features and narrow boundaries between species. Secondly, as most of the research was based on herbariums only, the ecological knowledge of the willow species and their populations was rather faint. And thirdly, selective willow collections for herbariums have resulted in biased sampling of the true populations.

Undoubtedly willows, however, are one of the genera in the Plant Kingdom with the greatest number of interspecific hybrids. Hybridization, introgresssion and the existence of polyploidy are most common in the youngest willow subgenus *Vetrix* (Jalas 1965). Taxonomic difficulties are also biggest in *Vetrix*. It is worth noticing that most of the Finnish as well as Scandinavian willows belong to this subgenus.

232. *Hybrid inviability and breakdown*

The fact that spontaneous hybridization has in the 1960s and 1970s found been rather rare, is largely attributable to the deepened knowledge how reproductive barriers between the willow species are formed. A comprehensive review on the topics has been given by Mosseler (1987).

The reproduction barriers can roughly be divided in two, into prezygotic and postzygotic barriers. The prezygotic barriers touch the artificial crossings: for one reason or another fertilization is not successful, or the fertilized ovule does not develop into a germinating seed. In practice, there is little what can be done to break a prezygotic barrier, or the phenomenon in the clonal selection.

Of the postzygotic reproduction barriers the hybrid inviability and hybrid breakdown are of importance when examining the possibilities of artificial crossings and selecting clones from their progenies. Hybrid inviability and breakdown partly explain the forms and magnitude of the spontaneous hybridization in the nature.

Hybrid inviability can be defined to refer to the mortality and inferior growth, observed in the hybrid offspring, following the seed germination up to the point of reproductive maturity of the grown up plant. Seed incompatibility, growth abnormalities of the hybrid plant and reduced fertility are all expressions of the hybrid inviability.

In his artificial hybridization studies with North American willows Mosseler (1987) found a number of various disturbancies in the hybrid offsprings; on the other hand some crossings produced very vigorous and well growing seedlings. The abnormalities and poor seedling growth among various combinations Mosseler explained with the hybrid inviability. A similar phenomenon was found also in the willow hybridization studies of the Finnish PERA-project (Viherä-Aarnio 1987, 1988).

In understanding the spontaneous willow hybridization in the nature, even more crucial is the *hybrid breakdown* (Stebbins 1958), also called as hybrid segregation (Skvortsov 1968). Hybrid breakdown is revealed in the F_2-progeny and later progenies.

Although F_1-progeny of the hybridization often appears vigorous and fertile, the F_2-progeny sometimes produces offspring with reduced viability, reduced fertility or lowered growth vigor. Besides in the further hybrid combinations of the downwards progenies, hybrid breakdown is to be expected in the introgression in which the offsprings of the original hybrids start to cross back to the parental species.

Hybrid breakdown in F_2- and subsequent generations may largely reflect disharmonious interactions between genes from diverse genomes or structural differences in chromosomes whether large or cryptic. The specific genetic causes of hybrid breakdown are still poorly understood (Mosseler 1987).

Hybrid breakdown can explain why willow hybrids do exist in the nature, but why they seldom or practically never dominate over the parental species. The hybrid forms that are found, are specimen from vigorous F_1-progenies, but they have a reproduction barrier due to hybrid breakdown. Consequently, F_2- and further generations are missing. This keeps the ratio of hybrids to parental species low. Spontaneous mass hybridization is rare, perhaps the only widespread exception is *Salix fragilis* L. × *Salix alba* L. (= *Salix* × *rubens* Schrank). Everywhere in Central Europe *S. fragilis* hybridizes so extensively with *S. alba*, that pure *S. fragilis* trees are less common than the hybrids.

Skvortsov (1968) used missing hybrid breakdown as one argument in proving that the eastern *Salix burjatica* is a true species, not hybrid *Salix cinerea* × *viminalis* or another related hybrid like it was hypothesized to be earlier (see also Robertsson 1984, Pohjonen 1987). He found out that the seed of various combinations within *Salix burjatica* are always normal, they germinate normally, and no form of hybrid segregation is found.

233. *Artificial hybrids*

The first major attempt to investigate crossability relationships among European willows was carried out by Nilsson (1918). Some of Nilsson's crosses were later analyzed cytologically by Håkansson (1929, 1938 and 1955). Nilsson's hybridization results were somewhat overwhelming. He seemed to have produced hybrid forms easily and in free combinations resulting in a number variants in the progenies. He further concluded that in the case of willows it was incorrect to speak in terms of species. Consequently, the concept of species has little meaning as applied to willow populations that hybridize so readily. In fact there would be only a huge pool of willow genes which form different populations in all possible combinations.

Such views have not been accepted, based on field experience, by willow systematists like Skvortsov (1968), Argus (1973, 1974) and Dorn (1976) nor willow breeders like Zsuffa et al. (1984) and Mosseler (1987). It is also significant to note that the artificial hybridization experiments of Nilsson (1918) are now considered unreliable (Skvortsov 1968, Dorn 1976).

The later studies on interspecific hybridization (e.g. by Argus 1974), have shown that species that belong to different sections under a particular subgenus can often be crossed with one another. The reproductive barriers to crossing species from different subgenera (e.g. *Salix* × *Vetrix*) are more difficult to overcome. The reproductive affinities within the genus are further supported by the hybridization studies of Weber (1963), Hunziker (1962) and Hathaway (1977).

Following these rules the artificial hybridization of willows has produced several important practical applications. Some of them are ornamental, like incorporating frost hardiness to the original weeping willow (*Salix babylonica* L.) with the help of *Salix alba* L. The resulting popular hybrid, golden weeping willow, *Salix* × *chrysocoma* Dode is now far more common in Britain than the original continental weeping willow. Other willow hybrids are related to timber production for pulp industry, like the successful crossings of the Danubian willows (mainly *Salix alba*) in Bulgaria, Czechoslovakia, Hungary, Romania and Yugoslavia (Krstinic 1979, cited by Stott 1984).

The most successful biomass willow hybridization progamme has been undertaken in New Zealand. Gains of 100 per cent in height have resulted from crossing of *Salix matsudana* Koidz. × *Salix alba* (*S. matsudana* is most probably the original eastern *Salix babylonica*, see Skvortsov 1968 and Appendix I). Comprehensive review on the achievements of basket and biomass willow breeding has been given by Stott (1984).

234. Summary

Based on his wide Eurasian experience, Skvortsov (1968) summarizes the situation concerning willow hybridization:

(i) Any species can not hybridize with any species. True hybrids occur but they are rather few. Mass hybridization is exceptional in the nature.
(ii) Hybridization is limited to certain regions and certain conditions outside which it is practically absent or very rare. Hybrids are relatively frequent in the cultivated European countryside. Polar regions like Northern Scandinavia and Northern Finland are rich in hybrids.
(iii) Hybrids do not predominate over the parental species.
(iv) Hybridization is not of substancial significance in the occurrence of intraspecific variability.
(v) Hybrids are not formed most easily by the most nearby species.

Skvortsov's deduction provides additional challenges for biomass willow breeding. Since natural hybrids are rare, or do not occur in some sections, selection from spontaneous hybrid populations is difficult or impossible. Hybrid populations can, however, be produced artificially and the selection can be done in controlled conditions in a nursery or field trial. As the biomass willow husbandry is based on use of clones, the hybrid breakdown of the F_2-progenies can be avoided by concentrating the clonal selection in the F_1-generation. Vegetative propagation allows also that the genetic improvement via interspecific hybridization is not limited by the average performance of the seedling families but by the performance of the best individual, or just one the very best, obtained from a progeny.

Artificial crossings and careful study of the resulting progeny variation may therefore bring significant gains in biomass willow breeding. Moreover, since willows occur naturally in small isolated populations and are usually associated with disturbed habitats they are subject to founder effects and genetic drift (Hedrick 1985). It is reasonable to expect a high degree of genetic restructuring between local populations of such widespread species (Mosseler 1987). Intraspecific, artificial hybrids of geographically distant clones, may reveal population variation in the F_1-progeny which is comparable to variation in interspecific crossings.

24. Current species definitions

Much of the confusion about willow species, subspecies and hybrids is due to changes in the species definition. Linné, who followed the typological, original species concept, seemed already to have doubts on the validity of this willow species definition. Why would he otherwise have admitted the difficulty?

When the typological species concept was changed into the morphological concept, in which the species are only manmade abstractions, this led first into mass description of willow species, later into hybridomania. This situation prevailed until Wimmer introduced into willow science the idea about biological species concept in which the members of a species constitute a reproductive community. He understood the species not simply as a variant of structure and function, but primarily as a certain ecological-geographical phenomenon occupying a definite niche in nature.

Currently the species definition follows the biological concept which has been amended with populations and their chances to mix. For instance Jones and Luchsinger (1979) define the species as a group of interbreeding populations that is reproductively isolated from other such groups. This, however, is not fully satisfactory with insect-pollinated willows. Local, isolated populations are formed too easily and frequently for this definition. Consequently, it would be easy to find different willow species in rather near locations between which the insects do not fly. In strict sense, there is a reproduction barrier for instance between two rather nearby islands but which are so remote that pollinating insects do not fly from island to island. The willow populations, no doubt, remain for long the same without resulting new species.

Hämet-Ahti et al. (1989) follow somewhat more practical concept; for practical reasons we must be able to recognize one species from another. The individuals belong to the same species if they greatly resemble each other by morphological or other characteristics, if they generally can cross with each other and if they do produce fertile offsprings. Different species usually do not cross with each other, or they cross seldom and still more seldom are their offsprings fertile.

Dorn (1976) chose specific status for the willow species when staminate and pistillate plants can be found in more than one locality, normal seeds are being produced, and the apparent backcross frequency is relatively low or not detectable. Dorn therefore was on a track of studying offsprings from the crossings of two proposed different willow species. This method was favored also by Skvortsov (1968).

There is no unique species definition which is applicable to evolutionary so young, morphologically and ecologically variable genus like *Salix*. In the case of biomass willows, which would be planted as arable crops, the species concept should have a practical meaning. The farmer should be able recognize one species from another. For the biomass willow breeder the species should mean a group of individuals the offspring of which follows detectable laws both from intra- and interspecific crossings. The next practical taxon from the species is the clone, the best of which have commercial cultivar names. Practical willow husbandry at least does not need intermediate taxons between species and clones.

25. Number of willow species

Even if the number of willow species has been reduced from the early extremes there is still no doubt that the genus *Salix* is one of the largest among the tree like genera in the Plant Kingdom. In many ways the willows resemble eucalypts (*Eucalyptus* sp. in *Myrtaceae*) in the evolution of tree species. *Salix* sp. occupies a similar niche in the nature west of the Wallace line as *Eucalyptus* sp. does east of the line (Eucalypts... 1979). Willows and eucalypts are both pioneer species, young in the evolutionary timing and hundreds of species have been determined, 445 species for eucalypts by Chippendale (1976) for instance.

Andersson was the first willow systematist who attempted for an accurate global survey of the willow species. He recognized 160 species for the world flora, including the Himalayas and North America. Nowadays the number of willow species is believed to be between 300–500 depending on how widely the species is defined (Bean 1980).

Skvortsov (1968) estimates 330–350 willow species in the world. Dorn (1976) recognizes 89 species in the American continent and Greenland (Alaska, Canada, Greenland, the continental United States, the West Indies, Central America and South America); the nine or so endemics from Mexico are excluded.

In the Finnish geographical area the number of willow species is 21, with 5 species divided in 2 subspecies (Hämet-Ahti et al. 1989, Table 1).

In Appendix I, compiled from various sources, altogether 275 willow designations carry a species rank. By no means this list is comprehensive as different authors define the species based on different criteria. The list includes species from all subgenera. As the artificial hybridization for still more productive biomass willows awaits for planned programmes, such a list is the prerequisite for initiation of the programme.

26. Evolutionary background

As a whole the family *Salicaceae* is one of the most ancient among the Dicotyledons. The fossil record of the *Salicaceae* was first reviewed by Penhallow (1905) who placed the earliest development of the family in the Cretaceous geological period. The evidence from the fossil record suggests that the genus *Populus* is the more primitive and that the genus *Salix* appeared later (Komarov 1970). The species in the genus *Salix* have apparently been evolved from subtropical *Populus*-like forms (Hegi 1958, Jalas 1965). Penhallow (1905), Skvortsov (1968) and Dorn (1976) suggest that the genus *Salix* probably arose in the subtropics of central and east-

Table 1. Indigenous willows in Finland: pure species, their subspecies and Finnish names (Hämet-Ahti et al. 1989).

Species or subspecies	Finnish name
1. *S. aurita* L.	Virpapaju
2. *S. borealis* (Fries) Nazarov	Outapaju
3. *S. caprea* L.	
– 3a *S. caprea* var. *caprea* (L.)	Raita
– 3b *S. caprea* var. *coaetanea* Hartman	Vuonoraita
4. *S. cinerea* L.	Tuhkapaju
5. *S. glauca* L.	
– 5a *S. glauca* subsp. *glauca* (L.)	Tunturipaju
– 5b *S. glauca* subsp. *stipulifera* (B. Flod. ex Häyren) Hiit.	Korvakepaju
6. *S. hastata* L.	Kalvaspaju
7. *S. herbacea* L.	Vaivaispaju
8. *S. lanata* L.	
– 8a *S. lanata* subsp. *lanata* (L.)	Villapaju
– 8b *S. lanata* subsp. *glandulifera* (B. Flod.) Hiit.	Nystypaju
9. *S. lapponum* L.	Pohjanpaju
10. *S. myrsinifolia* Salisb.	Mustuvapaju
11. *S. myrsinites* L.	Lettopaju
12. *S. myrtilloides* L.	Juolukkapaju
13. *S. pentandra* L.	Halava
14. *S. phylicifolia* L.	Kiiltopaju
15. *S. polaris* Wahlenb.	Napapaju
16. *S. pyrolifolia* Ledeb.	Talvikkipaju
17. *S. repens* L.	
– 17a *S. repens* subsp. *repens* (L.)	Hanhenpaju
– 17b *S. repens* subsp. *arenaria* (L.) Hiit.	Hietikkopaju
18. *S. reticulata* L.	Verkkolehtipaju
19. *S. rosmarinifolia* L.	Kapealehtipaju
20. *S. starkeana* Willd.	
– 20a *S. starkeana* subsp. *starkeana* (Willd.)	Ahopaju
– 20b *S. starkeana* subsp. *cinerascens* (Wahlenb.) Hulten	Kangaspaju
21. *S. triandra* L.	Jokipaju

ern Asia. The main development took place in the direction of cold temperate and cold regions.

The genus *Chosenia* has evolved from willows (Skvortsov 1968). It has only one species, *Chosenia bracteosa* (Trautv.) Nakai (earlier synonym *Salix eucalyptoides* Schneid.), which is a North East Asian tree up to 30 meters high. The inflorescence of *Chosenia* resembles willows, but the flowers are wind pollinated.

The evolution of *Vetrix* and *Chamaetia* took a northerly direction into colder climates. Subsequently the winter hardiness increased at the cost of tree form.

The species in the subgenus *Salix* contain features found in *Populus* species. Similarly to poplars most of the tree forms of subgenus *Salix* are native to subtropical and warm temperate climates of the northern hemisphere. Thus the subgenus *Salix* has been regarded phylogenetically more primitive and older than the subgenera *Vetrix* and *Chamaetia*. They have probably arisen in the early Tertiary (Skvortsov 1968). The subgenus *Vetrix* has been evolving actively since the glaciation, and is continuing even now (Julkunen-Tiitto 1989).

The reticulate morphological evolution of willows is probable (Dorn 1976), with widespread parallelisms and convergences making the phyletic relations obscure (Skvortsov 1968). Moreover, parental species have undoubtedly diverged from their original genotypes or may have become extinct (Dorn 1976).

The number of stamens has a special importance in the genus *Salix*, it is an indicator for the evolutionary age. There is a theory: the bigger the number of stamens, the older is the species in the evolutionary ladder. The oldest section is *Pentandrae* and *Diandrae* the youngest whereas *Triandrae* is between them. Of the single species *Salix pentandra* is believed to be the oldest. It has a correspondant in the New World, *Salix lucida* Muhl. with five stamens as well (Bean 1980). An exceptional section, old as well, is the subtropical *Humboldtianae* with stamen number of up to 12 (Bean 1980).

It is an interesting fact that the willows are insect-pollinated plants (many species are useful in apiculture). In this respect *Salix* differs from not only most other catkin-bearing genera (beech *Fagus* sp., oak *Quercus* sp., hazel *Corylus* sp.) but most clearly from the allied poplars (*Populus* sp.), all of which are wind-pollinated. This, again, is a reflection of the evolution. The poplars (which always have many catkins) are lower in th evolutionary ladders. Willows have evolved from poplar like wind-pollinated plants which bear many catkins.

The evolutionary background of the willows also explains the patterns of spontaneous hybridization and allows possibilities for breeding. A number of possible crosses must have been produced already by the nature herself.

3. Review of potential species for biomass willow husbandry

31. *Salix alba* L.

Salix alba L., White willow, belongs to the section *Salix* in the subgenus *Salix*. It is a tree willow, in suitable conditions a fast growing species. In the Soviet it attains height of 30 meters (Skvortsov 1968). In Europe *S. alba* is apparently the most productive tree-like broadleaved species. Yugoslavian selection V160 has been reported to have had a mean annual increment (MAI) of 68.9 m^3/ha/a at age of 7 years years (2 years from cuttings + 5 year from stools) (Krstinic 1979).

S. alba is common in lowland regions of western and central Europe. It also extends into western Asia and Mediterranean North Africa. It has been so widely planted that the limits of its natural distribution are probably no longer ascertainable (Meikle 1984). *S. alba* does not occur in Finland as indigenous species, but has been planted as ornamental tree.

Table 2. Cultivars of *Salix alba* and its hybrids.

Variety name	Designation
'Barlo'	*S. alba* L. 'Barlo'
'Belders'	*S. alba* L. 'Belders'
'Bredevoort'	*S. alba* L. 'Bredevoort'
'Britzensis'	*S. alba* L. 'Britzensis'
'Caerulea'	*S. alba* L. 'Caerulea'
'Calva'	*S. alba* L. 'Calva'
'Cardinal'	*S. alba* L. 'Cardinal'
'Chrysocoma'	*S. alba* × babylonica 'Chrysocoma'
'Crysostela'	*S. alba* L. 'Crysostela'
'Coccinea'	*S. alba* L. 'Coccinea'
'Drakenburg'	*S. alba* L. 'Drakenburg'
'Het Goor'	*S. alba* L. 'Het Goor'
'Lichtenvoorde'	*S. alba* L. 'Lichtenvoorde'
'Liempde'	*S. alba* L. 'Liempde'
'Lievelde'	*S. alba* L. 'Lievelde'
'Picarde'	*S. alba* L. 'Picarde'
'Rockanje'	*S. alba* L. 'Rockanje'
'Salomonii'	*S. alba* × babylonica 'Salomonii'
'Sauce Alamo'	*S. alba* L. 'Sauce Alamo'
'Sibirica'	*S. alba* L. 'Sibirica'
'Tristis'	*S. alba* L. 'Tristis'
'Vitellina'	*S. alba* L. 'Vitellina'
'Vitellina pendula'	*S. alba* × babylonica 'Vitellina pendula'
'Vitellina tristis'	*S. alba* L. 'Vitellina tristis'

S. alba is widely cultivated in temperate regions; it is tolerant of a range of rural sites with organic and sandy soils. *S. alba* forests along the Danube and its tributaries are an important economic timber resource in the Balkans (Krstinic 1979). The largest stands of *S. alba*, over 80000 ha, are found in Romania (Poplars... 1979). In Yugoslavia there are 20000 ha, in Hungary 16000 ha and in Bulgaria 2500 ha (Stott 1984).

S. alba does not occur in Finland, but it has been commonly planted as ornamental. The main species thrives from southern coast to level of Tampere, but a selected male clone *S. alba* 'Sibirica', Silver willow, is successful as garden tree up to the arctic circle. Of the numerous cultivars of *S. alba* and its hybrids (Table 2), at least 'Vitellina' (keltapaju), 'Vitellina tristis' (riippakeltapaju), 'Britzensis' (korallipaju) and 'Chrysocoma' (riippapaju) are successful in southern Finland (Hämet-Ahti et al. 1989).

The most widely planted cultivar is *S. alba* 'Caerulea', Cricket bat willow. It is a fine tree, sometimes called also Blue willow. Occasionally it reaches a height of 30 meters and 5 meters in diameter. It has been reported to grow "with extraordinary rapidity" in stiff, moist but not waterlogged soils (Beans 1980). It can be raised from cuttings, from which it attains in British conditions diameter of 1. 2–1. 5 meters in 12–14 years. *S. alba* 'Caerulea' is a female clone which first came to notice in willow husbandry at the end of the 1700s. It differs from the parent species in its pyramidal growth and erect branching. It has been planted in Britain for about 5000 ha.

The cultivar *S. alba* 'Britzensis' used to be one of the clones in basket willow husbandry in Europe, also in Finland (Tapio 1965). It is a male clone the name of which comes from the German nurseryman Späth at Britz near Berlin, who put it into commerce in 1878 (Bean 1980).

Tapio (1965) has tested *S. alba* 'Britzensis' in several locations of Finland. From the biomass production point of view the experience was discouraging: *S. alba* 'Britzensis' was the last (No 7) of the clones Tapio screened. Due to its bright red first year winter stems *S. alba* 'Britzensis' is a popular ornamental willow.

There are several *S. alba* cultivars with designation of 'Vitellina' or 'Vitellina pendula'. Bean

(1980) has pointed out that there are several clones involved, some females, the others males, and they should be called a group of clones rather than separate botanical varietas.

S. alba cultivars and clones have been tested in biomass willow trials in Britain, Sweden (e. g. Rönnberg-Wästljung and Thorsen 1988) and Finland. In Finland it has been tested as Swedish clone *S. alba* 77-0-803 and as Finnish clones *Salix alba* 'Sibirica' Oulu 13 and Oulu 32 (Pohjonen 1977). Also the most common *S. alba* hybrid, *Salix* × *rubens* (= *Salix alba* × *fragilis*) has been tested in Finnish biomass willow trials established by the Foundation for Forest Tree Breeding.

In Finland *S. alba* or its hybrids have usually not shown any superior performance, with the exception of the Swedish 77-0-803. Due to their relatively good winter hardiness and growth vigor they are potential candidates in further hybrididazation studies. Some of the most remarkable biomass willow breeding results have been achieved using *S. alba* as the other parent (Stott 1984). Nearby species to *S. alba* for possible hybridization schemes are its eastern equivalents *Salix jessoensis* Seemen and *Salix koreensis* Anderss.

32. *Salix burjatica* Nazarov

Salix burjatica Nazarov belongs to the section *Vimen* in the subgenus *Vetrix*. It is known also with names *Salix aquatica* cult. (Neumann 1981) and Salix *dasyclados* Skv. (Stott 1984). *S. burjatica* is a bushy willow, highly productive as a biomass producer. Some of the most widely experimented biomass willow clones, like *Salix* 'Aquatica No 56', belong to this species. In Sweden it is, besides *Salix viminalis* L., the other biomass willow under extensive breeding programme (Gullberg 1989). It is also planted in practical applications (Energiskog ... 1985). The highest annual biomass production figures in Sweden have been measured with this species.

