

Salix "Aquatica Gigantea" and Salix x dasyclados Wimm. in biomass willow research

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SELOSTE: VESIPAJU JA VANNEPAJU ENERGIAPAJUTUTKIMUKSISSA

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Salix "Aquatica Gigantea", widely experimented and promising species for temperate zone short rotation forestry, has since 1950 been recorded in Finland 23 times with different clone numbers. *Salix* x *dasyclados* Wimm., by morphological, cultivational and productivity characteristics similar willow has been recorded 16 times.

The nomenclature and origin of both willows have remained unclear in field research. Recent observations, based on morphological analyses and chromosome studies suggest that all *S.* "Aquatica Gigantea" and most *S.* x *dasyclados* clones can be collected under one Siberian species: *Salix burjatICA* Nasarov. The true *Salix* x *dasyclados* Wimm. is a female hybrid *S.* x *viminalis* x *cinerea*, famous West-European basket willow, very little experimented in Finland.

Vesipaju, *Salix* "Aquatica Gigantea", lupaavimpia ja eniten kokeiltuja metsäpuiden lyhytkiertoviljelyn puulajeja, on numeroitu Suomessa 23 eri klooninumerolla. Morfologisilta, viljely- ja tuotosominaisuuksiltaan sitä läheisesti muistuttava vannepaju, *Salix* x *dasyclados* Wimm., on vastaavasti numeroitu 16 eri klooninumerolla.

Molempien pajujen alkuperä ja asema systematiikassa ovat jääneet kenttätutkimuksissa hämäräksi. Tuoreet morfologiset ja kromosomitutkimukseen perustuvat selvitykset osoittavat että kaikki vesipajukloonit ja lähes kaikki vannepajukloonit kuuluvat samaan siperialaiseen lajiin *Salix burjatICA* Nasarov. Aito *Salix* x *dasyclados* Wimm. on emiklooni, koripajun ja harmaapajun hybridi, *S.* x *viminalis* x *cinerea*, Länsi-Euroopan maineikkaimpia koripajuja, jota on Suomessa tutkittu vain vähän.

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ODC 176.1 *Salix* "Aquatica Gigantea" + 176.1 *S.* x *dasyclados* + 238

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1. Introduction

Salix "Aquatica Gigantea" is one of the most important willows in the short rotation energy forestry research in Finland, Sweden, Ireland (Neenan 1980) and Great Britain (Stott 1984), as well as in Canada (Robertson 1984) and USA (Ringhofer 1981), even in New Zealand (Hathaway 1980). Since the beginning of the present biomass research, initiated by the 1973–74 energy crisis, *S.* "Aquatica Gigantea" has continuously belonged to the most productive species or clones in testing the willows for biomass plantations, in planning future willow breeding programmes and in developing suitable methods for willow husbandry.

But which of the numerous willows occurring in the northern temperate region is *Salix* "Aquatica Gigantea"? Where does it belong to in