S. burjatica is an eastern species, its range matches rather accurately with the range of *S. viminalis*, from central Russia to Middle Europe. *S. burjatica* is not indigenous in Finland or Scandinavia. As cultivated it thrives in Finland best in South Finland, along the western coast up to the city of Oulu.

Despite fundamental research with *S. burjatica* it has not yet been cultivated over wide areas; the total area under plantations in the world, is apparently under 1000 ha. As coarse-stemmed species it was never popular for basket industry. In biomass plantations it has suffered from occasional outbreaks of rust epidemies (*Melampsora epitea*). *S. burjatica* has therefore not advanced to level where plenty of commercial cultivars occur. The most often mentioned cultivars in Britain and Ireland are the original 'No 56' from Denmark, and 'Korso' which is apparently the same 'No 56' reshipped to Britain from Korso railway station in Finland (Pohjonen 1987).

There is another set of clones of *S. burjatica*, that are widely cultivated for biomass in Sweden, but most probably misnamed under *Salix* × *dasyclados* Wimm. The true hybrid *Salix* × *dasyclados* is a cross *Salix viminalis* × *cinerea* which has been distributed as clones in West European basket willow husbandry. *Salix burjatica* and *Salix* × *dasyclados* resemble each other greatly, and can accurately be separated only by chromosome counts. *S. burjatica* has chromosome number of 2n = 76, whereas *Salix* × *dasyclados* is a triploid with 2n = 57. Most of the Finnish clones at least, seem to belong to the eastern *S. burjatica*. The western *Salix* × *dasyclados* Wimm. has probably been imported to Finland only by Relander in 1950 with clonal identifications of 'No 63' and 'Duitse Dot No 125' (Pohjonen 1987).

S. burjatica is one of the basic species in biomass willow breeding also in Finland (Viherä-Aarnio 1988). As advantages it has a high growth potential, good rooting ability as cuttings and abundant coppicing. The disadvantages are the less erect growth habit of the coppices and susceptibility to *Melampsora* rust.

33. *Salix caprea* L.

Salix caprea L., Great sallow or Goat willow, belongs to the section *Vetrix* in the subgenus *Vetrix*. It is a tree-like willow, one of the few in *Vetrix*, frequently attaining a height of 10 meters. In favorable conditions *Salix caprea* is a fast growing species. Sidorov (1978) reports about female specimens, growing in plantations of upland oak forest along damp and deep gorges together with alder, which attained height of 12–14 meters and a diameter of 32 cm at age of 20–25 years.

S. caprea is more a woodland species and grows in North European coniferous forests where arboreal populations, occassionally to 24 meters tall with narrow crowns occur (Stott 1984). *S. caprea* is exceptionally adaptable as to site and is able to grow on calcareous soils and in dry conditions (Stott 1984). Compared to *Salix cinerea* L. *S. caprea* shows a slight preference for calcareous soil (Meikle 1984).

S. caprea is native of Europe and North West Asia. It grows throughout Finland. Predominantly it grows in fresh, fertile soils, in mixture with spruce and other broadleaved trees. Often it grows along the borders of forest as single trees. *S. caprea* does not form pure stands. This may be an indication of the susceptibility to rust.

Due to its growth vigor *S. caprea* would apparently have been grown more as a plantations species, but it has a serious drawback compared to other biomass willows: it does not root as cuttings. Plantation establishment via seed and seedlings has not been competitive enough.

Due to the poor rooting ability there are only few *S. caprea* cultivars, and those are for ornamental purposes propagated through grafting. The best known is *Salix caprea* 'Kilmarnock', also called *Salix caprea* 'Pendula' and 'Weeping sally'.

The greatest importance of *S. caprea* for biomass willow husbandry is genetic. It has a high growth potential and good winter hardiness. These traits are worth of transferring into nearby species which have the rooting ability. Such crossings already occur in nature e. g. a frequent hybrid *Salix* × *reichardtii* A. Kern. which is a crossing *Salix caprea* × *cinerea* L. (Bean 1980). Another spontaneous hybrid with the same parentage, *Salix* × *smithiana* Forbes, also called *Salix* × *sericans* Tausch ex A. Kerner, has been tested in biomass willow research. Similar hybrids can easily be artificially induced. However, only males of *S. caprea* can be used in the simple nursery hybridization techniques since the unrooting female twigs do not bear seeds.

Important for artificial crossings are the nearest relatives to *S. caprea*. *Salix aegyptica* L., Musk willow, is the closest. It is native of South East Anatolia, South East Transcaucasia and North Iran. Contrary to *S. caprea*, *Salix aegyptica* also roots as cuttings. Its name relates to Egypt where it has been cultivated for the male catkins; at one time a perfumed drink was made from them (Bean 1980).

Salix discolor Muhl. is a relative to *S. caprea* in the the American continent. It also roots as cuttings. Mosseler (1987) used *Salix discolor* with moderate success in his hybridization studies. Clones of Canadian *Salix discolor* have also been imported to Swedish biomass studies (Zsuffa 1990).

34. *Salix cinerea* L.

Salix cinerea L., Grey sallow, is a close relative to *Salix caprea*; similarly it belongs to the section *Vetrix* in the subgenus *Vetrix*. It is a low spreading bush in its wild state, rarely more than 4. 5 meters in height. The second year wood is prominently striated under the bark.

S. cinerea is native of Europe, West Asia and North Africa. In Finland it is found from southern coast to the arctic circle. Under the main species there is a taller subspecies: *Salix cinerea* subsp. *oleifolia* (Sm.) Macreight, Rusty sallow. This name may indicate rust susceptibility if grown in monocultural stands.

Rusty sallow attains height of up to 15 meters (Meikle 1984). It is native of western Europe, common in British Isles in a wide range of habitats. It is also known to tolerate acid conditions (Stott 1984).

S. cinerea has been tested in Finland and in Sweden for biomass, but it has not shown any promise. *S. cinerea* is, however, a potential candidate in breeding studies. The success of natural hybrid *Salix viminalis* × *cinerea* (= *Salix dasyclados* Wimm.) is a proof on that. *S. cinerea* has positive traits for breeding: it has the rooting ability, it is winter-hardy and it is probably the most tolerant of all willows to inundation.

Important for breeding is also *Salix atrocinerea* Brot., an ally to *S. cinerea*, which is often taller, up to 10 meters. It is native to western Europe, from Britain to Portugal.

35. *Salix daphnoides* Vill.

Salix daphnoides Vill. belongs to the section of *Daphnella* in the subgenus *Vetrix*. In a suitable environment it is a tree of up to 15 m in height, with an uneven trunk up to 20 cm in diameter.

S. daphnoides is native of Europe from southern Scandinavia to the Alps and northern Italy, east to the Urals. It is not indigenous in Finland.

Typical to *S. daphnoides* is its fairly undemanding character as to soil types. It grows successfully on bare sands, along gorges and ravines. In the Soviet it is used for the improvement of land by forestry measures for sand fixation and erosion control (Sidorov 1978). Due to its favorable cultivation characteristics and also ornamental appeal *S. daphnoides* is widely distributed in willow husbandy. It can be well propagated by cuttings.

S. daphnoides has two subspecii. The main subspecies, *Salix daphnoides* subsp. *daphnoides* (Vill.) grows taller, but the other, *Salix daphnoides* subsp. *acutifolia* (Willd). Blytt & O. C. Dahl. has been more often planted.

Salix subsp. *acutifolia* is an old, cultivated species which was spread into cultivation from South West Russia. Earlier it was called as 'Caspian willow' ('Kaspische Weide'). This has caused confusion with *Salix caspica* Pall. which is a different species (Hämet-Ahti et al. 1984).

S. daphnoides is a moderately well overwintering ornamental willow in Finland from southern coast up to latitude of Oulu. It has also been tested as biomass willow already in the 1970s. The clones *Salix daphnoides* Oulu 12, Oulu 19 and Oulu 24, did not show any remarkable success (Pohjonen 1977).

The potential of *S. daphnoides* is in the breeding. The first hybridization studies in Finland were not, however, successful. *Salix* subsp. *acutifolia* female clone no. H3177 from Hungary, as crossed with 7 species and 8 different males did not produce viable seed (Viherä-Aarnio 1987).

For possible biomass willow breeding there are two nearby species in the section *Daphnella*. *Salix kangensis* Nakai is native of Korea, the Ussuri region of Russia and of North East China. It is known in cultivation. *Salix rorida* Lakschewitz has a wide distribution in North East Asia, including Japan. It is also known in cultivation (Bean 1980).

36. *Salix fragilis* L.

In the section *Salix* of the subgenus *Salix* the Crack willow, *Salix fragilis* L., is one of the tallest tree-like willows. It is frequently a large tree attaining a height of 20 meters and a diameter of up to 1 meter. The record height, 27 m, has been measured for the cultivar 'Russelliana' (Clarke 1988).

Salix fragilis is native of much of Europe extending in Russia as far east as the Altai and south to the Caucasus, also occurring in parts of South West Asia. *S. fragilis* is not indigenous in Finland, but has been cultivated as ornamental

Table 3. Cultivars of *Salix fragilis*.

Cultivar name	Designation
'Bullata'	*S. fragilis* L. 'Bullata'
'Capitata'	*S. fragilis* L. 'Capitata'
'Russelliana'	*S. fragilis* L. 'Russelliana'
'Sanguinea'	*S. fragilis* L. 'Sanguinea'
'Sphaerica'	*S. fragilis* L. 'Sphaerica'

Table 4. *Salix fragilis* hybrids.

Crossing	Hybrid name
S. fragilis × *triandra*	*S.* × *alopecuroides* Tausch.
S. fragilis × *triandra*	*S.* × *speciosa* Host.
S. alba × *fragilis*	*S.* × *basfordiana* Scaling
S. alba × *fragilis*	*S.* × *rubens* Schrank
S. alba × *fragilis*	*S.* × *viridis* Fr.
S. babylonica × *fragilis*	*S.* × *dolorosa* Rowlee
S. babylonica × *fragilis*	*S.* × *pendulina* Wenderoth
S. pentandra × *fragilis*	*S.* × *cuspidata* Schultz
S. pentandra × *fragilis*	*S.* × *meyeriana* Rostk.

from southern coast to the arctic circle.

Due to its widespread cultivation *S. fragilis* is distributed throughout the whole Europe, except for the arctic zone. It is rather undemanding to the soil type, and grows well both in locations with an elevated moisture content and in dry valleys.

Similarly to *Salix alba*, several cultivars of *S. fragilis* have spread into willow husbandry (Table 3).

The most interesting cultivar from breeding point of view is *Salix fragilis* 'Russelliana'. It is a large and vigorous tree with straight, slender branches. It is common in the north of England. Only female trees are known. It is apparently a single clone originally selected for its fast growth and excellent timber.

S. fragilis is believed to form several spontaneous hybrids. Most common are hybrids with *Salix alba* (Table 4).

37. *Salix myrsinifolia* Salisb.

Salix myrsinifolia Salisb., Dark-leaved willow, belongs to the section *Nigricantes* in the sub-

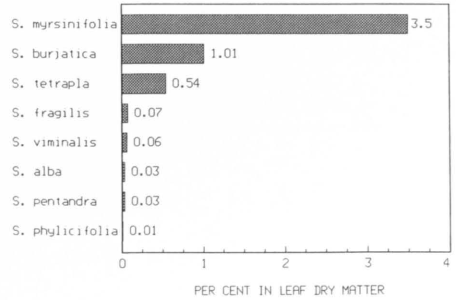


Fig. 1. Content of the most abundant phenolic glucoside: salicortin in dry matter of some willow leaves (data from Julkunen-Tiitto 1989).

genus *Vetrix*. It is a bushy shrub, attaining 5 meters in height.

Salix myrsinifolia is native of northern and central Europe and Siberia. In Finland it occurs throughout Finland.

S. myrsinifolia has not been of particular interest as ornamental or biomass willow. Bean (1980) for instance states that "the species is indeed one of the dullest and most uninteresting of hardy shrubs, and is not worth of a place in the garden proper". In the first willow screening trial for biomass production, of the Foundation for Forest Tree Breeding, *S. myrsinifolia* was, however, the secondmost productive indigenous species; the best clone V75 Mikkeli produced about 6 dry tonnes/ha/a over the first three years (Lepistö 1978).

In recent years *S. myrsinifolia* has been found to be rich in phenolic glucosides, much richer than the other indigenous Finnish species or some cultivated exotics (Fig. 1). Of the phenolic glucosides the most interesting are salicylates which are pharmacologically active having analgetic, antipyretic, antiphlogistic and antirheumatic effects (Julkunen-Tiitto 1989). Production of salicylates may prove feasible from *S. myrsinifolia* plantations, either as a main product or combined with other forms of biomass production (other chemicals and energy).

S. myrsinifolia is believed to hybridize commonly in the nature. The most common of the hybrids is *Salix* × *tetrapla* Walker ex Sm. (*Salix myrsinifolia* × *phylicifolia* L.), also called *Salix* × *majalis* Wahlenb. It combines the traits of the parents species in so many different ways that any clear boundary between the hybrid forms and the parental forms is difficult to draw. Based on this, some botanists have considered that *Salix myrsinifolia* and *Salix phylicifolia* are not specially distinct from each other (e.g. Bean 1980).

S. myrsinifolia Salisb. is one of the examples from the hybridomania period (Skvortsov 1968). This is based on small morphological characteristics. Mass hybridization between *Salix myrsinifolia* × *phylicifolia* (= *Salix tetrapla*) was earlier believed to occur in the nature. Skvortsov, however, based on comprehensive analysis, concluded that *S. myrsinifolia* is a clear and distinct species in every respect, and the putative hybrids can be explained with considerable morphological variation.

An allied species to *Salix myrsinifolia* is *Salix borealis* (Fries) Nazarov, which is native of North Fennoscandia and North Russia. In Finland it occurs north of the arctic circle. It is often a tree, taller (up to 8 m) than *S. myrsinifolia* (Hämet-Ahti 1989, Rehder 1964).

Salix myrsinifolia and *Salix borealis* are still largely unstudied species for willow husbandry; their untamed potential awaits exploration. Thorough studies of the local populations and the intraspecific variation followed by planned crossings should be applied on them.

38. *Salix pentandra* L.

Salix pentandra L., Bay willow, belongs to the section *Pentandrae* in the subgenus *Salix*. It is a tree-like willow which attains height of 18 meters in optimal conditions. In Finland it is one of the most productive indigenous willows. In the first screening trial for biomass willows (Lepistö 1978) it was the most productive indigenous species, comparable to *Salix fragilis*. The most productive clone V79 Somero produced about 8 tons/ha/a from cuttings at three years of age.

Salix pentandra is native of much of Europe, not in the westernmost parts, but east over Russia to Central Siberia. In Finland it occurs throughout the country. It is known to tolerate high water table. It grows in swampy forests, on grassy bogs and wet meadows and along the shores of marshy rivers and lakes. It is capable of growing also on acid organic soils of pH down to 4.5 (Stott 1984). In Finland its distribution is therefore concentrated in the central and northern Finland, along the distribution of peatland areas.

Only one cultivar of *S. pentandra* is widely known, *Salix* 'Superlaurina'. It has been in biomass willow tests in the Suonenjoki Forest Research Station of the Finnish Forest Research Institute. Otherwise, experiences of *S. pentandra* as plantation species are scanty. In Russia it is recommended for tannin production in commercial plantations in swampy flooded lands and wet habitats (Sidorov 1978).

S. pentandra has two North American correspondents *Salix lasiandra* Benth. and *Salix lucida* Muhl. *Salix lucida* has been sent from Canada to Sweden for biomass willow tests (Zsuffa 1990).

39. *Salix phylicifolia* L.

Salix phylicifolia L., Tea-leaved willow, belongs to the section *Nigricantes* in the subgenus *Vetrix*. It is a bushy shrub, only to 3 meters high. Similarly to *S. myrsinifolia* it has not been regarded a proper biomass willow. In the screening results of Lepistö (1978) *S. phylicifolia* was, however, the thirdmost productive indigenous willow after *Salix pentandra* and *Salix myrsinifolia*. The most productive clone V754 Kuru yielded about 5 tons/ha/a from cuttings at three years rotation.

S. phylicifolia is native of North Europe and West Siberia. It is one of the most common willows in Finland. There has not been any need for commercial varieties so far.

The biggest potential also for *S. phylicifolia* is in breeding. Its winter-hardiness and adaptability to poor conditions are traits which await transferring into more productive willow hybrids.

There are a few nearby species to *S. phylicifolia* which are of interest in germplasm collection. *Salix hibernica* Rech. occurs in Ireland (Krüssmann 1986). *Salix bicolor* Willd., is a close ally in southern and central Europe. *Salix hegetschweileri* Heer is often taller growing, up to 4. 5 meters, than *S. phylicifolia*. Eastwards *S. phylicifolia* gives way to *Salix pulchra* Cham. In North America the nearest correspondent is *Salix planifolia* Pursh.

310. *Salix schwerinii* E. Wolf

Salix schwerinii E. Wolf belongs to the section *Vimen* in the subgenus *Vetrix*. It is a tall shrub or a small tree up to 12 meters in height. *Salix schwerinii* is a fast-growing biomass willow. It has an erect growing habitus, suitable for machinery harvesting. Another typical trait is its adaptation to continental summers. It does not endure spring and summer frosts (Christersson et al. 1985).

S. schwerinii is native of East Siberia, from Baikal to east up to Kamtschatka and Japan. In Finland it has been cultivated as two clones. The one from Novosibirsk (SU8955), imported by L. Kärki, has been widely experimented in Sweden (with number 077). The other clone was imported by O. Luukkanen in 1975 from the Amur river.

S. schwerinii SU8955 has been used as parent in Finnish hybridization studies (Viherä-Aarnio 1989). As being near relative to other species in the section *Vimen*, the hybridization potential of *S. schwerinii* for biomass seems promising.

311. *Salix triandra* L.

Salix triandra L., Almond willow, belongs to the section *Amygdalinae* in the subgenus *Salix*. It is a shrub or small tree up to 9 meters high. *S. triandra* has been one of the most productive basket willows in Britain (Stott 1956).

S. triandra has wide distribution in temperate Eurasia, from British Isles to central Siberia. It is rare in Scandinavia. In Finland there are 3 occurrences: one along (16 km) the river of Temmesjoki in Liminka, the other along (100 km) the river of Tornionjoki and the third a scattered occurrence in Kuusamo, eastern Finland. The Finnish *S. triandra* stands are all male, probably of the same clone at one river side.

S. triandra has been cultivated for long as basket willow and a number of commercial varieties have been selected (Table 5).

Table 5. *Salix triandra* and its hybrid cultivars.

cv name	Designation
'French'	*S. triandra* L. 'French'
'Hippophaeifolia'	*S. triandra* × *viminalis* 'Hippophaeifolia'
'Black hollander'	*S. triandra* L. 'Black hollander'
'Black italian'	*S. triandra* L. 'Black italian'
'Black mauls'	*S. triandra* L. 'Black mauls'
'Jelstiver'	*S. triandra* L. 'Jelstiver'
'Lanceolata'	*S. triandra* × *viminalis* 'Lanceolata'
'Medwededii'	*S. triandra* L. 'Medwededii'
'Mottled spaniards'	*S. triandra* L. 'Mottled spaniards'
'Polyphylla'	*S. triandra* × *viminalis* 'Polyphylla'
'Pomeranian'	*S. triandra* L. 'Pomeranian'
'Schwurbitziana'	*S. triandra* × *viminalis* 'Schwurbitziana'

In Finland *S. triandra* and its hybrids have been tested for basket willow husbandry from the early 1900s by Johnsson, Mäkinen, Nordberg and Relander (Pohjonen 1984). As basket willow it had a remarkable yield potential. Based on good early results it was one of the main species to be tested for biomass in the University of Oulu (Pohjonen 1977).

S. triandra is one of the easiest rooting willows. Its Finnish occurrencies are predominantly males. The stands along the Temmes and Tornio rivers are most apparently spontaneous monoclonal bushes and small forest stands. The branches crack by the flooding iceblocks in spring. After floating down the river they root in suitable sand banks. This explain the monoclonal nature of the species along the rivers. The phenomenal rooting capacity of *S. triandra* is worth of transferring by genetic means to other biomass willows.

S. triandra hybridizes rather commonly with *Salix viminalis*. One female clone is called *Salix* × *lanceolata* Sm., also with cultivar name 'Lanceolata' (Meikle 1984, Clarke 1988). A group of hybrids between *Salix triandra* and *Salix viminalis* are called *Salix* × *mollissima* Ehrh. Typically the hybrid is a female plant which is nearer to *Salix viminalis* (Bean 1980). The cultivar *Salix* × *mollissima* 'Hippophaeifolia' is known both as male and female plants.

For biomass willow breeding the most important species is the near ally *Salix nipponica* Franch & Sav. which is perhaps just a race of *Salix triandra*. It is native of Japan and continental North East Asia reaching almost as far west as the eastern limit of *Salix triandra*.

312. *Salix viminalis* L.

Salix viminalis L., Osier, belongs to the section *Vimen* in the subgenus *Vetrix*. It is an erect shrub or small tree, up to 6 meters high. As a biomass willow *S. viminalis* is one of the most productive, commonly tested and planted together and as alternative to *Salix burjatica*.

S. viminalis is native of most of Central and East Europe, and of boreal Asia, occurring on the banks of streams, rivers and lakes, on floodplains and marshes. It is not found in the Mediterranean region, nor in Scandinavia. It has been so long cultivated that its distribution as wild plant can no longer be traced for certain. *S. viminalis* is one of the most important basket willows. It is apparently the oldest cultivated willow. One of the seven hills in the ancient Rome was named after this willow (*Collis viminalis*, hill of willows).

Table 6. Finnish collections of *Salix viminalis* clones.

Clone number	Collection site
E6690	Eurajoki
E6705	Parikkala
E6791	Hausjärvi
E7317	Pälkäne
E7327	Vehmaa
E7563	Aura
E7886	Köyliö
E7887	Vihti
E7888	Somero
E7889	Loimaa
E7891	Helsinki
E7895	Vääksy
E7896	Turku
E7898	Forssa
E7901	Tammisaari
E7923	Pori
E7924	Kullaa
K2387	Kurikka

S. viminalis has been collected in Finland in a number of sites. There is no record when and by whom the first import was undertaken. Most likely there have been several imports and consequently it has spread as ornamental in southern and western Finland. From those locations 15 basic clones were collected for screening trials for biomass (Table 6). It is not certain, however, if all the 15 clones are of different genetic origin; most probably some of them are renumberings.

As *S. viminalis* has been widely cultivated for basket industry in western Europe, a plenty of commercial varieties are known (Table 7).

Plenty of *S. viminalis* hybrids have also been reported (Table 8). Some of the hybrid names denote for the same crossing. It is not possible to identify from the willow literature which species in the crossing is male, which female. Neither is it known when the hybrid denotes a single clone from a unique crossing or a group of clones from similar crossings. Moreover, some of the numerous hybrids might be putative. Especially the triple and quadruple hybrids must be questioned in the light of present understanding of spontaneous willow crossings (Skvortsov 1968, Dorn 1976).

Table 7. Cultivars of *Salix viminalis*, its hybrids and nearby species, in the sections of *Vimen* and *Subviminalis*.

cv name	Designation
'Bowles hybrid'	*S. viminalis* L. 'Bowles hybrid'
'Brown Merrin'	*S. viminalis* L. 'Brown Merrin'
'Cinnamomea'	*S. viminalis* L. 'Cinnamomea'
'Eugenei'	*S. purpurea × viminalis* 'Eugenei'
'Hagensis'	*S. gracilistyla × caprea* 'Hagensis'
'Hippophaeifolia'	*S. triandra × viminalis* 'Hippophaeifolia'
'Kurome'	*S. gracilistyla* Miq. 'Kurome'
'Kuroyanagi'	*S. gracilistyla* Mig. 'Kuroyanagi'
'Long skein'	*S. viminalis* L. 'Long skein'
'Melanostachys'	*S. gracilistyla* Miq. 'Melanostachys'
'Mullatin'	*S. viminalis* L. 'Mullatin'
'Regalis'	*S. viminalis* L. 'Regalis'
'The Hague'	*S. gracilistyla × caprea* 'The Hague'
'Variegata'	*S. gracilistyla* Miq. 'Variegata'
'Yellow osier'	*S. viminalis* L. 'Yellow osier'

Table 8. Hybrids of *Salix viminalis* and nearby species in the sections of *Vimen* and *Subviminalis*.

Crossing	Hybrid name
S. viminalis × aurita	*S. × fruticosa* Doell.
S. viminalis × repens	*S. × fruticosa* Doell.
S. viminalis × cinerea	*S. × holosericea* Willd.
S. caprea × viminalis	*S. × sericans* Tausch ex A. Kerner
S. caprea × viminalis	*S. × smithiana* auct.
S. cinerea × viminalis	*S. × dasyclados* Wimm.
S. elaeagnos × caprea	*S. × seringeana* Gaud.
S. gracilistyla × bakko	*S. × leucopithecia* Kimura
S. gracilistyla × caprea	*S. × hagensis* G.A. Doorenbos
S. repens × viminalis	*S. × friesiana* Anderss.
S. triandra × viminalis	*S. × lanceolata* Sm.
S. triandra × viminalis	*S. × treviranii* Spreng.
S. atrocinerea × purpurea × viminalis	*S. × forbyana* Sm.
S. cinerea × viminalis × caprea	*S. × acuminata* Sm.
S. cinerea × viminalis × caprea	*S. × calodendron* Wimm.
S. cinerea × viminalis × caprea	*S. × stipularis* Sm.
S. myrsinifolia × phylifolia × caprea × viminalis	*S. × dasycladoides* Nilsson
S. viminalis × caprea × cinerea × viminalis	*S. × dasylaurina* Nilsson

Table 9. Potential biomass willow species in the sections of *Vimen* and *Subviminales*.

Species	Section	Range
S. alaxensis Coville	*Vimen*	Eastern Siberia, Alaska, Yukon
S. arbusculoides Anderss.	*Vimen*	Alaska, British Columbia
S. argyracea E. Wolf	*Vimen*	China, East Russia
S. armeno-rossica Skv.	*Vimen*	Caucasus, Turkish, Armenia
S. burjatica Nazarov	*Vimen*	Western and Central Russia
S. drummondiana Barratt ex Hook	*Vimen*	Yukon, California
S. gracilistyla Miq.	*Subv.*	Far East, Manchuria
S. pantosericea Goerz	*Vimen*	Caucasus
S. pellita Anderss.	*Vimen*	Eastern Canada
S. rehderiana Schneid.	*Vimen*	West Szechwan, China
S. sachalinensis Fr. Schmidt	*Vimen*	Sakhalin, Japan, Russian Far East
S. sajanensis Nazarov	*Vimen*	Sayan, Altai
S. schwerinii E. Wolf	*Vimen*	Baikal, Mongolia, China, Japan
S. sericea Marsh.	*Vimen*	
S. sitchensis Sanson ex Bong.	*Subv.*	
S. turanica Nazarov	*Vimen*	Northern Himalayas
S. udensis Trautv. & Mey	*Vimen*	Sakhalin, China, Eastern Siberia
S. viminalis L.	*Vimen*	Central Eurasia, Western Siberia

The whole section of *Vimen* is worth of a nearer consideration for biomass species. It is a group of about 15 pure species in Europe, Asia and North America (Table 9). In addition there is a nearby section *Subviminales* with 2 species.

According to Skvortsov (1968) there are 9 species in the Russian territory and one in Himalayas. As the older basket willow and newer biomass willow husbandry has been largely developed around *S. viminalis* and *Salix burjatica*, this section and all the other species in it are important for biomass willow breeding.

The two sections *Vimen* and *Subviminales* form most probably the kernel of the highest production in the biomass willows. They are also advanced in the plant evolution. A true pioneer characteristics has evolved in them: bushy growth habit, fast growth, abundant early seeding and vigorous coppicing. They also have an excellent adaptibility to severe winters in Siberia. All these are positive traits which biomass willow research is looking for.

Salix sachalinensis Fr. Schmidt is one of the interesting allies to *Salix viminalis*. It is a tree up to 9 meters tall, native of Sakhalin, North Japan, the Russian Far East and eastern Siberia. In Europe it is mainly represented by a male clone called 'Sekka' or 'Setsuka'. An allied species is also *Salix udensis* Trautv. & Mey., from the Okhotsk peninsula. Further ally is *Salix rehderiana* Schneid., also a tree of 9 meters tall, from West Szechwan in China.

A nearby species, already in cultivation, is *Salix kinuyanagi* Kimura, from Japan, to which it was probably introduced from Korea. Only male trees are known. It is perhaps a variant of *Salix schwerinii* E. Wolf.

A relative to *Salix viminalis* in the section *Subviminalis* is *Salix gracilistyla* Miq. It is native of Japan, Korea and North East China. It was introduced to Europe already in 1895.

4. Early Finnish selections

41. Johnsson and Mäkinen 1910–13

The first commercial willow plantations in Finland were established at the end of 1800s in Mustiala and Oulu (Makkonen 1975). The purpose was to produce tannin bark for leather factories. The area of these plantations or the willow species planted in them is no more known.

Next plantations were established in the 1910s in the Ostrobothnia (Etelä-Pohjanmaa) and at the horticultural college of Lepaa in Tyrväntö (southern Finland). In Lepaa about 10 selected Russian clones were introduced (Makkonen 1975).

The first willow species trials were established in the beginning of 1910s by J. W. Johnsson in the vicinity of Lohja and Kuopio (Nordberg 1914). Johnsson also gave the first species recommendation list for southern and central Finland (Table 10).

The origin of Johnsson's clones has not been verified. It is remarkable that of the indigenous species *Salix triandra* is well represented as pure and as crossings (*Salix × alopecuroides* Tausch = *Salix fragilis × triandra*, *Salix* 'Polyphylla' = *Salix triandra × viminalis* 'Polyphylla', see Appendix I).

Table 10. Species recommendation of Johnsson, from the 1910s, for willow husbandry in the southern Finland (Nordberg 1914).

Rank	Species
1.	*Salix triandra* L.
2.	*Salix purpurea* L.
3.	*Salix × rubra* L.
4.	*S. daphnoides* subsp. *acutifolia* (Willd.) Blytt & O.C. Dahl
5.	*Salix viminalis* L.
6.	*Salix × alopecuroides* Tausch.
7.	*S. triandra × viminalis* 'Polyphylla'

Additional import of Russian willow clones to Finland took place in 1912–13 (Mäkinen 1913). Survival and performance of these imports have not been reported.

42. Nordberg 1914–30

Great effort to develop willow husbandry in Finland was done by Seth Nordberg during the years 1914–1930 (Nordberg 1930). He also im-

Table 11. Most productive five basket willows based on Nordberg's studies between 1914–1930 (e.g. Nordberg 1930).

Rank	Species, hybrid or variety
1.	*S.* × *undulata* Ehrh.
2.	*S. viminalis* L.
3.	*S. triandra* × *viminalis* 'Polyphylla'
4.	*S. triandra* × *viminalis* 'Lanceolata'
5.	*S. triandra* L.

ported several clones to Finland. Based on Nordberg's trial results, *Salix triandra,* with its crossing, was one of the most productive species for basket willow husbandry (Table 11).

Again, *Salix triandra* is well represented (*Salix* × *undulata* Ehrh. = *Salix triandra* × *viminalis*, *Salix* 'Lanceolata' = *Salix triandra* × *viminalis* 'Lanceolata').

43. Relander and Tapio 1949–1953

The third effort in introducing productive basket willow clones was done by Eeva Tapio (née Relander) in 1949–1953 (Tapio 1965). She had an extensive experimental programme into the performance of a number of promising clones at ten different sites in Finland. She also imported several new clones from Central and Eastern Europe.

Based on Tapio's experiments a new priority list for basket willows can be composed (Table 12).

In Tapio's recommendation *Salix viminalis* was well represented (*Salix* × *smithiana* = *Salix caprea* × *viminalis*), whereas there was no *Salix triandra*. *Salix burjatica* Nazarov was introduced in Finland by Tapio. She recommended this coarse-stemmed species not for fine rod basketry but for hoops in preparing (strengthening) wooden drums.

Table 12. Most productive seven basket and hoop willows in Tapio's (née Relander) experiments between 1949–1953 (Tapio 1965).

Rank	Species, hybrid or variety
1.	*S. viminalis* L.
2.	*S. burjatica* Nazarov 'Aquatica'
3.	*S.* × *smithiana* Forbes
4.	*S. purpurea* L.
5.	*S.* × *americana* Hort. ex Schwerin
6.	*S. longifolia* Muhl., non Lam.
7.	*S. alba* L. 'Britzensis'

It is worth of noticing that in Tapio's selection there were two clones from North America: *Salix* × *americana* Hort. ex Schwerin (= *Salix rigida* Muhl. × *Salix gracilis* Anderss.) and *Salix longifolia* Muhl. (= *Salix interior* Rowlee). They were received from Central European collections. In late 1800s or early 1900s they had been imported from North America.

44. Foundation for Forest Tree Breeding 1973–1978

The first Finnish species and clone collection with biomass in mind was organized by the Foundation for Forest Tree Breeding. During the years 1973–78 altogether 375 clones were selected in the southern and central Finland (Lepistö 1978). Out of the 375 clones 59 were selected for a field trial. They were grown from cuttings for 3 years and the biomass production was determined.

The collection included both indigenous species and fast growing exotics which were found in Finland. The ten best clones are presented in Fig. 2. The yield figures have been expressed in the study as dry tonnes per hectare, even if the separate yield plots (adjacent to each other) were small (only 9 seedlings per plot were planted).

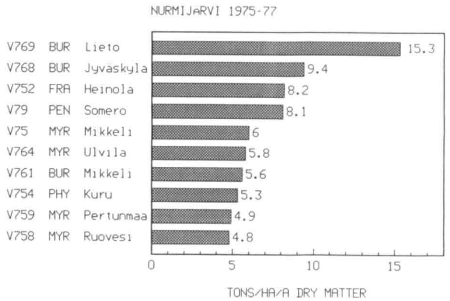


Fig. 2. Stem dry matter production of the ten best biomass willow clones in the Foundation for Forest Tree Breeding selection of 1973. Mean annual dry matter production from the harvest at 3 years (3-year roots, 3-year stems) (data from Lepistö 1978). For abbreviations see page 4.

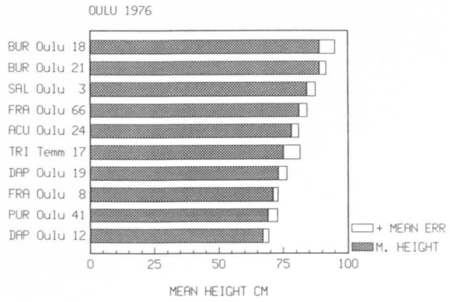


Fig. 3. One year height growth from cuttings of the 10 best biomass willow clones in the University of Oulu trial in 1976 (1-year roots, 1-year stems) (data from Pohjonen 1977). For abbreviations see page 4.

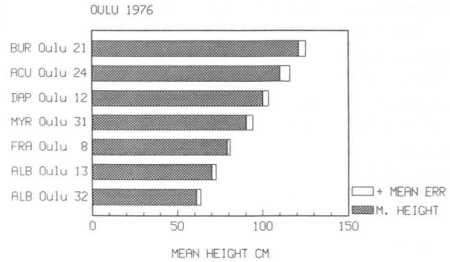


Fig. 4. One year height growth from replanted stool of 7 selected biomass willow clones in the University of Oulu trial in 1976 (2-year roots, 1-year stems) (data from Pohjonen 1977). For abbreviations see page 4.

Salix burjatica was the most productive in the trial. The best clone V769 Lieto produced 15. 3 tn/ha/a dry matter. It is a male clone, originally imported from Nova Sadi Breeding Station in Yugoslavia (Hagman 1976).

The best indigenous clone produced 8.2 tn/ha/a dry matter (*Salix pentandra* V79 from Somero). The plots, although they have been replicated and buffer zones were used, were only 6 m² in size and the per hectare values should be taken carefully. Notable in the collection of Foundation of Forest Tree Breeding collection is the presence of *Salix myrsinifolia*, four out of the ten best.

45. Pohjonen 1976–77

As a part of the research project on the production and utilization of short-rotation wood funded by SITRA (Finnish National Fund for Research and Development, see Hakkila et al. 1979) 36 biomass willow clones were collected in the surroundings of Oulu in 1976 (Pohjonen 1977). Most of the clones were collected from the botanical garden of the University of Oulu. Some clones were collected outside the city skirts. The microclimate in the city of Oulu (delta of Oulu river) is more favorable for arboretal collections than at these latitudes on average. Therefore some surprisingly southern species and clones thrive there (Figs. 3 and 4).

The clone No 31 Ainola was erroneously named as *Salix caprea* (c.f. Pohjonen 1977). *Salix caprea* does not, however, root that well as No 31 did. Later the species was recognized as *Salix myrsinifolia*.

In the trial of Oulu different planting methods were also tested, planting either as cuttings or as pre-established stools (one year growth in nursery from cutting, removal of stem and replanting as stool). *Salix daphnoides* benefitted from the planting as stools.

46. Summary for the end of 1970s

The biomass willow research in Finland was transferred from its rather casual and rudimentary phase of the 1970s into a totally new level in 1979 (in terms of man years and funding there was an increase of over 10-fold). This needed an interim evaluation of the performance of the species and clones tested so far.

The species selection for research and development into practical applications for the 1980s could be based on field experience from three sources: 1) old selections for basket willow husbandry, 2) selection of 1973–78 in the Foundation for Forest Tree Breeding and 3) selection of 1976–77 in the University of Oulu.

By far the most promising species was *Salix burjatica*. *Salix viminalis* was not represented in the selections of 1970s mainly due to geographical concentration of the collections. They were carried out throughout Finland. *Salix viminalis* is growing as ornamental, most in garden hedges in southern Finland, south of Salpausselkä. It was not at all represented in the collection of the Foundation, neither was it found in the parks of Oulu. It is most common in the southern coast. *Salix viminalis*, however, was known without further studies to be one of the most promising biomass willow for the southern coast.

Another promising exotic biomass willow, based on screenings of 1970s was *Salix fragilis*. Clone V752 Heinola was number 3 in Nurmijärvi, clone Oulu 66 and Oulu 8 were promising in Oulu. Rooting of *Salix fragilis* as cuttings, however, was not reliable and it was not regarded suitable for further studies.

Salix daphnoides was well represented in the trials in Oulu. It did not give any further advantage over *Salix burjatica*, but was selected for further studies still.

Of the indigenous species, *Salix pentandra* was number 4 in Lepistö's (1978) list. It did not do especially well in Pohjonen's (1977) experiments. However, seed collection of *Salix pentandra* was organized in 1979 as a part of the PERA-project (Hakkila 1985). Vigorous clones of *Salix pentandra* were, however, continuously collected.

Salix myrsinifolia was well represented as indigenous species already in 1970's. Its value was not properly understood since neither Nurmijärvi's nor Oulu's clones were selected for plantation studies.

The beginning studies of 1980s concentrated therefore almost all in *Salix burjatica* and, to minor extent, in *Salix viminalis*. More selections for them from abroad, mainly from Sweden, were regarded necessary. For the indigenous species and additional countrywide collection was decided to be organized in order to further study their yield potential.

5. Selection of biomass willows in the 1980s

51. Material

511. Kopparnäs; exotic species

The screening of biomass willows in Kopparnäs experimental site (60:10 N, 25:30 E, for latitudes and longitudes of the trial sites in Finland, see the map in Fig. 20, p. 39), in the southern coast of Finland, 50 km west of Helsinki, was started in 1983. The basic research material consisted of 63 exotic willow clones from Sweden selected by G. Sirén. The selection was done on the basis of the experience from 1977–82 from the Swedish biomass willow programme (e.g. Sirén 1983). In addition, two Finnish clones (*Salix viminalis* E7888 Somero and *Salix burjatica* E7899 Parainen) were included in the trials (Table 13). Nine of the Swedish clones had been earlier exported from Finland to Sweden. They occur thus also with Finnish clone numbers.

Most of the clones (31) were selections of *Salix viminalis*. There were 16 *Salix burjatica* clones (some of them may be hybrids *Salix* × *dasyclados* Wimm.) and 6 hybrids *Salix* × *smithiana* (*Salix caprea* × *viminalis*). There was one import of Swedish *Salix pentandra* (81-0-95) which in this case is regarded exotic.

The first series of clones (31 clones) was planted in a row experiment with 2 replications in 1983. Each row with one clone was 50 meters long and had 100 plants. It was cut back in spring 1984, and then followed as coppices over the years 1984–87 (Series I). One of the replications was reharvested in spring 1987 and followed as coppices between 1987–89 (Series II). The other replication was reharvested in spring 1988 and followed as coppices between 1988–89 (Series III).

In addition to the row experiment, a plot trial (plot size 7. 5 × 7. 5 m) was established in 1984. It was cut back in spring 1985, and partly in spring 1986 due to heavy browsing by moose and by winter damage. The time of harvesting was, however, calculated in all plots at spring 1985. The plots were followed as coppices over 1986–89 (Series IV). Another plot trial (plot size 15 × 15 m) was established in 1986, cut back in spring 1987, and followed as coppices over 1988–89 (Series V). In all trials the Swedish spacing arrangement was used (twin rows, 130 cm + 70 cm, stocking of 20 000 cuttings per ha, see e. g. Handbook ... 1986). Summary on the Kopparnäs trial is presented in Table 14.

After each of the growing seasons of 1984–89 the biomass production per stool was determined based on measurements of height, and diameter at 110 cm level. The layout and history of the Kopparnäs trials have been explained in more detail by Viljanen (1992) and the applied biomass models by Tahvanainen (1992).

Table 13. Species and clones of Swedish biomass willows in Kopparnäs willow screening trial (for clone numbers see Ager et al. 1986, Gullberg 1989).

Clone identity	Alias	Species	Remarks
77-0-56	056	*S. burjatica*	Finnish, E4856
77-0-75	075	*S. burjatica*	Finnish, V761
77-0-77	077	*S. schwerinii*	Finnish, SU8953
77-0-82	082	*S. viminalis*	
77-0-83	083	*S.* × *undulata*	
77-0-192	192	*S.* × *smithiana*	
77-0-590	590	*S. fragilis*	
77-0-666	666	*S.* × *smithiana*	
77-0-670	670	*S.* × *smithiana*	
77-0-681	681	*S.* × *smithiana*	
77-0-683	683	*S. viminalis*	
77-0-690	690	*S.* × *smithiana*	
77-0-699	699	*S. viminalis*	
77-0-801	801	*S. viminalis*	
77-0-802	802	*S.* × *rubens*	
77-0-803	803	*S. alba*	
78-0-3	L78-3	*S. viminalis*	
78-0-13	L78-13	*S. viminalis*	
78-0-21	L78-21	*S. viminalis*	
78-0-22	L78-22	*S.* sp.	
78-0-44	L78-44	*S. burjatica*	
78-0-60	L78-60	*S. burjatica*	
78-0-90	L78-90	*S. viminalis*	
78-0-91	L78-91	*S. viminalis*	
78-0-101	L78-101	*S. viminalis*	
78-0-102	L78-102	*S. viminalis*	
78-0-104	L78-104	*S. burjatica*	
78-0-112	L78-112	*S. viminalis*	
78-0-115	L78-115	*S. viminalis*	
78-0-118	L78-118	*S. viminalis*	
78-0-120	L78-120	*S. viminalis*	
78-0-133	L78-133	*S. burjatica*	
78-0-146	L78-146	*S. burjatica*	
78-0-166	L78-166	*S.* sp.	
78-0-183	L78-183	*S. viminalis*	
78-0-195	L78-195	*S. viminalis*	

Clone identity	Alias	Species	Remarks
78-0-196	L78-196	*S. burjatica*	
78-0-198	L78-198	*S. viminalis*	
79-0-4	L79-4	*S. viminalis*	
79-0-26	L79-26	*S. viminalis*	
79-0-36	L79-36	*S. viminalis*	
79-0-46	902	*S. viminalis*	
79-0-50	809	*S. viminalis*	
79-0-52	908	*S. burjatica*	
79-0-54	79054, JGT	*S. burjatica*	
79-0-69	E78-22	*S. schwerinii*	
79-0-97	CSD1	*S. burjatica*	
79-0-113	CSV2	*S. viminalis*	
79-0-118	LSL5	*S.* sp.	
80-0-49	L80-49	*S. viminalis*	
80-0-51	L80-51	*S. viminalis*	
80-0-72	GB80-2	*S. viminalis*	
80-0-73	GB80-3	*S. viminalis*	
81-0-90	8100	*S. burjatica*	
81-0-91	8101	*S.* × *smithiana*	
81-0-92	8102	*S. viminalis*	
81-0-95	8103	*S. pentandra*	
82-0-55	P6011	*S. burjatica*	Finnish, Oulu
82-0-56	E7894	*S. burjatica*	Finnish, Pennala
82-0-57	P6010	*S. triandra*	Finnish, Liminka
82-0-67	E7901	*S. viminalis*	Finnish, Tammisaari
88-0-3	4856	*S. burjatica*	Finnish, Ruotsinkylä
88-0-5	V768	*S. burjatica*	Finnish, Jyväskylä
E7888		*S. viminalis*	Finnish, Somero
E7899		*S. burjatica*	Finnish, Parainen

Total 65 clones

Table 14. Experimental arrangements in the biomass willow trial of Kopparnäs, Inkoo.

Series	Years	No. of clones	Type	Replications	Age of stool and coppices (yrs) at final measurement: Stool	Copp.
I	84–87	33	Row	2	5	4
II	87–89	31	Row	no	7	3
III	88–89	17	Row	no	7	2
IV	86–89	21	Plot	2	6	4
V	88–89	10	Plot	no	4	3

Note: Series I had 2 replications only over years 1984–86; one replication was transferred into row series II in spring 1987, the other replication into row series III in spring 1988.

512. Suomusjärvi and Nurmijärvi; exotic and indigenous species

As a continuation of the first biomass screening trial (Lepistö 1978) the Foundation of Forest Tree Breeding established in spring 1979 two new screening trials for biomass willows, both exotics and indigenous. They were reselection from the earlier collected material (original 375 clones, first selection 59 clones, this new selection 32 clones).

Trial I was established in Nurmijärvi (60:30 N, 24:41 E), trial II in Suomusjärvi (60:20 N, 24:00 E). The trials are identical; both of them have 32 clones. 13 clones which were finally

Table 15. Indigenous and exotic biomass willow clones in the Suomusjärvi and Nurmijärvi trials of the Foundation for Forest Tree Breeding (13 best clones of the original 32). Ascending order of the clone identity number.

Clone identity	Species	Origin	Remarks
V75	*S. myrsinifolia*	Mikkeli	
V77	*S. myrsinifolia*	Kuhmoinen	
V78	*S. myrsinifolia*	Loppi	
V752	*S. fragilis*	Heinola	
V754	*S. phylicifolia*	Kuru	
V766	*S. phylicifolia*	Pieksämäki	
V768	*S. burjatica*	Jyväskylä	
V776	*S.* × (hybrid)	Loppi × Pieks.	
V769	*S. burjatica*	Lieto	
P6287	*S. burjatica*	Oulu	P6011
E7335	*S.* 'Polyphylla'	Helsinki	TRI×VIM
D11134	*S.* × *rubens*	Germany	
CS11842	*S.* × *rubens*	Czechoslovakia	

among the ten best in either of the trials have been explained in Table 15.

The trials were established at spacing of 1 × 1 meters, 9 cuttings in a plot, with 5 replications. The trial in Suomusjärvi was cut back in spring 1980 and measured by height after the growing season 1980. The growth differences were indicated based on dominant height (average of the tallest coppice in each stool).

The trial in Nurmijärvi was harvested in autumn 1983, the clones grew over 5 seasons from cuttings. At the harvest both the fresh and dry biomass of the plots were determined.

513. Kannus; indigenous species

The screening of indigenous biomass willows in Kannus (64:35 N, 23:50 E) and in Haapavesi (64:15 N, 24:25 E) was based on nationwide collection in 1978–79. It was organized as a joint venture between the Finnish Forest Research Institute and the Finnish 4H-organization (Heino and Pohjonen 1981).

The collection of willow clones was organized as a competition between the 65000 4H-members of Finland. The country was first divided into 5 geographical zones from south to north. Inside each zone one year old willow coppices, as long as possible, were collected and sent into Kannus Forest Research Station.

The collected willow rods were prepared into

Table 16. The species and hybrids composition in the original 4H collection of indigenous willows (1979, Clone Archive I, total of 566 clones) and subsequent selections in the Kannus Forest Research Station. Piip. = Clone Archive II in Haapavesi, Leht. = Clone Archive III in Kannus, Scre = selection of 49 best in Clone Archive III, B 15 = selection of 15 best in Clone Archive III.

	Orig. 1979	Piip. 1980	Leht. 1985	Scre 1990	B 15 1990
S. phylicifolia	213	33	179	5	1
S. myrsinifolia	110	26	85	30	12
S. myr. × *phy.*	69	12	29	3	1
S. cinerea	26	1	4	-	-
S. caprea	21	1	8	1	-
S. pentandra	19	-	9	1	-
S. triple hybrid	18	3	5	2	-
S. phy. × *cin.*	10	1	3	-	-
S. phy. × *pen.*	6	-	-	-	-
S. myr. × *cin.*	5	-	2	-	-
S. phy. × *cap.*	4	-	-	-	-
S. myr. × *pen.*	3	1	2	-	-
S. cin. × *cap.*	3	-	2	-	-
S. myr. × *cap.*	1	-	-	-	-
S. cin. × *pen.*	1	-	-	-	-
Unidentified	57	7	57	7	1
Total	566	85	385	49	15

20 cm long cuttings in the nursery. In 1978 they were planted in nursery beds inside plastic house. The cuttings were let root, after rooting the plastic cover was removed. In 1979 the cuttings were planted in nursery beds in the open. The rooted plants were replanted in spring 1980 in Clone Archive I.

In the original collection altogether 566 clones were recorded out of which 509 were identified. The most frequent species was S*alix phylicifolia* (213 occurrences). *Salix myrsinifolia* or the crossing between it and *Salix phylicifolia* (*Salix* × *tetrapla*) occurred also often. Most likely, however, some of the 566 clones are renumberings of same clones.

The species and clone distribution of the rooted cuttings is not exactly the same as with the sent clones. A great deal of the collected clones were of *Salix caprea* coppices the cuttings of which rooted poorly.

The first screening and selection of the 4H-collection was done after the growing season of 1979. Based on height growth, 85 best clones were selected, cuttings were prepared and planted in Clone Archive II, in the Piipsanneva peat-

land test area in Haapavesi in spring 1980.

The second selection was done in spring 1986 from the Clone Archive I in Kannus. Based on height and diameter growth over 6 years, cuttings of 375 best clones clones were prepared and planted in Clone Archive III in Lehtoranta of the Kannus Forest Research Station (Table 16).

The Clone Archives I and III in Kannus were evaluated several times. Usually the evaluation was done on the basis of dominant height (longest coppice in the stool). In some occasions also the dominant diameter (10 cm level, thickest stem in the stool) was measured. The last evaluation was done in autumn 1990 at the age of 6 years. Based on height growth, 49 best clones were selected from Clone Archive III. Based on both height and diameter growth, the selection was reduced to 15 best clones.

514. Selection from F1-progenies

Based on the Clone Archive I in Kannus and other willow collections in the Finnish Forest Research Institute, willow hybridization studies were started in 1981 as a part of the PERA-project (Hakkila 1985). The hybridization aimed principally in combining high productivity of the exotics *Salix burjatica* and *Salix viminalis* with the good winter hardiness and crop certainty of the indigenous species, mainly of *Salix caprea* and *Salix phylicifolia* and *Salix triandra*. With *Salix caprea* crossings an additional aim was to transfer genes of good rooting from the exotics into it.

The crossings were done in the Ruotsinkylä Forest Tree Breeding Station using a method which had been developed for poplars in 1930s (Wettstein 1941). Pollination was done manually in a glass house in spring. The seeds matured within 10–30 days. They were collected and sown as families in glass house. Later the seedlings were transplanted out.

The crossings have been explained in detail by Viherä-Aarnio (1987, 1988, 1989). Only some parental combinations for winterhardiness × growth potential and for hybrid vigor (heterosis) are discussed here. The clones and their origins are described in Table 17 and the selected crossings in Table 18.

The seedlings of 1981 crossings were grown over the first growing season in the nursery. In the autumn the first selection in the families was done at ratio 1 to 10 based on height. The subfamilies were planted as cuttings in a new trial. After 2 years a new selection was done from the (10 %) subfamilies, again at ratio 1 to 10, and based on height growth. The cuttings of the selected clones (one per cent of the original family) were planted into screening trial I in Vantaa (60:17 N, 25:03 E) and Kannus in spring 1984.

Table 17. Parent clones of crossings for winterhardiness × productivity and for hybrid vigor in the PERA-project, (from Viherä-Aarnio 1987, see also Hakkila 1985).

Species	No	Sex	Origin
S. burjatica	E4856	Male	Tuusula, originally Denmark (No 56)
S. burjatica	H3159	Female	Hungary/ Wageningen
S. burjatica	V768	Male	Jyväskylä
S. caprea	E6761	Male	Tuusula
S. caprea	E7311	Male	Mäntsälä
S. myrsinifolia	K2442	Male	Kannus
S. myrsinifolia	V759	Female	Pertunmaa
S. phylicifolia	V754	Male	Kuru
S. viminalis	H3157	Female	Hungary, originally East Germany, Graupa

Table 18. Crossing combinations for winterhardiness × productivity and for hybrid vigor in the PERA-project (from Viherä-Aarnio 1987, see also Hakkila 1985).

Female	Male	Target
S. viminalis H3157	*S. caprea* E6761	growth × winter hardiness
S. viminalis H3157	*S. caprea* E7311	growth × winter hardiness
S. viminalis H3159	*S. phylicifolia* V754	growth × winter hardiness
S. burjatica H3159	*S. burjatica* E4856	heterosis in *S. burjatica*
S. burjatica H3159	*S. burjatica* V768	heterosis in *S. burjatica*
S. myrsinifolia V759	*S. myrsinifolia* K2442	heterosis in *S. myrsinifolia*

The seedlings of 1982 crossings were grown as full families over growing seasons 1982–84. Based on their height at 3 years the selection was done at ratio 1 to 10, and cuttings of the selected best clones (10 per cent of the original family) were planted in spring 1986 in a screening trial II in Kannus.

Screening of the clones and progenies was done in each trial based on weighing the biomass per stool or cutting (without leaves). Based on weighing, the biomass of poorest, average clone and the best clone in the subfamilies was determined.

52. Results and discussion

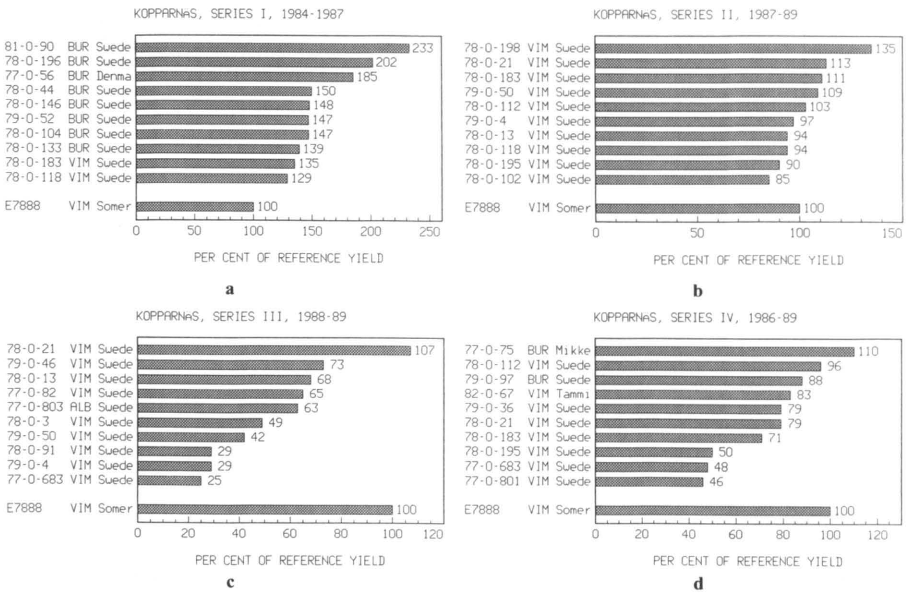
521. Selection of exotics in Kopparnäs

There were five screening series in Kopparnäs. The evaluation was done after each series. The average biomass production per stool was determined for each row and plot. In the row series I–III and in the plot series IV where the plot size was small (7. 5 × 7. 5 m). Therefore the biomass production is presented only in relation to the control clone S*alix viminalis* E7888 Somero. Its biomass per stool was always denoted by 100. The results, based on measurement after each series are presented in Fig. 5a–5d.

In the series V the plot size is 15 × 15 m, which is large enough for proper yield measurement, although proper consideration to border effect with regard to yield level analysis must still be given (see e. g. Cannell 1980). The results are shown in Fig. 6. The control clone VIM E7888 Somero was not included in this trial.

Based on each year measurements a priority list was prepared for the clones. In the measurement of each year and each series in growth, ten best clones were determined based on their average biomass production. The best clone was given 10 points, the second best 9 points etc. There were altogether 15 determinations in the five different growing series. The points were summed over the years 1984–89. Altogether 39 clones of the original 65 clones received points in this calculation (Table 19).

The Swedish imports and the best Finnish exotics were studied also in Kannus. In 1982 an



Figs. 5a–5d. Relative biomass production (stems only, mean annual increment) of exotic willow species in Kopparnäs screening trials, Inkoo, between 1984-87. In each series 10 most productive clones has been presented, compared to the reference clone *Salix viminalis* E7888 Somero, the production of which has been denoted by 100. For different series see Table 14, for clones see Table 13, for abbreviations see page 4.

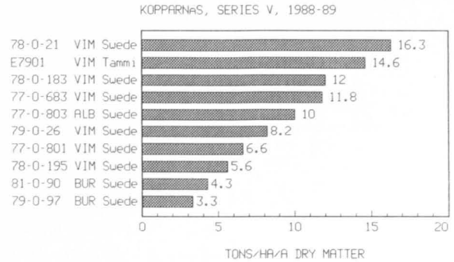


Fig. 6. Biomass production (stems only, mean annual increment) of the ten best exotic willow clones in Kopparnäs plot screening trial, Inkoo, between 1988–89. Plot size 15 × 15 m, 4-year roots, 3-year stems. For clones see Table 13, for abbreviations see page 4.

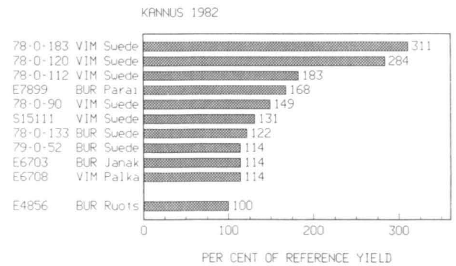


Fig. 7. Evaluation of the early stem biomass growth of the exotic willow clones belonging to the International Screening Test (IST, see Zsuffa 1990) in Kannus in 1982. 1-year roots, 1 year stems. The biomass of reference clone *Salix burjatica* has been denoted by 100. For clones see Table 13, for abbreviations see page 4.

International Screening Trial (IST, e.g. Zsuffa 1990) was established. It was evaluated immediately after one year growth (Fig. 7).

The overall results of the Kopparnäs trial indicate great between clone variation in the growth of the exotic species. For instance in the series III the clone number 10, *Salix viminalis* 77-0-683 yield only about one fifth of the clone number 1, *Salix viminalis* 78-0-21. In this series the roots were 7 years and coppices 2 years; the surviving stools had therefore already adapted to prevailing climatic conditions. The effect of the exceptionally cold winter 1986–87 might have affected the growth potential of the stools still.

There were not proper replications in the Kopparnäs trial. The interpretation of the results from row trial I–III poses additional problems.

Table 19. Priority list of exotics based on ratings each year for Kopparnäs (1984-89). Points have been calculated based on 15 end-of-season measurements in the 5 different trial series.

No	Species	Identity	Alias	Points
1.	*S. viminalis*	78-0-183	183	83
2.	*S. viminalis*	E7888	Somero	67
3.	*S. viminalis*	78-0-21	021	61
4.	*S. alba*	77-0-803	803	47
5.	*S. burjatica*	81-0-90	8100	39
6.	*S. burjatica*	78-0-44	044	37
7.	*S. viminalis*	78-0-112	112	34
8.	*S. burjatica*	78-0-196	196	34
9.	*S. viminalis*	78-0-195	195	33
10.	*S. viminalis*	78-0-198	198	33
11.	*S. burjatica*	77-0-75	075	30
12.	*S. viminalis*	77-0-801	801	26
13.	*S. viminalis*	78-0-101	191	23
14.	*S. viminalis*	E7901	Tamm.	22
15.	*S. viminalis*	79-0-50	809	20
16.	*S. viminalis*	78-0-13	013	20
17.	*S. burjatica*	79-0-97	CSD1	20
18.	*S. viminalis*	77-0-683	683	19
19.	*S. viminalis*	79-0-26	026	19
20.	*S. burjatica*	77-0-56	056	16
21.	*S. viminalis*	79-0-46	902	14
22.	*S. viminalis*	79-0-36	036	14
23.	*S. viminalis*	80-0-72	GB802	12
24.	*S. viminalis*	78-0-118	118	11
25.	*S. viminalis*	79-0-4	004	11
26.	*S. viminalis*	77-0-82	082	10
27.	*S. burjatica*	78-0-146	146	9
28.	*S. viminalis*	80-0-49	8049	8
29.	*S. burjatica*	79-0-52	908	8
30.	*S. smithiana*	77-0-681	681	7
31.	*S. viminalis*	78-0-91	091	6
32.	*S. viminalis*	80-0-51	051	6
33.	*S. viminalis*	78-0-3	003	6
34.	*S. burjatica*	78-0-104	104	5
35.	*S. viminalis*	78-0-90	090	5
36.	*S. viminalis*	80-0-73	GB803	3
37.	*S. burjatica*	78-0-133	133	3
38.	*S. viminalis*	78-0-102	102	2
39.	*S. burjatica*	79-0-54	79054	2

If a clone has a poor neighbor, the better clone gets additional space and advantage from the neigboring row. This effect is to certain extent beneficial since it boosts the growth differences between the rows. The growth differences are however, affected by the position of a certain clone to its neighbors, and without replications this effect cannot be eliminated.

The main result of this trial is however clear without replications:*Salix viminalis* overyielded *Salix burjatica*, the superiority was the bigger the longer the years passed by.

The Kopparnäs trial contains three other important elements. First is the yield collapse of almost all *Salix burjatica* clones. They were high yielding and superior in some years, especially in the first series of row trials. The Swedish clone BUR 81-0-90 yielded over twice the control clone VIM E7888 Somero in the Series I. This superiority in the productivity, however, disappeared already in the next series. This cannot be a coincidence.

The apparent reason for the yield collapse is the combined effect of rust (*Melampsora epitea*) and consequent reduced winter hardiness. The rust outbreak with *Salix burjatica* is not only Finnish phenomenon. It is becoming more and more serious in Sweden (Gullberg 1989, Åhman 1990) as well as in Ireland and Britain (Layton 1988, Dawson 1988). The problem of *Melampsora* rust is fundamental with *Salix burjatica*: if plant breeding cannot introduce a rust resistant clone, this species might be doomed to disappear from the biomass willow husbandry.

In selection of Finnish biomass willows the fate of *Salix burjatica* has wide consequences. First of all the national planning on energy forestry relied heavily on positive results with *Salix burjatica* from the 1970s. Had the practical applications been built on monocultures of this clone in 1980s, the outbreak of *Melampsora* would have meant economic disaster in the practical biomass willow husbandry. Secondly, if *Salix burjatica* fades out from the species selection, more emphasis must be put on indigenous willow species. The only current alternative, *Salix viminalis* is poorer in winterhardiness and not applicable in central or northern Finland.

One *Salix burjatica* clone, BUR 77-0-75 (originally from Finland, V761 Mikkeli) produced best in the series IV. For one reason or another the rust did not attack it in this series. This is still more problematic as the same clone faded out in the row series. This clone got rating of 11 in the final selection. Even this clone, however, cannot be recommended for practical applications. Besides, its growth habit is one of the poorest (not erect) for mechanical farming applications.

The second important observation in the Kopparnäs trial is the good crop certainty of the best *Salix viminalis* clones. They showed better hardiness against rust. The southern coast is mild enough for *Salix viminalis*, even if this species is relatively poor in winter hardiness. Not all the *Salix viminalis* clones, however, were equally productive. Three clones were quite remarkably above the others, namely VIM 78-0-183, VIM E7888 and VIM 78-0-21. Their yields remained relatively stabile from year to year, irrespective of cold winters. The apparent reason for better crop certainty with *Salix viminalis* is the better resistance to rust (*Melampsora epitea*). The results from Sweden (Ager et al. 1986, Rönnberg-Wästljung and Gunnerbeck 1985) are supportive. *Salix viminalis* clones are more susceptible to insect pests, although a mass invasion comparable to rust attack has not been experienced.

The Swedish *Salix viminalis* clone 78-0-183 which was ranked number one in the overall rating, was also rated best in 2 measurements out of 15. It is therefore a clone of both high yield capacity and of good crop certainty. It can be recommended for further research and development as well as practical applications in southern Finland. It is also worth of noticing that the Finnish *Salix viminalis* clone E7888 Somero performed almost as well as the best clone 78-0-183. Had the Kopparnäs trial been established with replications, the yield differences of these two best clones would probably been insignificant. Enough cuttings for practical applications are available for VIM E7888 Somero. It can also be recommended for further studies and use.

The third remarkable observation in the Kopparnäs trial is the good performance of *Salix alba* cloneALB 77-0-803. It was number four in the final rating, before any *Salix burjatica* clones. This calls for further testing of *Salix alba* and use of it as a breeding parent. The origin of ALB 77-0-803 has not been indicated in the Swedish clone register (Ager et al. 1986).

The one year preliminary test in Kannus supports *Salix viminalis* clone 78-0-183; it was the best after the first growing season. At this stage the coppices had not experienced winter, and the list would have changed in the later measurements. In general, *Salix viminalis* overwinters poorly at the latitude of Kannus.

A curiosity in the trial of 1982 in Kannus was the clone numer 10, *Salix viminalis* E6708, a clone from Pälkäne Agricultural Research Station. It is one of the clones selected for Finnish basket willow husbandry by Tapio (1965). In general, the old basket willow selections have not performed particularly well in biomass trials. Either the target for basket willow husbandry did not fully coincide with biomass production,

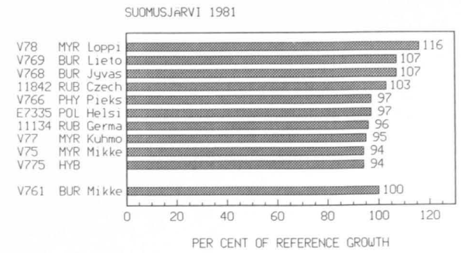


Fig. 8. Relative height growth of the 10 best exotic and indigenous biomass willow clones in Suomusjärvi trial of the Foundation for Forest Tree Breeding in 1981. Dominant height per stools has been measured, reference clone *Salix burjatica* V761 Mikkeli has been denoted by 100. 2-year roots, 1-year stems. For abbreviations see page 4.

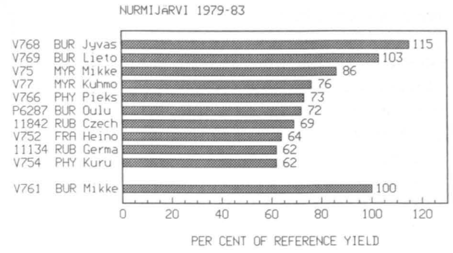


Fig. 9. Relative biomass production (stems only, mean annual increment) of the 10 best exotic and indigenous willow clones in Nurmijärvi trial of the Foundation for Forest Tree Breeding between 1979–83. Biomass production per stool has been measured, reference clone *Salix burjatica* V761 has been denoted by 100 (= 8. 2 tn/ha/a dry matter, mean annual increment). 5-year roots, 5-year stems. For abbreviations see page 4.

or the current selections have been more efficient.

522. Selection of exotics and indigenous in Suomusjärvi and Nurmijärvi

Based on dominant height of the first year after coppicing, *Salix myrsinifolia* grew best in the Suomusjärvi trial, even better than the exotic species (Fig. 8).

In the parallel trial in Nurmijärvi the willow stands were followed over 5 years, which is one of the longest biomass willow trials in Finland. Exotic clones of *Salix burjatica* were the best in this trial (Fig. 9.).

The new trials of the Foundation for Forest Tree Breeding support the earlier results. *Salix burjatica*, clones V769 Lieto, V768 Jyväskylä and V761 Mikkeli produced again best. This is quite remarkable since one would have expected similar outbreak of rust than has happened in larger scale trials. Most probably the scale of the trial (plots of 3 × 3 m) and a complete randomization of indigenous (over half) and exotic clones has created an environment which is unsuitable for mass invasion of *Melampsora epitea*.

Salix myrsinifolia was the most productive of the indigenous species. The clone MYR V75 Mikkeli was number 4 in this trial; it was number 5 in the previous trial (Lepistö 1978). The experience is totally from 8 years which is sufficient to recommend the clone for further research and development as well as for practical applications. On the contrary to *Salix viminalis* all *Salix myrsinifolia* clones overwinter north of Salpausselkä. Where would be the northern limit for this clone, remains unrevealed. It must be remembered however, that a close relative to *Salix myrsinifolia*, namely *Salix borealis* (by habitus bigger than *Salix myrsinifolia*) occurs throughout the northern Finland.

Salix fragilis FRA V752 Heinola did rather well in both trials, it was number 3 in the first (Lepistö 1978), and number 9 in the second trial in Nurmijärvi. This clone should be experimented more, perhaps it should also be used in breeding. *Salix pentadra* PEN V79 Somero, which was number 4 in the first trial did poorly in the second trial of Nurmijärvi. Actually, the Nurmijärvi site is not suitable for moisture demanding *Salix pentandra*. The rooting of *Salix pentandra* is not the surest of willows. Dry spring weathers do not favor planting such clones in the southern Finland.

523. Selection of indigenous in Kannus

Selection from the Clone Archives I–III in Kannus was done in several stages. Also a few intermediate evaluations were done in the Clone Archives, which did not immediately lead into any selections for further studies.

The first selection was done after the growing season of 1979. Based on the first year height growth 85 best clones were selected for a peatland trial in Piisanneva, Haapavesi. 33 of them were *Salix phylicifolia* and 26 *Salix myrsinifolia* (Table 16). Only one *Salix caprea* clone was accepted at this time (many of the originally planted and somehow rooted *Salix caprea* clones were not viable over the first winter). The exact measurements of this rating are no more available.

In 1980 the first evaluation for 10 best clones so far in Clone Archive I, was done on the basis of current height. The plants of the collection of 1978 had grown over 3, the plants of the collection 1979 over 2 growing seasons (Fig. 10).

The Clone Archive I was evaluated second time in autumn 1982. The previous stems had been harvested in 1980, so the roots were 4–5 years and stems 2 years (Fig. 11.)

In 1982 there was another evaluation, both in Kannus and Piipsanneva. Cuttings from the tallest clones had been selected based on the growth after 1981 growing season. Cuttings were collected and planted in a screening trial at spacing 1 × 1 meters in experimental sites of Kannus Forest Research Station and Piipsanneva in Haapavesi (Figs. 12 and 13)

In 1983 the clone archives were evaluated both in Kannus and Haapavesi. In Kannus 10 most vigorous were selected first visually. Then for the best five all coppices were measured and the average calculated. For the rest five only the tallest shoot was measured (Fig. 14).

In Haapavesi only the seven best were evaluated. The same clones had been measured also one year earlier (1982, Fig. 15).

Based on evaluations and screenings on indigenous, and also exotic species, in Kannus and Haapavesi so far, and interim species and clone selection list was prepared in autumn 1983. It was divided in groups for *Salix viminalis*, *Salix burjatica*, *Salix myrsinifolia*, *Salix triandra*, *Salix × americana*, *Salix × mollissima*, *Salix × tetrapla*, *Salix fragilis* and others, which also reveals the prevailing opinion about suitable species in 1983 (Table 20).

The clone archive II was evaluated for the first time in September 1990. The clones had grown for 6 years from cuttings. 49 best clones were selected. They included 30 *Salix myrsinifolia* clones and 5 *Salix phylicifolia* clones; the other were hybrids and unidentified species.

All the 49 clones were measured by dominant height. Ten best were selected for Fig. 16. Out of 49 clones 17 thickest were measured by the diameter at 10 cm level. Ten best were selected for Fig. 17.

The final rating of the indigenous clones was calculated by denoting the biggest dominant height with 100 and calculating the relative value for each species. Similarly the biggest dominant height was denoted with 100 and calculating the relative values for other clones. The two relative values were added together and the ranking list for 15 best indigenous clones was prepared based on this sum (Table 21).

The screening and evaluation of the 4H-collection in Kannus (Clone Achives I and III) and in Haapavesi (Clone Archive II) were done in rather casual manner and irregularly. As the importance of indigenous species was not considered high in the beginning of 1980s no real

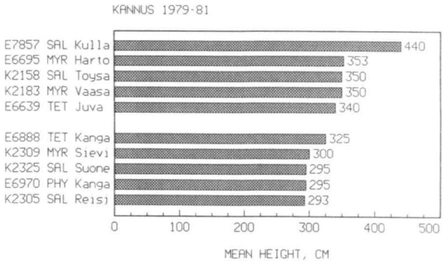


Fig. 10. Height in autumn 1980 of the five best biomass willow clones of the 4H-collection of 1978 (3-year roots, 3-year stems, upper half in figure) and of 1979 (2-year roots, 2-year stems, lower half in figure), in Kannus Forest Research Station (data from Heino and Pohjonen 1981). For abbreviations see page 4.

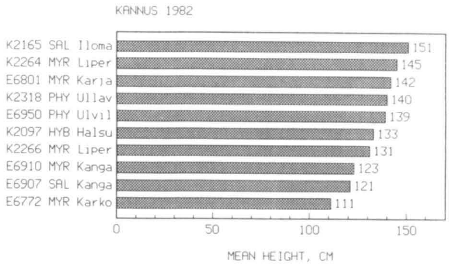


Fig. 11. Mean height of the 10 best biomass willow clones in Clone Archive I of the 4H-collection of 1978, Kannus Forest Research Station 1982. 4-5 old roots, 2-year stems. For abbreviations see page 4.

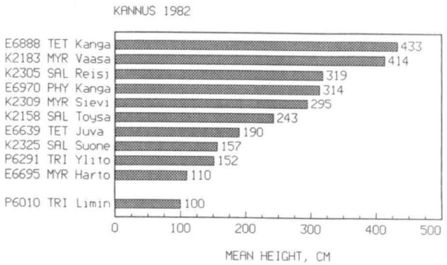


Fig. 12. Relative biomass production of the 10 best 4H-clones in the indigenous willow trial of Kannus in 1982. 1-year roots, 1-year stems. Reference clone *Salix triandra* P6010 Liminka has been denoted by 100. For abbreviations see page 4.

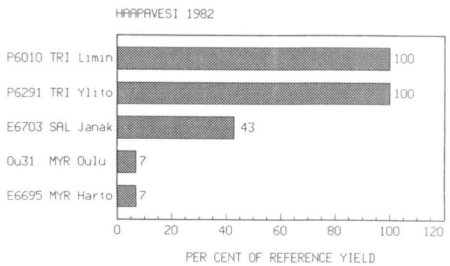


Fig. 13. Relative biomass production of the 5 best 4H-clones in an indigenous willow trial of Piipsanneva, Haapavesi in 1982. 1-year roots, 1-year stems. Reference clone *Salix triandra* P6010 Liminka has been denoted by 100. For abbreviations see page 4.

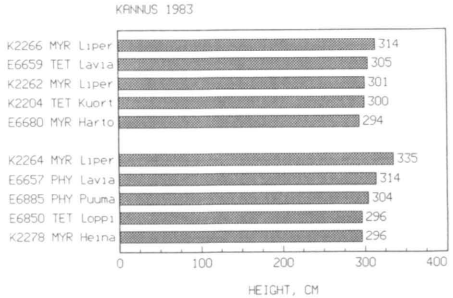


Fig. 14. Height of the 10 best indigenous biomass willow clones in Clone Archive I of the 4H-collection of 1978, Kannus Forest Research Station 1983. For the first five (upper half in figure) average height of all coppices per stool, for the next five (lower half in figure) dominant height has been measured. 5–6 years old roots, 3-year stems. For abbreviations see page 4.

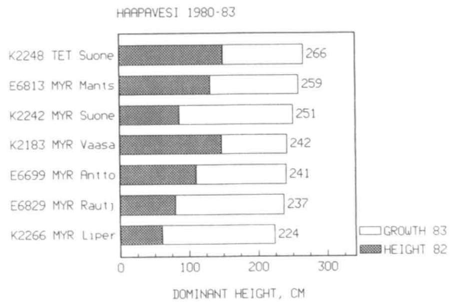


Fig. 15. Dominant height of the 7 best indigenous biomass willow clones in Clone Archive II of the 4H-collection of 1978, Piipsanneva trial area, Haapavesi in 1982 and 1983. 4-year roots, 4-year stems in 1983.

Table 20. Interim selection (1983) of species and clones in the PERA-project (Hakkila 1985) for exotic and indigenous biomass willows worth of further studies in Kannus.

Species	Identity	Origin
S. viminalis	78-0-183	Sweden
S. viminalis	S15111	Sweden
S. viminalis	E6708	Pälkäne
S. viminalis	E7895	Vääksy
S. burjatica	E7899	Parainen
S. burjatica	E4856	Ruotsinkylä
S. burjatica	E6703	Janakkala
S. burjatica	P6011	Oulu
S. myrsinifolia	E6695	Hartola
S. myrsinifolia	K2183	Vaasa
S. myrsinifolia	K2242	Kannus
S. triandra	P6291	Ylitornio
S. triandra	P6010	Liminka
S. × americana	E7314	Pälkäne
S. × mollissima	E7198	Helsinki
S. × tetrapla	E6888	Kangasniemi
S. phylicifolia	E6970	Kangasniemi
S. fragilis	P6293	Oulu
Salix sp.	E6907	Kangasniemi
Salix sp.	K2156	Ylivieska
Salix sp.	K2158	Töysä

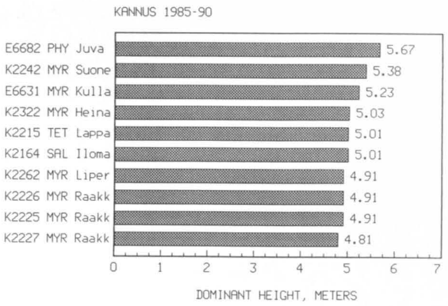


Fig. 16. Dominant height of the ten best indigenous biomass willow clones in the Clone Archive III of the 4H-collection of 1978 in Kannus Forest Research Station in 1990. 6-year roots, 6-year stems. For abbreviations see page 4.

Table 21. Priority list for the best 15 indigenous biomass willow clones based on dominant height and dominant diameter, of the 4H-collection in Kannus in 1990 (Clone Archive III). 6-year roots, 6-year stems.

Rank	Identity	Species	Origin
1.	E6631	*myrsinifolia*	Kullaa
2.	E6682	*phylicifolia*	Juva
3.	K2322	*myrsinifolia*	Heinävesi
4.	E6695	*myrsinifolia*	Hartola
5.	E6783	*myrsinifolia*	Asikkala
6.	K2164	*Salix* sp.	Ilomantsi
7.	K2242	*myrsinifolia*	Suonenjoki
8.	K2227	*myrsinifolia*	Rääkkylä
9.	K2226	*myrsinifolia*	Rääkkylä
10.	E6772	*myrsinifolia*	Kärkölä
11.	E6748	*myrsinifolia*	Lammi
12.	K2255	*myrsinifolia*	Pielavesi
13.	K2225	*myrsinifolia*	Rääkkylä
14.	K2215	*tetrapla*	Lappajärvi
15.	K2262	*myrsinifolia*	Liperi

inputs were placed in experimenting with indigenous willows. Correspondingly, there are no replicated trials nor repeated biomass measurements. The clone archives have served as archives: the collected species and clones awaiting for further needs.

Especially poorly followed has been the Clone Archive II in Piipsanneva peatland study area of Haapavesi. Since the planting of the archive the willows have grown more or less without any care. No fertilizer inputs have been given, no tending has been practised, nor has the trial

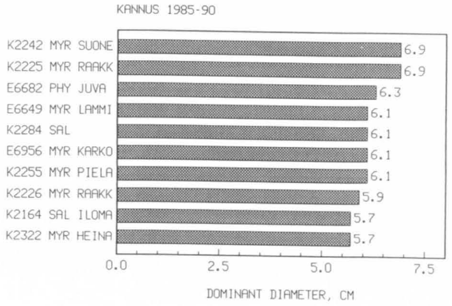


Fig. 17. Dominant diameter at 10 cm level, of the ten best indigenous biomass willow clones in the Clone Archive III of the 4H-collection of 1978 in Kannus Forest Research Station in 1990. 6-year roots, 6-year stems. For abbreviations see page 4.

been harvested. The few screenings done in Piipsanneva are therefore of importance in telling about the adaptability of indigenous clones in extreme conditions of willow husbandry.

Despite uncoordinated follow up, the few evaluations of the original 4H-collection and the clone archives reveal interesting phenomena. First, the initial dominance of *Salix phylicifolia* changes gradually over to dominance of *Salix myrsinifolia*. This can be seen in Table 16, which displays the selections of different time points.

The most remarkable research finding from the Kannus indigenous screening was the finding of the superiority of *Salix myrsinifolia* as an indigenous biomass willow. This was not in the original research hypotheses. For instance *Salix pentandra* was thought to be more productive, based on its remarkably showy habitus in northern Finland, and also on the good early results of Lepistö (1978).

It is also remarkable that all the finally selected clones are from southern part of Finland, and most of them are from the lake area in eastern or south-eastern Finland (exception: number one E6631 Kullaa is from western Finland). This may be an indication of suitable genetic environment in the lake area.

There was a number of hybrid willows in the original selection (the species and hybrid identification was done in the Department of Botany, University of Helsinki). The proportion of hybrids diminished as the selection progressed. In the final list of 15 there is only one hybrid left, as number 14 (*Salix* × *tetrapla* K2215 Lappajärvi). Is this an indication of poor growth vigor

of local hybrids, as might be expected based on Skvortsov (1968) and Dorn (1976)?-The question of hybrids in the clone archives should in any case be studied in more detail in the light of current opinions about willow hybridization.

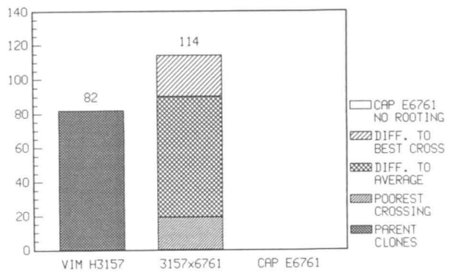
Based on about 10 years of screening and evaluation of the indigenous willows, a species and clone recommendation can be given — but only with care. The various screenings are not parallel; the top ten list seems to be totally different in 1983 and 1990. Early selection might be unreliable with willows. Early measurements might as well have disturbed too much by natural variation which cannot be eliminated in a screening without replications. But in any case, there are clear, visible growth differences in the Clone Archive II in the willows at age of 6 years. *Salix myrsinifolia* dominates. Therefore it is not totally unsafe to recommend MYR E6631 Kullaa and K2322 Heinävesi for further research and development. The third recommended clone is, rather surprisingly, *Salix phylicifolia*, the clone E6682 from Juva.

524. Selection from F_1-progenies

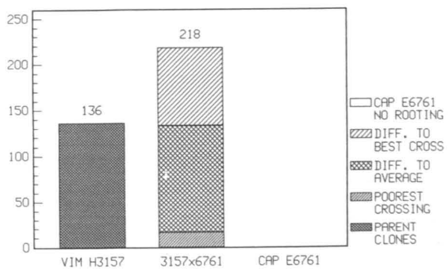
The possible selection from F_1-progenies is discussed in two separate cases. The progenies are from crossings where the winter hardiness of *Salix caprea* or *Salix phylicifolia* was to be combined via crossings with growth vigor and good rooting ability of *Salix viminalis* (Fig. 18a–18c). It must be noted that *Salix caprea* as male never rooted and there is no reference data for its growth from cuttings.

In the other crossings the aim was to find possible heterosis by first crossing different *Salix burjatica* clones (Fig. 19 a–c). There was only one female clone available, H3159 from Hungary which was crossed with two different males. A similar crossing for heterosis was done also with indigenous species: *Salix myrsinifolia* V759 Pertunmaa × *Salix myrsinifolia* K2442 Kannus (Fig 19d).

The inter- and intraspecific crossings between some exotic and indigenous willow species revealed most interesting features of the population variation. Even if original selection into the studied subfamilies had been done at level of 10 per cent or even at one per cent there was plenty of variation left. At this point it must, however, be remembered that the very early selection might not fully correlate with later biomass production. Even if sampling for growth vigor was done at 10 or one per cent level, the resulting



a



b

c

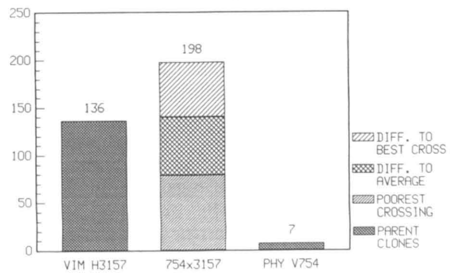


Fig. 18a–18c. Examples of biomass production from interspecific crossings of exotic and indigenous biomass willows for improved winterhardiness, growth vigor and rooting ability in the PERA-project (Hakkila 1985). 18a: *S. viminalis* × *caprea* (3-year roots, 2-year stems, 1 % early selection from the original family). 18b: *S. viminalis* × *caprea* (2-year roots, 2 year stems, 10 % early selection). 18c: *S. viminalis* × *phylicifolia* (2-year roots, 2-year stems, 10 % early selection). Stem biomass production per stool of the reference clone *Salix burjatica* E4856 has been denoted by 100 in each case. Data from Viherä-Aarnio (1987), for abbreviations see page 4.

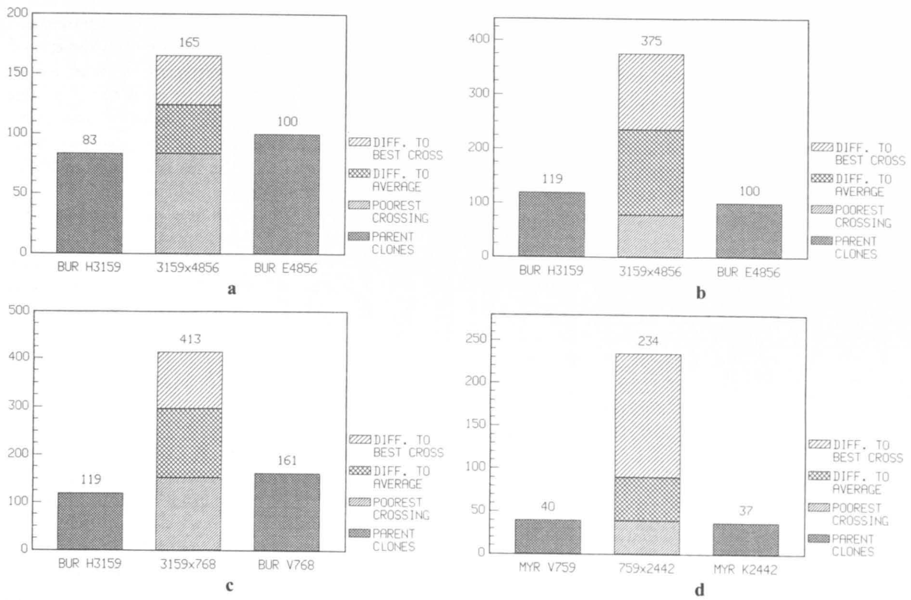


Fig. 19a-19d. Examples of biomass production from intraspecific crossings of *Salix burjatica* and *Salix myrsinifolia* for possible heterosis in the PERA-project (Hakkila 1985). 19a: H3159 Unkari × E4856 Ruotsinkylä (3-year roots, 2-year stems, 1 % early selection from the original family). 19b: H3159 Unkari × E4856 Ruotsinkylä (2-year roots, 2-year stems, 10 % early selection). 19c: H3159 Unkari × V768 Jyväskylä (2-year roots, 2-year stems, 10 % early selection). 19d: V759 Pertunmaa × K2442 Kannus (2-year roots, 2-year stems, 10 % early selection). Stem biomass production per stool of the reference clone *Salix burjatica* E4856 has been denoted by 100 in each case. Data from Viherä-Aarnio (1987), for abbreviations see page 4.

subpopulation might as well have been a subsample of the full original variation.

The population variation leads into 3 conclusions. First, the original selection of the parent clones has apparently been rather poor. In the case of *Salix burjatica* both the female (from Hungary) and male (from Denmark) are most probably not results of thorough population investigations but rather selections at more or less random for immediate cultivation in mind.

In the case of indigenous willows the selection has been done in connection of nation wide collections. In each of them the aim had been in selecting the most vigorous shoots for the clonal archives. But who can guarantee that the superior growth was based on a superior genotype? As well, and apparently rather, the superior growth had been due to favorable growing conditions. It is quite likely that both of the Finnish national collections resulted in clonal archives of good fenotypes, not good genotypes.

The second conclusion follows: the superiority of genotypes is hidden in the genes of the collected germplasm. It is revealed in the population variation of the F_1-progeny. By selecting the best clone from this variation the original aim of the collection is finally fulfilled. Superior genotypes are found for propagation. This leads into practical deduction. Provided the countrywide clonal archives are kept alive, there is no point to go for further selection of indigenous species. Selection for productive biomass clones is much more efficient by making planned F_1-progenies and carrying out the selection there.

The third conclusion is for the heterosis. With heterosis we can explain the hybrid vigor found in the crossing of geographically remote clones of *Salix myrsinifolia* V754 from Pertunmaa and *Salix myrsinifolia* K2442 from Kannus. The distance between the growing sites is about 400 km. It is far more than what the pollinating insects can fly. Due to the modality of insect pollination genetically narrow populations have built up in particular locations. Bringing such

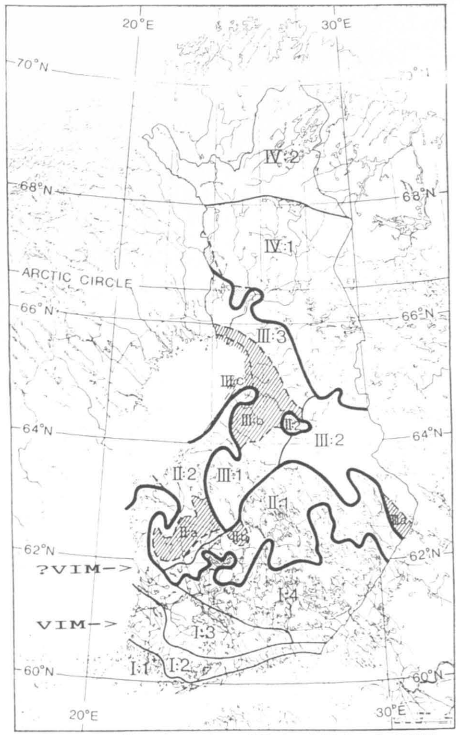


Fig. 20. Agroclimatic zoning of Finland (Solantie 1990). Recommendable zone for *Salix viminalis* biomass forestry is I:2, with a questionmark zone I:3.

populations artificially together brings the classical heterosis in the F_1-progeny. As the willow husbandry is built upon using clones, the superiority of the best individual in the F_1-progeny, boosted by heterosis, can be maintained and there is no fear for hybrid segregation in the practical cultivation.

53. Summary

The results from the selection of 1980s for suitable biomass willow clones can be summarized as follows:

1. Plain reliance on exotic species, or even on one single exotics, is hazardous for practical willow husbandry. A good example is the collapse of yields with *Salix burjatica* in several trials, both in Finland and abroad.
2. Counting on increased crop certainty with the expense of high yield capacity pays for in the long run. The farming systems in Finland as well as everywhere in the world base in crop certainty, and this will be the case with practical biomass willow husbandry as well. An example of good crop certainty with exotic species in *Salix viminalis* in the southern coast of Finland.
3. Species diversity (multispecies approach) is an important asset in large scale biomass willow husbandry. Willows are pioneer species and they are bound to have continuous threats from pathogens and insect pests. Species diversity includes both exotics and indigenous species. The diversity is to be expanded into clones as well.
4. Clonal selection from F_1-progenies of planned crossings is likely to increase the selection efficiency, which is higher than the selection in the parental natural populations. Prerequisite for the methods is the availability of clonal archives with geographically wide entries of germplasm. Additional germplasm can be acquired from planned collections. They should be preceded by careful studies of the distribution of species and of the possible clustering of the local populations.
5. As willows are practically untamed for arable crop husbandry, the prospects for breeding seem good. Breeding schemes should, however, be based on studies of natural populations.

54. Species recommendation

The early results (1910–1965) from the research and development into basket willow husbandry and the later results (1973–1990) into biomass willow screening in Finland lead into a practical species recommendation. All such recommendations should be based on agroclimatic zoning of the country, the most recent one for Finland is that of Solantie (1990).

Based on long term experience *Salix viminalis* can be recommended for practical biomass forestry applications in the southernmost zone (zone I:2 in Solantie's classification, Fig. 20). It has proved to be high-yielding, frost hardy and resistant to calamities (especially rust) both in the Kopparnäs trials and in a number of garden applications (mainly hedges) in that zone.

For the next zone, I:3 in Solantie's classification, *S. viminalis* can be recommended only with a questionmark. There are not enough experimental data from that zone, although the climate might suggest that *S. viminalis* would thrive there. The research and development with *S.*

viminalis should continue in the zone I:3.

For the more northern agroclimatic zones (I:4, II and III) the obvious choice for further research and development is *Salix myrsinifolia*. A practical recommendation for any arable applications cannot, however, be given since this species has not yet been grown in plantation applications. Even if the frost hardiness is sufficient there is no information about the potential rust outbreaks. Such possibilities should be tested in wide enough plantation scale over a period of at least five years. The prospects for finding high-yielding indigenous *S myrsinifolia* seem good, and the research and development should go further.

55. Further selection needs in Finland

Biomass willow husbandry entered practical farming applications in 1986 in Sweden. As it has been the case with all arable crops, the farmers are continuously expecting availability of commercial cultivars of both high yield capacity and good crop certainty. Such a programme, based on planned hybridization has also been started in Sweden (e. g. Ledin et al. 1990).

It may be anticipated that Finland follows the model of bioenergy applications developed in Sweden. For the southernmost cultivation zone in Finland the results of the Swedish research and development can be applied — with good cooperation and exchange of information and germplasm. But for the main part of Finland (north of the zone I:2), the Finnish biomass research must be developed according to special needs.

First of all, mass selection of indigenous clones does not seem necessary at the moment, provided the clonal archives for indigenous species are well maintained. The next step for selection is to study the F1-progenies from hybrids combinations based on the national collections.

Further development of the willow hybridization studies seems feasible and payable. This should be preceded by population studies for the anticipated parents. For theoritizing the possible parental combinations, the full range of willow species, populations and clones i. e. the spectrum of willow germplasm should be considered. In this work a compilation and further updating of present willow species, subspecies and cultivars (Appendix I) will be of great assistance.

A rich, untamed source of willow germplasm is found east of Finland, over the whole taiga zone of Siberia up to Kamtschatka peninsula. Another center of unexplored willow germplasm is nearer to the Himalayas. Planned expeditions to these areas would already now be needed.

As the world is seeking for modes of renewable energy for the 2000s, the selection of biomass willows and clones is facing more demanding challenges in the near future. Further strengthening of the international cooperation to achieve this goal is therefore ahead.

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Total of 116 references

Appendix

Willows–*Salix* sp.: species (SPE), subspecies (SUB), varieties (VAR), forms (FOR), hybrids (HYB), cultivars (CUL) and synonyms (SYN).

Name	Type	Correct name	Reference
S. abscondita	SPE	S. abscondita Laksch.	2,12
S. acmophylla	SPE	S. acmophylla Boiss.	2,8
S. acuminata Sm.	HYB	S. cinerea × viminalis × caprea	8
S. acutifolia (Hook.) Schneid.	VAR	S. glauca var. acutifolia (Hook.) Schneid.	10
S. acutifolia Willd.	SUB	S. daphnoides subsp. acutifolia (Willd.) Blytt & O.C. Dahl	1
S. adenophylla Hook.	SYN	S. cordata Michx.	8
S. adenophylla Hort. non Hook.	SYN	S. syrticola Fern.	10
S. adenophylloides Flod.	SYN	S. karelinii Turcz. ex Stschegl.	2
S. aegyptica	SPE	S. aegyptica L.	2,10
S. aequitriens Seemen	SYN	S. udensis Trautv. & Mey	2
S. aemulans Seem.	SYN	S. saximontana Rydb.	10
S. aglaia	CUL	S. daphnoides subsp. daphnoides Vill. 'Aglaia'	8
S. alatavica	SPE	S. alatavica Kar. ex Stschegl.	2
S. alaxensis	SPE	S. alaxensis Coville	2,12
S. alba	SPE	S. alba L.	1
S. alba-viminalis Rgl.	SYN	S. kirilowiana Stschegl.	2
S. albertii Rgl.	SYN	S. tenuijulis Ledb.	2
S. albicans Bonj.	SYN	S. appendiculata Vill.	2
S. albomaculata	CUL	S. purpurea L. 'Albomaculata'	9
S. alifera Goerz	SYN	S. pseudomedemii E. Wolf	2
S. alopecuroides Tausch.	HYB	S. fragilis × triandra	10
S. albicans	SYN	S. laggerii Wimm.	19
S. alpicola	SUB	S. myrsinifolia subsp. alpicola Buser ex Jaccard	2
S. alpina	SPE	S. alpina Scop.	2,8
S. altaica Lundström	SYN	S. arctica Pall.	2
S. altobracensis Coste	SYN	S. basaltica Coste	2
S. amandae Anderss.	HYB	S. glauca × myrsinifolia	17
S. ambigua Ehrh.	HYB	S. aurita × repens	17
S. ambrosia	CUL	S. viminalis L. 'Ambrosia'	19
S. americana Hort. ex Schwerin	HYB	S. gracilis × rigida	8
S. amnicola E. Wolf	SYN	S. udensis Trautv. & Mey	2
S. amplexicaulis	SPE	S. amplexicaulis Bory & Chaubard	3,8
S. amygdalina L.	SYN	S. triandra L.	2,8
S. amygdaloides	SPE	S. amygdaloides Anderss.	2
S. anadyrensis	SYN	S. pulchra Cham.	2
S. ancorifera	SYN	S. occidentalis Walt.	9,18
S. andersoniana Sm.	SYN	S. myrsinifolia Salisb.	8
S. anglorum Cham.	SYN	S. arctica Pall.	2
S. angrenica Drobov	SYN	S. olgae Rag.	2
S. angustata	VAR	S. rigida var. angustata (Pursh) Fern.	8
S. angustifolia	SUB	S. elaeagnos subsp. angustifolia (Cariot) Rech.	3
S. angustifolia Willd. non Wulf.	SYN	S. wilhelmsiana Bieb.	2,8
S. annularis	SYN	S. babylonica L. 'Crispa'	8
S. antiplasta Schneid.	SYN	S. arctica var. petraea Anderss.	8
S. apennina	SPE	S. apennina Borzi	19
S. apoda	SPE	S. apoda Trautv.	2,8
S. appendiculata	SPE	S. appendiculata Vill.	2,8
S. aquatica	CUL	S. burjatica Nazarov 'Aquatica'	1
S. aquatica gigantea	CUL	S. burjatica Nazarov 'Aquatica'	14
S. aquatica Sm.	SYN	S. cinerea L.	8
S. aquilonia Kimura	SYN	S. nakamurana Koidz.	2
S. araioclada Schneid.	SYN	S. arctica var. petraea Anderss.	8
S. arbuscula	SPE	S. arbuscula L.	2,8
S. arbusculoides	SPE	S. arbusculoides Anderss.	12
S. arbutifolia auct. non Pall.	SYN	S. fuscescens Anderss.	2
S. arbutifolia Pall.	SYN	Chosenia bracteosa (Turcz.) Nakai	2,8
S. arbutifolia Willd., non Pall.	SYN	S. breviserrata Flod.	8
S. arctica	SPE	S. arctica Pall.	2
S. arctophila	SPE	S. arctophila Cockerell ex Heller	18
S. arenaria	SUB	S. repens subsp. arenaria (L.) Hiit.	1
S. argentea Sm. non Wimm.	SUB	S. repens subsp. argentea (Sm.) E.A. & G. Camus	8
S. argentea auct. fenn.	SYN	S. alba L. 'Sibirica'	1
S. argentinensis Rag.	HYB	S. babylonica × humboldtiana	16
S. argophylla Nutt.	SYN	S. exigua Nutt.	8
S. argyracea	SPE	S. argyracea E. Wolf	2
S. argyrocarpa	SPE	S. argyrocarpa Anderss.	18
S. argyrophylla Laksch. ex Goerz	SYN	S. pantosericea Goerz	2
S. arizonica	SPE	S. arizonica Dorn	18
S. armena Schischk.	SYN	S. triandra L.	2
S. armeno-rossica	SPE	S. armeno-rossica Skv.	2
S. arnellii Lundström	SYN	S. saxatilis Turcz.	2
S. astatulana Murrill & Palmer	SYN	S. floridana Chapman	18
S. athabascensis	SPE	S. athabascensis Raup	18
S. atrocinerea	SPE	S. atrocinerea Brot.	2,3
S. aurea	CUL	S. alba L. 'Vitellina Pendula'	8
S. aurora	HYB	S. myrtilloides × repens (Laest.) Anderss.	2
S. aurita	SPE	S. aurita L.	1
S. australior Anderss.	SYN	S. excelsa S.G. Gmelin	2
S. austriaca	HYB	S. grandifolia × purpurea	
S. babylonica	SPE	S. babylonica L.	2,3
S. baicalensis Turcz. ex Nazarov	SYN	S. krylovii E. Wolf	2
S. bakko	SPE	S. bakko Kimura	8
S. balfourii E.F. Linton	HYB	S. caprea × lanata	8
S. ballii	SPE	S. ballii Dorn	18
S. balsamifera Barrat ex Bebb	SYN	S. pyrifolia Anderss.	8
S. barclayi	SPE	S. barclayi Anderss.	12
S. barlo	CUL	S. alba L. 'Barlo'	10
S. barrattiana	SPE	S. barrattiana Hook.	8
S. basaltica	SPE	S. basaltica Coste	2
S. basfordiana Scaling	HYB	S. alba × fragilis	3,8
S. bebbiana	SPE	S. bebbiana Sarg.	2,8
S. belders	CUL	S. alba L. 'Belders'	10
S. berberifolia	SPE	S. berberifolia Pall.	2
S. bicolor	SPE	S. bicolor Willd.	3,8
S. bifax Woloszczak	SYN	S. phylicifolia L.	2
S. bistyla	SPE	S. bistyla	19
S. black hollander	CUL	S. triandra L. 'Black hollander'	8
S. black italian	CUL	S. triandra L. 'Black italian'	8
S. black mauls	CUL	S. triandra L. 'Black mauls'	8
S. blakii Goerz	SYN	S. linearifolia E. Wolf	2
S. blakolgae Drobov	SYN	S. linearifolia E. Wolf	2
S. blanda Anderss.	CUL	S. babylonica × fragilis 'Blanda'	1,8
S. blinii	SPE	S. blinii Levl.	2
S. blue streak	CUL	S. daphnoides subsp. acutifolia Willd. Blytt & O.C. Dahl 'Pendulifolia'	1
S. bockii	SPE	S. bockii Seem.	8
S. bogadinensis	SPE	S. bogadinensis Trautv.	2
S. bonplandiana	SPE	S. bonplandiana H.B.K.	12,18
S. boothii	SPE	S. boothii Dorn	12
S. bordensis Nakai	SYN	S. microstachya Turcz. ex Trautv.	2

S. borealis	SPE	S. borealis (Fries) Nazarov	1
S. bornmuelleri Hausskn.	SUB	S. triandra subsp. bornmuelleri (Hausskn.) Skv.	2
S. bowles hybrid	CUL	S. viminalis L.'Bowles hybrid'	11
S. boydii E. F. Linton	CUL	S. reticulata × lapponum × herbacea 'Boydii'	8
S. brachycarpa	SPE	S. brachycarpa Nutt.	2
S. brachypoda	SPE	S. brachypoda Kom.	2
S. bracteosa Turcz.	SYN	Chosenia bracteosa (Turcz.) Nakai	2,8
S. brayi	SPE	S. brayi Ledeb.	2
S. bredevoort	CUL	S. alba L. 'Bredevoort'	10
S. breweri	SPE	S. breweri Bebb.	18
S. brevijulis	SYN	S. divaricata Pall.	2
S. breviserrata	SPE	S. breviserrata Flod.	2,8
S. britzensis	CUL	S. alba L. 'Britzensis'	1
S. brown merrin	CUL	S. viminalis L. 'Brown Merrin'	8
S. brownei Lundström	SYN	S. arctica Pall.	2
S. brownii Bebb.	SYN	S. arctica Pall.	
S. bullata	CUL	S. fragilis L. 'Bullata'	1
S. buxifolia Trautv.	SYN	S. phlebophylla Anderss.	2
S. borealis	SPE	S. borealis (Fries) Nazarov	1
S. burjatica Nazarov	SPE		1
S. caerulea Sm.	CUL	S. alba L. 'Caerulea'	8
S. caesia	SPE	S. caesia Vill.	2,10
S. caesifolia Drob.	SYN	S. purpurea L.	2
S. calcicola	SPE	S. calcicola Fernald & Wiegand	18
S. calodendron Wimm.	HYB	S. cinerea × viminalis × caprea	8
S. calliantha J. Kerner	HYB	S. daphnoides × purpurea	8
S. callicarpaea	SPE	S. callicarpaea Trautv.	3
S. calva	CUL	S. alba L. 'Calva'	10
S. canaliculata Bess.	SYN	S. rosmarinifolia L.	2
S. canariensis	SPE	S. canariensis Buch	8
S. candida	SPE	S. candida Fluegge ex Willd.	8
S. cantabriga	SPE	S. cantabriga Rech.	3
S. cantoniensis Hance	SYN	S. babylonica L.	2
S. capensis	SPE	S. capensis Thunb.	19
S. capitata Snarskis	CUL	S. fragilis 'Capitata'	2
S. capitata Chou & Skv.	SYN	S. babylonica L.	2
S. caprea	SPE	S. caprea L.	1
S. capsica	SPE	S. capsica Pall.	12
S. capusii	SPE	S. capusii Franch.	2,12
S. cardinalis Hort. ex A.B. Jacks	CUL	S. alba L. 'Cardinal'	8
S. cardiophylla	SPE	S. cardiophylla Trautv. & Mey.	2
S. caroliniana	SPE	S. caroliniana Michx.	12
S. carpatica	SPE	S. carpatica	19
S. cascadensis	SPE	S. cascadensis Cockerell	18
S. caspica auct.	SYN	S. ledebouriana Trautv.	2
S. caspica Pall.	SPE	S. caspica Pall.	3,10
S. cassia Vill.	SPE	S. cassia Vill.	4
S. catalaunica	SUB	S. atrocinerea subsp. catalaunica R. Görz	3
S. caucasica	SPE	S. caucasica Anderss.	2
S. caudata	SPE	S. caudata Heller	2
S. cernua E.F. Linton	HYB	S. herbacea × repens	8
S. chaenomeloides	SPE	S. chaenomeloides Kimura	8,18
S. chamissonis	SPE	S. chamissonis Anderss.	2
S. chapmanii Small.	SYN	S. floridana Chapman	18
S. cheilophila	SPE	S. cheilophila Schneid.	2
S. chermesina Hartwig	CUL	S. alba L. 'Britzensis'	1
S. chlorolepis	HYB	S. brachycarpa × pedicellaris	18
S. chlorostachya Turcz.	SYN	S. rhamnifolia Pallas	2
S. chrysocoma Dode	CUL	S. alba × babylonica 'Chrysocoma'	9
S. chrysostela	CUL	S. alba L. 'Crysostela'	8
S. ciliata DC.	SYN	S. pyrenaica Gouan	8

S. cinerascens	SUB	S. starkeana subsp. cinerascens (Wahlenb.) Hultén	1
S. cinerea	SPE	S. cinerea L.	1
S. cinnamomea	CUL	S. viminalis L. 'Cinnamomea'	10
S. coaetanea	VAR	S. caprea var. coaetanea Hartman	1
S. coccinea	CUL	S. alba L. 'Coccinea'	2
S. coerulangrenica Drobov	SYN	S. olgae Rag.	2
S. coerulea E. Wolf	SYN	S. capusii Franch.	2
S. coerulea Sm.	CUL	S. alba L. 'Caerulea'	10
S. coeruleiformis Drobov	SYN	S. niedzwieckii Goerz	2
S. commutata	SPE	S. commutata Bebb.	18
S. compacta Anderss.	HYB	S. aurita × lapponum	17
S. concolor	VAR	S. triandra var. concolor Wimm. & Grab.	
S. cordata	SPE	S. cordata Michx.	8
S. cordata Muhl., non Michx.	SYN	S. rigida Muhl.	8
S. cottetii Lagger ex Kern.	HYB	S. myrsinifolia × retusa	8
S. cotinifolia	CUL	S. myrsinifolia Salisb. 'Cotinifolia'	19
S. coulteri Anderss.	SYN	S. sitchensis Sanson ex Bong.	10,18
S. crassijulis Trautv.	SUB	S. arctica Pall. subsp. crassijulis (Trautv.) Skv.	2
S. crataegifolia	SPE	S. crataegifolia Bertol.	3
S. cremensis Kern.	HYB	S. caprea × daphnoides	10
S. crispa Loud.	CUL	S. babylonica L. 'Crispa'	8
S. cryptodonta	HYB	S. bebbiana × candida	18
S. cuneata Turcz. ex Ledeb.	SYN	S. sphenophylla Skv.	2
S. cuspidata Schultz	HYB	S. fragilis × pentandra	8
S. cutleri Tuckerman	SYN	S. uva-ursi Pursh	8
S. cyclophylla Rydb.	SYN	S. ovalifolia Trautv.	2
S. cyclophylla (non Rydb.) Seemen	SYN	S. nakamurana Koidz.	2
S. dahurica Turcz. ex Laksch.	SYN	S. miyabeana Seem.	8
S. daiseniensis Seem.	SYN	S. vulpina Anderss.	8
S. daltoniana	SPE	S. daltoniana Anderss.	2
S. daphneola	VAR	S. lapponum var. daphneola Tausch.	10
S. daphnoides	SPE	S. daphnoides Vill.	1
S. dasycladoides Nilsson	HYB	S. myrsinifolia × phylifolia × caprea × viminalis	4
S. dasyclados auct. ross.	SYN	S. burjatica Nazarov	14
S. dasyclados Wimm.	HYB	S. cinerea × viminalis	1
S. dasylaurina Nilsson	HYB	S. viminalis × caprea × cinerea × viminalis	4
S. daviesii Boiss.	SYN	S. acmophylla Boiss.	2
S. dealbata Anderss.	SYN	S. acmophylla Boiss.	2
S. decipiens Hoffm.	SYN	S. fragilis L.	2,8
S. delnortensis Schneid.	HYB	S. lasiolepis × sitchensis	18
S. denticulata	SPE	S. denticulata Anderss.	19
S. dependens Nakai	SYN	S. babylonica L.	2
S. deserticola Goerz	SYN	S. cinerea L.	2
S. devestita Arvet-Touvet	SYN	S. laggerii Wimm.	2
S. dichroa Kern.	HYB	S. aurita × purpurea	
S. dicks	CUL	S. purpurea L. 'Dicks'	8
S. dinsmorei Enander ex Post	SYN	S. acmophylla Boiss.	2
S. diplodictya Trautv.	SYN	S. arctica Pall.	2
S. dischgensis Goerz	SYN	S. excelsa S.G. Gmelin	2
S. discolor	SUB	S. triandra subsp. discolor (Koch) Arcangeli	3
S. discolor Muhl.	SYN	S. occidentalis Walt.	8,9
S. discolor Wimm. & Grab.	VAR	S. triandra var. discolor Wimm. & Grab.	
S. divaricata	SPE	S. divaricata Pall.	2
S. divergens Anderss.	SYN	S. caesia Vill.	8
S. dodgeana Rydb.	SYN	S. rotundifolia Trautv.	18
S. dolichostyla Seemen	SYN	S. pierotii Miq.	2
S. dolorosa Rowlee	HYB	S. babylonica × fragilis	10
S. dracunculifolia Boiss.	SYN	S. wilhelmsiana Bieb.	8
S. drakenburg	CUL	S. alba L. 'Drakenburg'	10

S. drummondiana Barratt	SPE	S. drummondiana Barratt ex Hook	12
S. dshugdshurica	SPE	S. dshugdshurica Skv.	2
S. duclouxii	SPE	S. duclouxii Levl.	8
S. doniana Sm.	HYB	S. purpurea × repens	8
S. eastwoodiae	SPE	S. eastwoodiae Cockerell ex Heller	18
S. egberti-wolfii Toepffer	SYN	S. capusii Franch.	2
S. ehlei Flod.	SYN	S. arctica Pall.	2
S. ehrhartiana Sm.	HYB	S. alba × pentandra	8
S. elaeagnos	SPE	S. elaeagnos Scop.	2,8
S. elburnensis	SPE	S. elburnensis Boiss.	2,8
S. elegans Bess.	SYN	S. myrtilloides L.	2
S. elegantissima K. Koch.	CUL	S. babylonica × fragilis 'Elegantissima'	9
S. enanderi Flod.	SYN	S. abscondita Laksch.	2
S. erdingeri J. Kerner	HYB	S. caprea × daphnoides	8
S. erecta Anderss.	SYN	S. waldsteiniana Willd.	8
S. ernestii	SPE	S. ernestii Schneid.	2
S. eriocarpa Fr. & Sav.	SYN	S. pierotii Miq.	2
S. eriocaulos Lundström	SYN	S. reptans Rupr.	2
S. eriocephala Michx.	SYN	S. occidentalis Walt.	9,18
S. eripolia Hand.-Mazz.	SYN	S. pseudomedemii E. Wolf	2
S. erythrocarpa	SPE	S. erythrocarpa Kom.	2
S. erythroflexuosa Rag.	HYB	S. alba 'Tristis' x S. babylonica 'Tortuosa'	10
S. euapiculata Nazarov	SYN	S. excelsa S.G. Gmelin	2
S. eucalyptoides F.N. Meyer ex Schneid.	SYN	Chosenia bracteosa (Trautv.) Nakai	2,8
S. eugenei	CUL	S. purpurea × viminalis 'Eugenei'	8
S. exelsa	SPE	S. exelsa S.G. Gmelin	2
S. exigua	SPE	S. exigua Nutt.	6,8
S. falcata Pursh	SYN	S. nigra Marsh.	8
S. fargesii	SPE	S. fargesii Burkill	8
S. farriae	SPE	S. farriae Ball.	18
S. fedtschenkoi	SPE	S. fedtschenkoi Goerz	2
S. fenghuanschanica Chou & Skv.	SYN	S. kangensis Nakai	2
S. ferganensis Nazarov	SYN	S. pycnostachya Anderss.	2
S. fimbriata	SUB	S. brayi subsp. fimbriata Skv.	2
S. finalis Kimura	SYN	S. brachypoda Kom.	2
S. finnmarchica Willd.	HYB	S. myrtilloides × repens	8,17
S. flabellaris Anderss.	SYN	S. nummularia Anderss.	2
S. flavicans Haoe	SYN	S. brachypoda Kom.	2
S. flavida Chang & Skv.	SYN	S. gordejevii Chang & Skv.	2
S. floderi Nakai	SYN	S. abscondita Laksch.	
S. floridana	SPE	S. floridana Chapman	18
S. fluviatilis	SPE	S. fluviatilis Nutt.	18
S. foetida	SPE	S. foetida Schleich. ex Lam.	2,3
S. forbyana Sm.	HYB	S. atrocinerea × purpurea × viminalis	3
S. formosa Willd.	SYN	S. arbuscula L.	8
S. fragilis	SPE	S. fragilis L.	1
S. fragilissima Host	HYB	?	2
S. french	CUL	S. triandra L. 'French'	8
S. french purple	CUL	S. daphnoides Vill. 'French purple'	8
S. friesiana Anderss.	HYB	S. repens × viminalis	8
S. fruticosa Doell.	HYB	S. aurita × viminalis S. repens × viminalis	
S. fruticulosa	SPE	S. fruticulosa Anderss.	9
S. fuiri-koriyanagi	CUL	S. purpurea L. 'Fuiri-koriyanagi'	9
S. fulcrata Anderss.	SYN	S. udensis Trautv. & Mey	2
S. fumosa Turcz.	SYN	S. saxatilis Turcz.	2
S. furcata Anderss.	SYN	S. fruticulosa Anderss.	9
S. fusca	SYN	S. repens var. fusca Jacq.	9
S. fuscata Goerz	SYN	S. pseudomedemii E. Wolf	2
S. fuscescens	SPE	S. fuscescens Anderss.	2
S. geyeriana	SPE	S. geyeriana Anderss.	12
S. gigantea	CUL	S. burjatica Nazarov 'Aquatica'	14

S. gilgiana	SPE	S. gilgiana Seem.	2,8
S. gillotii A. & E.G. Camus	CUL	S. myrisnifolia × retusa 'Gillotii'	8
S. ginme	CUL	S. integra × vulpina 'Ginme'	8
S. glacialis Anderss.	SYN	S. ovalifolia Trautv.	2
S. glabra	SPE	S. glabra Scop.	2,8
S. glandulifera	SUB	S. lanata subsp. glandulifera (B. Flod.) Hiit.	17
S. glanudulosa	SPE	S. glandulosa Seem.	19
S. glatfelderi Gullberg			22
S. glauca	SPE	S. glauca L.	1
S. glaucescens Moench	SYN	S. foetida Schleich. ex Lam.	2
S. galucoides Anderss.	HYB	S. glauca × myrsinites	17
S. glaucophylla Anderss.	SYN	S. acmophylla Boiss.	2
S. glaucophylla (Ser.) Seemen	VAR	S. triandra var. glaucophylla (Ser.) Seemen	
S. glaucophylloides	SPE	S. glaucophylloides Fernald	11
S. glaucosericea B. Flod.	SYN	S. glauca L.	2,8
S. gmelini Pall.	SYN	S. viminalis L.	2
S. gooddingii	SPE	S. gooddingii Ball	8,12
S. gordejevii	SPE	S. gordejevii Chang & Skv.	2
S. graciliglans Nakai	SYN	S. gracilistyla Miq.	2
S. gracilior Nakai	SYN	S. miyabeana Seem.	2
S. gracilis	CUL	S. purpurea L. 'Gracilis'	1
S. gracilis	SPE	S. gracilis Anderss.	10
S. gracilis	VAR	S. purpurea var. gracilis Gren. & Godr.	8
S. gracilistyla	SPE	S. gracilistyla Miq.	2,8
S. gracilistyloides Kimura	SYN	S. gracilistyla Miq.	2
S. grahamii Borrer	HYB	S. aurita × herbacea × repens	9
S. grandifolia Ser.	SYN	S. appendiculata Vill.	2,8
S. grandis	CUL	S. burjatica Nazarov 'Aquatica'	14
S. grataegifolia	SYN	S. grataegifolia Bertoloni	2
S. grenierana Anderss.	HYB	S. cinerea × purpurea	8
S. grisea Willd.	SYN	S. sericea Marsh.	10
S. guinieri Chassagne & Görz	HYB	S. atrocinerea × cinerea	16
S. hagensis G.A. Doorenbos	CUL	S. caprea × gracilistyla 'Hagensis' ('The Hague')	8
S. hakuro nishiki	CUL	S. purpurea L. 'Hakuro Nishiki'	9
S. hallaisanensis Nakai	SYN	S. caprea L.	2
S. hamatidens Levl.	SYN	S. triandra L.	2
S. hartmaniana Anderss.	HYB	S. hastata × lanata	17
S. hartwegii	SPE	S. hartwegii	18
S. hastata	SPE	S. hastata L.	1
S. hebecarpa Fern.	SYN	S. fuscescens Anderss.	2
S. hegetschweileri	SPE	S. hegetschweileri Heer	3,8
S. helix	SYN	S. purpurea L.	8
S. helvetica	SPE	S. helvetica Vill.	2,8
S. herbacea	SPE	S. herbacea L.	1,2
S. herberifolia	SPE	S. herberifolia Pall.	19
S. het goor	CUL	S. alba L. 'Het Goor'	10
S. heterandra Dode	SYN	S. caucasica Anderss.	2
S. heteromera Hand.-Mazz.	SYN	S. babylonica L.	2,10
S. hexandra auth. non Ehrh.	HYB	S. alba × pentadra	10
S. hibernica	SPE	S. hibernica Rech.	3,10
S. hibrido	CUL	S. babylonica × humboldtiana 'Hibrido'	16
S. hidaka-montana Hara	SYN	S. kurilensis Koidz.	2
S. hidewoi Koidz.	SYN	S. reinii Franch. & Sav.	2
S. himalayensis Flod.	SYN	S. karelinii Turcz. ex Stschegl.	2
S. hippophaeifolia Thuill.	CUL	S. triandra × viminalis 'Hippophaeifolia'	1,8
S. hirosakensis Koidz.	SYN	S. pierotii Miq.	2
S. hoffmanniana	VAR	S. triandra var. hoffmanniana Sm.	8
S. holargyrea Goerz	SYN	S. pycnostachya Anderss.	2
S. holosericea Willd.	HYB	S. cinerea × viminalis	
S. hondoensis Koidz.	SYN	S. pierotii Miq.	2
S. hookeriana	SPE	S. hookeriana Barratt ex Hook.	8,18

S. hsinganica Chang & Skv.	SYN	S. bebbiana Sarg.	2
S. hultenii Flod.	SYN	S. caprea L.	2
S. humboldtiana	SPE	S. humboldtiana Willd.	2,8
S. humilis	SPE	S. humilis Marsh.	8,18
S. hylematica Schneid.	SYN	S. fruticulosa Anderss.	9
S. hypericifolia Goloskokov	SYN	S. songarica Anderss.	2
S. hypoleuca	SYN	S. farkesii Burkill	8
S. idae Goerz	SYN	S. caprea L.	2
S. iliensis	SPE	S. iliensis Rg.	2
S. incana Michx., non Schrank	SYN	S. candida Fluegge ex Willd.	8
S. incana Schrank	SYN	S. elaeagnos Scop.	3,8
S. integra Thunb.	SYN	S. purpurea L.	9
S. interior	SPE	S. interior Rowlee	8
S. iranica Bornm. ex Topffee	SYN	S. pycnostachya Anderss.	2
S. irrorata	SPE	S. irrorata Anderss.	8
S. issykiensis Goerz ex Nazarov	SYN	S. kirilowiana Stsehegl.	2
S. jacquinii Host	SYN	S. alpina Scop.	8,19
S. jahandiezi	SYN	S. atrocinerea Brot.	2
S. jaliscana	SYN	S. bonplandiana H.B.K.	18
S. japonica Nakai	SYN	S. koriyanagi Kimura	10
S. japonica Thunb.	SPE	S. japonica Thunb.	8
S. jeholensis Nakai	SYN	S. babylonica L.	2
S. jejuna	SPE	S. jejuna Fernald	18
S. jelstiver	CUL	S. triandra L. 'Jelstiver'	8
S. jenisseensis	SPE	S. jenisseensis Flod	2
S. jepsonii	SPE	S. jepsonii Schneid.	18
S. jessoensis Kimura	SYN	S. schwerinii E. Wolf	2
S. jessoensis Seemen	SYN	S. pierotii Miq.	2
S. josephinae	CUL	S. purpurea × viminalis 'Eugenei'	8
S. kakista Schneid.	SYN	S. reinii Franch. & Sav.	2
S. kalarica	SUB	S. divaricata subsp. kalarica Skv.	2
S. kamtschatica	SUB	S. brayi subsp. kamtschatica Skv.	2
S. kangensis	SPE	S. kangensis Nakai	2,8
S. karelinii	SPE	S. karelinii Turcz. ex Stschegl.	2
S. kazbekensis	SPE	S. kazbekensis Skv.	2
S. kecks	CUL	S. purpurea L. 'Kecks'	8
S. ketoiensis Kimura	SYN	S. nakamurana Koidz.	2
S. kikodseae	SPE	S. kikodseae Goerz	2
S. kilmarnock	CUL	S. caprea L. 'Kilmarnock'	1
S. kimurana	SYN	S. berberifolia Pall.	
S. kinashii Levl. & Van.	SYN	S. triandra L.	2
S. kingoi Kimura	SYN	S. chamissonis Anderss.	2
S. kinuyanagi Kimura	SYN	S. schwerinii E. Wolf	2
S. kirilowiana	SPE	S. kirilowiana Stsehegl.	2,12
S. kitaibeliana Willd.	SYN	S. retusa L.	2
S. kochiana	SPE	S. kochiana Trautv.	2
S. kolymensis Seemen	SYN	S. bogadinensis Trautv.	2
S. komarovii E. Wolf	SYN	S. pycnostachya Anderss.	2
S. koreensis Anderss.	SYN	S. pierotii Miq.	2
S. koriyanagi	SPE	S. koriyanagi Kimura	8
S. korshinskyi Goerz	SYN	S. pycnostachya Anderss.	2
S. krylovii	SPE	S. krylovii E. Wolf	2
S. kudoi Kimura	HYB	S. fuscescens × udensis	2
S. kurilensis	SPE	S. kurilensis Koidz.	2
S. kurome	CUL	S. gracilistyla Miq. 'Kurome'	8
S. kuroyanagi	CUL	S. gracilistyla Miq. 'Kuroyanagi'	8
S. kuznetzovii	SPE	S. kuznetzovii Lasch ex Goerz	2
S. laevigata	SYN	S. bonplandiana H.B.K.	18
S. laggerii	SPE	S. laggerii Wimm.	2,10
S. lambertiana Sm.	CUL	S. purpurea L. 'Lambertiana'	19
S. lanata L.	SPE	S. lanata L.	1
S. lanceolata Sm.	CUL	S. triandra × viminalis 'Lanceolata'	9
S. lancifolia Anderss.	SYN	S. lasiandra Benth.	8
S. lapponum	SPE	S. lapponum L.	1

S. laschewitziana Toepffer	SYN	S. rorida Laksch.	2
S. lasiandra	SPE	S. lasiandra Benth.	2,10
S. lasiogyne Seemen	SYN	S. babylonica L.	2
S. lasiolepis	SPE	S. lasiolepis Benth.	8
S. latifolia	CUL	S. daphnoides Vill. 'Latifolia'	8
S. laurentiana	SPE	S. laurentiana Fern.	18
S. laurifolia Wesm.	SYN	S. pentandra L.	10
S. laurina Håkansson	HYB	S. cinerea × phylicifolia	4
S. laurina Sm.	HYB	S. caprea × phylicifolia	10
S. lavallei	CUL	S. babylonica L. 'Lavallei'	8
S. lavendulifolia	FOR	S. elaeagnos f. lavendulifolia K. Koch	10
S. leiocarpa Ledeb.	SYN	S. microstachya Turcz. ex Trautv.	8
S. ledebouriana	SPE	S. ledebouriana Trautv.	2
S. lemmonii	SPE	S. lemmonii Bebb.	18
S. lenensis Flod.	SYN	S. myrtilloides L.	2
S. lepidostachya Seemen	SYN	S. miyabeana Seem.	2
S. leucophylla Hartig	CUL	S. alba L. 'Sibirica'	1,8
S. leucopithecia Kimura	HYB	S. bakko × gracilistyla	8
S. libani Bornm.	SYN	S. pedicellata Desf.	2
S. lichtenvoorde	CUL	S. alba L. 'Lichtenvoorde'	10
S. liempde	CUL	S. alba L. 'Liempde'	8
S. lievelde	CUL	S. alba L. 'Lievelde'	10
S. ligulata Kimura	CUL	S. sachalinensis Fr. Schmidt 'Sekka'	10
S. ligulifolia	SPE	S. ligulifolia Ball ex Schneid.	18
S. liliputa Nazarov	SYN	S. Turczaninowii Laksch.	2
S. lindleyana Anderss.	SYN	S. fruticulosa Anderss.	9
S. linearifolia	SPE	S. linearifolia E. Wolf	2,12
S. linearistipularis Hao	SYN	S. miyabeana Seem.	2
S. lipskyi Nazarov	SYN	S. kirilowiana Stsehegl.	2
S. lispoclados Dode	SYN	S. excelsa S.G. Gmelin	2
S. litwinovii Goerz. ex Nazarov	SYN	S. excelsa S.G. Gmelin	2
S. livida Wahl.	SYN	S. starkeana Willd.	8,17
S. long skein	CUL	S. viminalis L. 'Long Skein'	8
S. longepetiolata Flod.	SYN	S. kurilensis Koidz.	2
S. longifolia Muhl., non Lam.	SYN	S. interior Rowlee	8
S. longiflora	SPE	S. longiflora Anderss.	19
S. longipes	SPE	S. longipes	19
S. longistyla Rydb.	SYN	S. alaxensis Coville	2
S. louisii Camus et Gombault	SYN	S. acmophylla Boiss.	2
S. lucida	SPE	S. lucida Muhl.	2,8
S. luctuosa	SPE	S. luctuosa Lev.	19
S. lutea	SPE	S. lutea Nutt.	8
S. lyallii Heller	SYN	S. lasiandra Benth.	10
S. maccalliana	SPE	S. maccalliana Rowlee	11,18
S. macilenta Anderss.	HYB	S. fuscescens × udensis	2
S. mackenzieana	SPE	S. mackenzieana Barratt ex Anderss.	8
S. macrolepis Turcz.	SYN	Chosenia bracteosa (Turcz.) Nakai	8
S. macropoda P. Poliakov	SYN	S. iliensis Rg.	2
S. macrophylla Anderss.	SYN	S. lasiandra Benth.	8
S. macrophylla Kerner	HYB	S. appendiculata × caprea	3
S. macrostachya E. Wolf	SYN	S. pycnostachya Anderss.	2
S. madagascariensis	SPE	S. madagascariensis Boj.	19
S. magnifica	SPE	S. magnifica Hemsl.	8
S. majalis Wahlenb.	HYB	S. myrsinifolia × phylicifolia	17
S. margaritifera E. Wolf	SYN	S. pycnostachya Anderss.	2
S. marrubifolia	SYN	S. helvetica Vill.	2
S. martiana	SUB	S. humboldtiana var. martiana Anderss.	16
S. mas	CUL	S. caprea L. 'Mas'	19
S. massalskyi Goerz.	SYN	S. alba L.	2
S. matsudana Koidz.	SYN	S. babylonica L.	2
S. maximowiczii Kom.	SYN	S. cardiophylla Trautv. & Mey.	2
S. medemii Boiss.	SYN	S. aegyptica L.	8
S. medwedewii Dode.	CUL	S. triandra L. 'Medwedewii'	8
S. melanopsis	SPE	S. melanopsis Nutt.	18

S. melanostachys Makino	CUL	S. gracilistyla Miq. 'Melanostachys'	8
S. metaformosa Nakai	SYN	S. divaricata Pall.	2
S. mesnyi	SPE	S. mesnyi Hance	19
S. mestizo	CUL	S. babylonica × humboldtiana 'Mestizo'	16
S. mestizo amos	CUL	S. babylonica × humboldtiana 'Mestizo Amos'	16
S. mexicana	SPE	S. mexicana	18
S. meyeriana Rostk.	HYB	S. fragilis × pentadra	8
S. mezereoides E. Wolf	SYN	S. udensis Trautv. & Mey	2
S. micans	SUB	S. alba subsp. micans (Anderss.) Rech.	2,3
S. michelsonii	SPE	S. michelsonii Goerz ex Nazarov	2
S. microphylla (Anderss.) Fern.	SYN	S. tristis Ait.	8
S. microstachya Turcz.	SPE	S. microstachya Turcz. ex Trautv.	2,8
S. mielichhoferi	SPE	S. mielichhoferi Sauter	2,8
S. minutiflora	SYN	S. caesia Vill.	2
S. miquelii Anderss.	SYN	S. vulpina Anderss.	2
S. missourensis	SPE	S. missourensis Bebb	8
S. mixta Korsh.	SYN	S. Pierotii Miq.	2
S. miyabeana	SPE	S. miyabeana Seem.	2,8
S. mollissima Ehrh.	HYB	S. triandra × viminalis	1,8
S. mongolica Siuzev	SYN	S. miyabeana Seem.	2
S. monochroma Ball	SYN	S. mackenzieana Barratt ex Anderss.	8
S. monticola	Spe	S. monticola Bebb.	18
S. montis-lopatinii	SYN	S. berberifolia Pall.	2
S. moorei F.B. White	HYB	S. herbacea × repens × aurita	8
S. mottled spaniards	CUL	S. triandra 'Mottled spaniards'	8
S. moupinensis	SPE	S. moupinensis Franch.	8
S. mullatin	CUL	S. viminalis L. 'Mullatin'	19
S. multinervis Doell.	HYB	S. aurita × cinerea	17
S. multinervis Franch. & Sav., non Doel.	SYN	S. purpurea L.	2,9
S. muscina	SPE	S. muscina	19
S. mutabilis Hort.	SYN	S. gracilistyla Miq.	8
S. myracoides	SPE	S. myracoides	11
S. myricifolia Anderss.	SYN	S. caesia Vill.	8
S. myricoides	SPE	S. myricoides (Muhl.) Carey	12
S. myrsinifolia	SPE	S. myrsinifolia Salisb.	1
S. myrsinites	SPE	S. myrsinites L.	1
S. myrtillifolia	SPE	S. myrtillifolia Anderss.	18
S. myrtilloides	SPE	S. myrtilloides L.	1
S. nakai Kimura	SYN	S. gracilistyla Miq.	2
S. nakaramuna	SPE	S. nakaramuna Koidz.	2,8
S. nana	CUL	S. purpurea 'Nana'	8
S. napoleonis F. Schultz	CUL	S. babylonica 'Napoleonis'	10
S. nazarovii	SPE	S. nazarovii Skv.	2
S. neidzwieckii	SPE	S. neidzwieckii Goerz.	12
S. neodaviesii Bornm. et Goerz	SYN	S. excelsa S.G. Gmelin	2
S. neoforbesii Toepffer	HYB	S. petiolaris × sericea	18
S. neofuscata Kimura	SYN	S. pseudomedemii E. Wolf	2
S. neolasiogyne Nakai	SYN	S. babylonica L.	2
S. neoreticulata Nakai	SYN	S. nakamurana Koidz.	2
S. neoteinuifolia Kimura	SYN	S. miyabeana Seem.	2
S. neriifolia Schleich.	HYB	S. grandifolia × purpurea	
S. nicholsonii purpurascens Dieck	SYN	S. rigida Muhl.	8
S. niedzwieckii	SPE	S. niedzwieckii Goerz	2
S. nigra	SPE	S. nigra Marsh.	6,8
S. nigricans Sm.	SYN	S. myrsinifolia Salisb.	8
S. nipponica	SUB	S. triandra subsp. nipponica (Fr. & Sav.) Skv.	2
S. nitida S.G. Gmelin	SYN	S. aegyptica L.	8
S. nitida	SUB	S. arenaria subsp. nitida (Ser.) Wenderoth	17
S. nivalis	SPE	S. nivalis Hook.	10
S. nivea Ser.	SYN	S. helvetica Vill.	10

S. nummularia	SPE	S. nummularia Anderss.	2
S. nupsinifolia	SPE	S. nupsinifolia	4
S. nyivensis Kimura	SYN	S. saxatilis Turcz.	2
S. oblongifolia Trautv. & Mey	SYN	S. udensis Trautv. & Mey	2
S. occidentalis	SPE	S. occidentalis Walt.	9
S. ohsidare Kimura	SYN	S. babylonica L.	2
S. oleifolia Sm.	SUB	S. cinerea subsp. oleifolia (Sm.) Macreight	8
S. oleninii Nazarov	SYN	S. abscondita Laksch.	2
S. olgae	SPE	S. olgae Rgl.	2
S. olgangrenica Drobov	SYN	S. olgae Rag.	2
S. onusta Bess.	HYB	S. aurita L.	19
S. opaca Anderss. ex Seem.	SYN	S. sachalinensis Fr. Schmidt	8
S. orbicularis Anderss.	SYN	S. reticularis L.	2
S. orestera	SPE	S. orestera Schneid.	18
S. orotchonorum Kimura	SYN	S. bebbiana Sarg.	2
S. orthostemma Nakai	SYN	S. divaricata Pall.	2
S. ovalifolia	SPE	S. ovalifolia Trautv.	2
S. ovalis Wimm.	FOR	S. alba f. ovalis Wimm.	5
S. ovata Ser.	HYB	S. helvetica × herbacea	9
S. oxica Dode	SYN	S. excelsa S.G. Gmelin	2
S. oxylepis	SYN	S. lasiolepis Benth.	18
S. palaeoneura Rydb.	SYN	S. phlebophylla Anderss.	2
S. pallasii Anderss.	SYN	S. arctica Pall.	2
S. pallida Ledb. non	SYN	S. ledebourana Trautv.	2
S. paludicola Koiz.	SYN	S. fuscescens Anderss.	2
S. palustris Host	HYB	S. alba × fragilis	20
S. pamirica Drobov	SYN	S. pycnostachya Anderss.	2
S. pantosericea	SPE	S. pantosericea Goerz	2
S. paracaucasica Goerz	SYN	S. caucasica Anderss.	2
S. paradoxa	SYN	S. lasiolepis Benth.	18
S. paralepsis	SPE	S. paralepsis Schneid.	2
S. paraleuca Fernald	HYB	S. myricoides × occidentalis	18
S. parallelinervis auct.	SYN	S. udensis Trautv. & Mey	2
S. paramushirensis Kudo	SYN	S. udensis Trautv. & Mey	2
S. paraplesia	SPE	S. paraplesia Schneid.	19
S. parviflora Host.	HYB	S. purpurea × repens	10
S. pauciflora Koidz.	SYN	S. nummularia Anderss.	2
S. peasei Fernald	HYB	S. herbacea × uva-ursi	18
S. pedunculata	SYN	S. occidentalis Walt.	9,18
S. pedicellaris	SPE	S. pedicellaris Pursh.	18
S. pedicellata	SPE	S. pedicellata Desf.	2,8
S. pekinensis	VAR	S. babylonica var. pekinensis Henry	10
S. pellita	SPE	S. pellita Anderss.	6
S. peloritana	SPE	S. peloritana Prestrandr ex Tineo	2
S. pendula Moench.	SYN	S. babylonica L.	8
S. pendula	CUL	S. caprea L. 'Pendula'	1,10
S. pendula	CUL	S. babylonica L. 'Pendula'	8
S. pendula	CUL	S. purpurea L. 'Pendula'	8
S. pendulifolia	CUL	S. daphnoides subsp. acutifolia Willd. Blytt & O.C. Dahl 'Pendulifolia'	1
S. pendulina Wenderoth	HYB	S. babylonica × fragilis	9
S. pennsylvanica Forbes	SYN	S. sericea Marsh.	8
S. pentandra	SPE	S. pentandra L.	1
S. pentandroides	SPE	S. pentandroides Skv.	2
S. perrostrata Rydb.	SYN	S. bebbiana Sarg.	2
S. persica Boiss.	SYN	S. acmophylla Boiss.	2
S. petiolaris	SPE	S. petiolaris Sm.	8
S. petraea Anderss.	VAR	S. arctica var. petraea Anderss.	8
S. petrophila Rydb.	SYN	S. arctica var. petraea Anderss.	8
S. pet-susu Kimura	SYN	S. schwerinii E. Wolf	2
S. petzoldii hort.	CUL	S. babylonica × fragilis 'Petzoldii'	2,8
S. phlebophylla	SPE	S. phlebophylla Anderss.	2
S. phlomoides Bieb.	SYN	S. aegyptica L.	2,8

S. phylicifolia	SPE	S. phylicifolia L.	1
S. phylicoides Anderss.	SYN	S. udensis Trautv. & Mey	2
S. picarde	CUL	S. alba L. 'Picarde'	19
S. pierotii	SPE	S. pierotii Miq.	2
S. piperi	SPE	S. piperi Bebb	18
S. planifolia	SPE	S. planifolia Pursh.	8
S. podophylla Anderss.	SYN	S. rhamnifolia Pallas	2
S. pogonandra Levl.	SYN	S. pierotii Miq.	2
S. polaris	SPE	S. polaris Wahlenb.	1
S. polia Schneid.	SYN	S. viminalis L.	2
S. polyadenia Hand.-Mazz.	SYN	S. nummularia Anderss.	2
S. polyphylla	CUL	S. triandra × viminalis 'Polyphylla'	15
S. pomeranian	CUL	S. triandra L. 'Pomeranian'	8
S. pomeranica Willd.	CUL	S. daphnoides Vill. 'Pomeranica'	1,8
S. pontederana Parl. non Willd.	HYB	S. gradifolia × purpurea	
S. pontederana Trautv.	SYN	S. kochiana Trautv.	2
S. pontederana Willd.	HYB	S. cinerea × purpurea	8
S. praecox Hoppe	SYN	S. daphnoides Vill.	10
S. praecox Salisb.	SYN	S. caprea L.	7,8
S. pronaica Kimura	SYN	S. fuscescens Anderss.	
S. prunifolia Kar. & Kir.	SYN	S. karelinii Turcz. ex Stschegl.	2
S. prunifolia Sm.	SYN	S. arbuscula L.	10
S. pruinosa Bess.	SYN	S. daphnoides subsp. acutifolia (Willd.) Blytt & O.C. Dahl	2
S. przewalskii E. Wolf	SYN	S. tenuijulis Ledb.	2
S. pseudalba E. Wolf	SYN	S. olgae Rag.	2
S. pseudodepressa	SPE	S. pseudodepressa Skv.	2
S. pseudofragilis Goerz	SYN	S. fragilis L.	2
S. pseudojessoensis Levl.	SYN	S. pierotii Miq.	2
S. pseudojessoensis Levl.	SYN	S. babylonica L.	2
S. pseudokoreensis Koidz.	SYN	S. pierotii Miq.	2
S. pseudolapponum Seemen	SYN	S. glauca L.	2
S. pseudolasiogyne Levl.	SYN	S. babylonica L.	2
S. pseudolinearis Nazarov	SYN	S. schwerinii E. Wolf	2
S. pseudolivida Goerz	SYN	S. iliensis Rg.	2
S. pseudomatsudana Chou & Skv.	SYN	S. babylonica L.	2
S. pseudomedemii	SPE	S. pseudomedemii E. Wolf	2
S. pseudomonticola	SPE	S. pseudomonticola Ball.	12
S. pseudopentandra	SPE	S. pseudopentandra Flod.	2
S. pseudopolaris Flod.	SYN	S. polaris Wahlenb.	2
S. pseudo-safsaf Canus & Gombault	SYN	S. acmophylla Boiss.	2
S. psiloides Kom.	SYN	S. hastata L.	2
S. pubescens Hao	SYN	S. caesia Vill.	2
S. pubescens Schleich	SYN	S. appendiculata Vill.	2
S. pulchra	SPE	S. pulchra Cham.	2,8
S. pulchra Wimm., non Cham.	SYN	S. daphnoides Vill.	8
S. pulchroides Kimura	SYN	S. chamissonis Anderss.	2
S. punctata Wahlenb.	HYB	S. myrsinifolia × myrsinites	17
S. purpurea	SPE	S. purpurea L.	1
S. pycnostachya	SPE	S. pycnostachya Anderss.	2,12
S. pyramidalis	CUL	S. humboldtiana 'Pyramidalis'	16
S. pyramidalis	CUL	S. purpurea × viminalis 'Eugenei'	8
S. pyramidalis Wrobl.	VAR	S. alba var. pyramidalis Wrobl.	11
S. pyrenaica	SPE	S. pyrenaica Gouan	2,8
S. pyrifolia	SPE	S. pyrifolia Anderss.	8
S. pyrolifolia	SPE	S. pyrolifolia Ledeb.	1
S. raddeana Laksch. ex Nazarov	SYN	S. abscondita Laksch.	2
S. rashuwensis Kimura	SYN	S. nakamurana Koidz.	2
S. raupii	SPE	S. raupii Argus	18
S. rehderiana	SPE	S. rehderiana Schneid.	8
S. regalis Hort. ex K. Koch	CUL	S. alba L. 'Sibirica'	1,8
S. regalis	CUL	S. viminalis L. 'Regalis'	10
S. rectijulis	SPE	S. rectijulis Ledeb. ex Trautv.	2
S. rectispica Nakai ex Flod.	SYN	S. jenisseensis Flod	2

S. recurvigemmis	SPE	S. recurvigemmis Skv.	2,3
S. red-bud	CUL	S. purpurea L. 'Red-bud'	8
S. regelii Anderss.	SYN	S. tenuijulis Ledb.	2
S. reichardtii A. Kern	HYB	S. caprea × cinerea	4,8
S. reinii	SPE	S. reinii Franch. & Sav.	2,8
S. repens	SPE	S. repens L.	1
S. reptans	SPE	S. reptans Rupr.	2
S. reticulata	SPE	S. reticulata L.	1
S. retusa	SPE	S. retusa L.	2,8
S. rhaetica Kern.	SYN	S. hegetschweileri Heer	8
S. rhamnifolia Hook & Arnott	SYN	S. fuscescens Anderss.	2
S. rhamnifolia	SPE	S. rhamnifolia Pallas	2
S. richardsonii	SPE	S. richardsonii Hook.	18
S. rigida	SPE	S. rigida Muhl.	8
S. rockanje	CUL	S. alba L. 'Rockanje'	10
S. rorida	SPE	S. rorida Laksch.	2,8
S. roridaeformis Nakai	SYN	S. kangensis Nakai	2
S. rosmarinifolia	SPE	S. rosmarinifolia L.	1
S. rosmarinifolia Host, non L.	CUL	S. elaeagnos Scop. 'Rosmarinifolia'	19
S. rossica Nazarov	SYN	S. viminalis L.	2
S. rostrata Richardson non Thuill.	SYN	S. bebbiana Sarg.	8
S. rotundifolia	SPE	S. rotundifolia Trautv.	2,8
S. rowleei	SYN	S. lasiolepis Benth.	18
S. rubens Schrank	HYB	S. alba × fragilis	1,8
S. ruberrima	CUL	S. daphnoides Vill. 'Ruberrima'	10
S. rubra Huds.	HYB	S. purpurea × viminalis	3,8
S. rubricapsula Toepffer	SYN	S. vestita Pursh	2
S. rubrobrunnea Drobov	SYN	S. pycnostachya Anderss.	2
S. rufescens (Turcz.) Nazarov	SYN	S. viminalis L.	2
S. rufinervis DC.	SYN	S. atrocinerea Brot.	2
S. rugulosa Anderss.	HYB	S. aurita × myrtilloides	3
S. russelliana Sm.	CUL	S. fragilis L. 'Russelliana'	9
S. sachalinensis	SPE	S. sachalinensis Fr. Schmidt	8
S. sacramento	CUL	S. babylonica L. 'Sacramento'	10
S. sadleri Syme	HYB	S. herbacea × lanata	8
S. safsaf	SPE	S. safsaf Forsk.	10
S. sajanensis	SPE	S. sajanensis Nazarov	12
S. salomonii Carr. ex Henry	CUL	S. alba × babylonica 'Salomonii'	2,10
S. salviifolia	SPE	S. salviifolia Brot.	2,10
S. sanguinea Scaling	CUL	S. fragilis L. 'Sanguinea'	8
S. saposhnikovii	SPE	S. saposhnikovii Skv.	2
S. sarawschanica Rgl.	SYN	S. pycnostachya Anderss.	2
S. sauce alamo	CUL	S. alba L. 'Sauce Alamo'	16
S. savatieri Camus	SYN	S. purpurea L.	10
S. saxatilis	SPE	S. saxatilis Turcz.	2
S. saximontana	SPE	S. saximontana Rydb.	10
S. schaffneri	SPE	S. schaffneri	18
S. scharfenbergensis	CUL	S. purpurea L. 'Scharfenbergensis'	8
S. schraderiana Willd.	SYN	S. bicolor Willd.	8
S. schugnanica	SPE	S. schugnanica	2
S. schwerinii	SPE	S. schwerinii E. Wolf	2,8
S. schwurbitziana	CUL	S. triandra × viminalis 'Schwurbitziana'	15
S. scouleriana	SPE	S. scouleriana Barratt ex Hook.	18
S. sekka	CUL	S. sachalinensis Fr. Schmidt 'Sekka'	8
S. seemannii Rydb.	SYN	S. glauca L.	2
S. seemenii B. Fedtsch.	SYN	S. alatavica Kar. ex Stschegl.	2
S. semicordata Dulac	SYN	S. basaltica Coste	2
S. semiviminalis E. Wolf	HYB	S. caprea × viminalis	2
S. sepulchralis Simonk.	HYB	S. alba × babylonica	2,8
S. sequitertia F.B. White	HYB	S. purpurea × aurita × phylicifolia	
S. sericans Tausch ex A. Kerner	HYB	S. caprea × viminalis	1,8
S. sericea Anderss.	SYN	S. caprea var. coaetanea Hartm.	8
S. sericea Gaud.	SYN	S. alba L. 'Sibirica'	1
S. sericea (Ser.) Koch	VAR	S. purpurea var. sericea (Ser.) Koch	

S. sericea	SPE	S. sericea Marsh.	8
S. sericea pendula	CUL	S. repens L. 'Sericea Pendula'	8
S. sericeo-cinerea Nakai	SYN	S. glauca L.	2
S. seringeana Gaud.	HYB	S. caprea × elaeagnos	8
S. serissima	SPE	S. serissima Fern.	2,8
S. serotica Pall.	SYN	S. viminalis L.	2
S. serpyllifolia	SPE	S. serpyllifolia Scop.	2,8
S. serrata Neilr.	VAR	S. myrsinites var. serrata Neilr.	10
S. serrulatifolia E. Wolf	SYN	S. tenuijulis Ledb.	2
S. sessifolia	SPE	S. sessifolia Nutt.	18
S. setchelliana	SPE	S. setchelliana Ball.	18
S. setsuka	CUL	S. sachalinensis Fr. Schmidt 'Setsuka'	8
S. shikokiana Makino	SYN	S. udensis Trautv. & Mey	2
S. shikotanica Kimura	SYN	S. reinii Franch. & Sav.	2
S. sibirica Pall.	SYN	S. rosmarinifolia L.	8
S. sibirica	CUL	S. alba L. 'Sibirica'	1
S. sieboldii hort.	CUL	S. babylonica × fragilis 'Sieboldii'	2
S. sikkimensis	SPE	S. sikkimensis Anderss.	2
S. silesiaca	SPE	S. silesiaca Willd.	2,8
S. silicicola	SPE	S. silicicola Raup.	18
S. simulatrix F.B. White	HYB	S. arbuscula × herbacea	8
S. sitchensis	SPE	S. sitchensis Sanson ex Bong.	10,18
S. siuzevii Seemen	SYN	S. udensis Trautv. & Mey	2
S. smithiana Forbes	HYB	S. caprea × viminalis	1
S. solheimii Kelso	HYB	S. reticulata × rotundifolia	18
S. songarica	SPE	S. songarica Anderss.	2
S. sordida Kern	HYB	S. cinerea × purpurea	8
S. spaethii Koopmann	SYN	S. wilhelmsiana Bieb.	8
S. spathulata Willd.	HYB	S. aurita × repens	17
S. speciosa Host.	HYB	S. fragilis × triandra	10
S. speciosa Nutt., non Host	SYN	S. lasiandra Benth.	8
S. sphaerica Hryniewiecki	CUL	S. fragilis L. 'Sphaerica'	2
S. sphacelata Sm.	SYN	S. caprea var. coaetanea Hartm.	8
S. sphenophylla	SPE	S. sphenophylla Skv.	2
S. spinidens E. Wolf	SYN	S. tenuijulis Ledb.	2
S. spissa Anderss.	SYN	S. alatavica Kar. ex Stschegl.	2
S. splendens (Bray) Anderss.	VAR	S. alba L. 'Sibirica'	1,8
S. splendens Ledeb.	VAR	S. viminalis var. gmelini (Pall.) Anderss.	
S. starkeana Willd.	SPE	S. starkeana Willd.	1
S. stenocarpa Fernald	HYB	S. myricoides × occidentalis	18
S. stenophylla Sukacz.	SYN	S. microstachya Turcz. ex Trautv.	2
S. stipularis Sm.	HYB	S. cinerea × viminalis × caprea	8
S. stipulifera	SUB	S. glauca subsp. stipulifera (B. Flod. ex Häyren) Hiit.	17
S. stolonifera	SPE	S. stolonifera Coville	18
S. stoloniferoides Kimura	SYN	S. saxatilis Turcz.	2
S. strobilacea (E. Wolf) Nazarov	SYN	S. viminalis L.	2
S. stuartiana	SPE	S. stuartiana Sm.	8
S. stuartii Druce	HYB	S. lanata × lapponum	8
S. subalpina Forbes	HYB	S. elaeagnos × repens	8
S. subfragilis Anderss.	SYN	S. babylonica L.	2
S. subfragilis auct. (non Anderss.)	SYN	S. triandra L.	2
S. subglabra Kerner	HYB	S. glabra × nigricans	3
S. subintegrifolia B. Flod.	VAR	S. hastata var. subintegrifolia	17
S. subopposita	SPE	S. subopposita Miq.	8
S. subphylicifolia Laksch.	SPE	S. abscondita Laksch.	2
S. subpyrolifolia	SYN	S. pyrolifolia Ledeb.	2
S. submyrsinites Flod.	SYN	S. rectijulis Ledeb. ex Trautv.	2
S. subreniformis Kimura	SYN	S. kurilensis Koidz.	2
S. subsericea (Anderss.) Schneid. em. Forbes	HYB	S. petiolaris × sericea	18
S. sugawarana Kimura	SYN	S. abscondita Laksch.	2
S. sungkianica Chou & Skv.	SYN	S. miyabeana Seem.	2
S. superlaurina	CUL	S. pentandra L. 'Superlaurina'	1

S. syrticola	SPE	S. syrticola Fern.	10
S. taimyrensis	VAR	S. arctica var. taimyrensis Nazarov	2
S. taimyrensis Trautv.	SPE	S. taimyrensis Trautv.	2
S. taraikensis Kimura	SPE	S. taraikensis Kimura	12
S. tarraconensis	SPE	S. tarraconensis Pau	2,3
S. tatewakii Kimura	SYN	S. abscondita Laksch.	2
S. tatronum Zapalowicz	SYN	S. phylicifolia L.	2
S. taxifolia	SPE	S. taxifolia H.B.K.	12,18
S. tenuifolia Sm.	HYB	S. myrsinifolia × phylicifolia	4,10
S. tenuijulis	SPE	S. tenuijulis Ledb.	2,12
S. tetrapla Walker ex Sm.	HYB	S. myrsinifolia × phylicifolia	8,17
S. tetrasperma	SPE	S. tetrasperma Roxb.	21
S. thunbergiana Anderss.	SYN	S. gracilistyla Miq.	8
S. tianschanica	SPE	S. tianschanica Rgl.	2
S. tontomussirensis Koidz.	SYN	S. reinii Franch. & Sav.	2
S. torulosa	SUB	S. arctica subsp. torulosa (Trautv.) Skv.	2
S. tortuosa	CUL	S. babylonica L. 'Tortuosa'	8
S. tracyi	SPE	S. tracyi Ball	18
S. trautvetteriana Rgl.	SYN	S. wilhelmsiana Bieb.	2
S. treviranii Spreng.	HYB	S. triandra × viminalis	10
S. triandra L.	SPE	S. triandra subsp. triandra L.	1
S. tricolor	CUL	S. cinerea L. 'Tricolor'	8
S. tristis Ait.	SPE	S. tristis Ait.	8
S. tristis	CUL	S. alba L. 'Vitellina Tristis'	8
S. tristis Chmelar	CUL	S. alba L. 'Tristis'	13
S. tschanbaischanica Chou & Chang	SYN	S. nummularia Anderss.	2
S. tschuktschorum	SPE	S. tschuktschorum Skv.	2
S. tsugalensis Koidz.	HYB	S. integra × vulpina	8
S. tundricola Schljakov	SYN	S. nummularia Anderss.	2
S. turanica	SPE	S. turanica Nazarov	2,12
S. turczaninowii	SPE	S. turczaninowii Laksch.	2
S. turgaiskensis E. Wolf	SYN	S. rosmarinifolia L.	2
S. turnorii	SPE	S. turnorii Raup	18
S. tuvinensis Gudoschn.	SYN	S. caesia Vill.	2
S. tweedyi	SPE	S. tweedyi (Bebb) Ball	8
S. udensis	SPE	S. udensis Trautv. & Mey	2,8
S. umbraculifera	CUL	S. babylonica L. 'Umbraculifera'	8
S. undulata Ehrh.	HYB	S. triandra × viminalis	8
S. uralensis Späth	VAR	S. purpurea var. uralensis Späth	10
S. urbaniana Seem.	SYN	S. cardiophylla Trautv. & Mey.	2
S. uva-ursi	SPE	S. uva-ursi Pursh	8
S. vagans Anderss.	SYN	S. starkeana Willd.	2
S. waldsteiniana	SPE	S. waldsteiniana Willd.	2,8
S. wallichiana	SPE	S. wallichiana Anderss.	16
S. variegata	SPE	S. variegata Franch.	2,8
S. variegata Hort.	CUL	S. cinerea L. 'Tricolor'	10
S. variegata Kimura	CUL	S. gracilistyla Miq. 'Variegata'	8
S. variifolia Freyn & Sintenis	SYN	S. excelsa S.G. Gmelin	2
S. watsonii Bebb	SYN	S. lutea Nutt.	8
S. weeping sally	CUL	S. caprea L. 'Kilmarnock Weeping Sally'	8
S. vegeta	SUB	S. hastata subsp. vegeta Anderss.	3
S. wehrhahnii	CUL	S. hastata L. 'Wehrhahnii'	1,8
S. weigeliana Willd.	SYN	S. phylicifolia L.	10
S. welch	CUL	S. purpurea L. 'Welch'	8
S. veriviminalis Nazarov	SYN	S. viminalis L.	2
S. versifolia Wahlenb.	HYB	S. lapponum × myrtilloides	17
S. verticilliflora E. Wolf	SYN	S. tenuijulis Ledb.	2
S. vestita	SPE	S. vestita Pursh.	8,18
S. wiegandii	SPE	S. wiegandii Fern.	18
S. wilhelmsiana	SPE	S. wilhelmsiana Bieb.	2,8
S. villarsiana (Flügge) Rouy	VAR	S. triandra var. villarsiana (Flügge) Rouy	3
S. viminalis	SPE	S. viminalis L.	1
S. wimmeriana Gren & Godr.	HYB	S. caprea × purpurea	8
S. vinogradovii	SPE	S. vinogradovii Skv.	2

S. violacea Andrews	SYN	S. daphnoides subsp. acutifolia (Willd.) Blytt & O.C. Dahl	1
S. violet	CUL	S. daphnoides Vill. 'Violet'	8
S. viridis Fries	HYB	S. alba × fragilis	8,17
S. viridula Anderss.	SYN	S. jenisseensis Flod	2
S. vitellina (L.) Stokes	CUL	S. alba L. 'Vitellina'	1
S. wolfii	SPE	S. wolfii bebb.	18
S. volgensis Anderss.	SYN	S. rosmarinifolia L.	2
S. wolseyana	CUL	S. repens L. 'Wolseyana'	8
S. woolgariana Sm.	CUL	S. purpurea L. 'Woolgariana'	8
S. voorthuizen	CUL	S. repens L. 'Voorthuizen'	8
S. vulcani Nakai	SYN	S. nummularia Anderss.	2
S. vulpina	SPE	S. vulpina Anderss.	2,8
S. xerophila B. Flod.	SUB	S. starkeana subsp. cinerascens (Wahlenb.) Hultén	1
S. yellow osier	CUL	S. viminalis L. 'Yellow Osier'	
S. yezoalpina Koidz.	SYN	S. nakaramuna Koidz.	2

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ACTA FORESTALIA FENNICA

219 **Heliövaara, Kari, Väisänen, Rauno & Immonen, Auli.** Quantitative biogeography of the bark beetles (Coleoptera, Scolytidae) in northern Europe. Seloste: Pohjois-Euroopan kaarnakuoriaisten kvantitatiivinen eliömaantieteellinen analyysi.

220 **Kuusela, Kullervo & Salminen, Sakari.** Suomen metsävarat 1977–1984 ja niiden kehittyminen 1952–1980. Summary: Forest resources of Finland in 1977–1984 and their development in 1952–1980.

221 **Pohjonen, Veli.** Selection of species and clones for biomass willow forestry in Finland. Tiivistelmä: Biomassan viljelyyn sopivien pajulajien ja -kloonien valinta Suomessa.

222 **Häme, Tuomas.** Spectral interpretation of changes in forest using satellite scanner images. Seloste: Metsän muutosten spektrinen tulkinta satelliittikeilainkuvien avulla.

223 **Finér, Leena.** Effect of fertilization on dry mass accumulation and nutrient cycling in Scots pine on an ombrotrophic bog. Seloste: Lannoituksen vaikutus männyn kuivamassan kertymään ja ravinteiden kiertoon ombrotrofisella rämeellä.

224 **Heikkilä, Risto.** Moose browsing in a Scots pine plantation mixed with deciduous tree species. Tiivistelmä: Hirven ravinnonkäyttö lehtipuusekoitteisessa mäntytaimikossa.

Acta Forestalia Fennica 221— Pohjonen

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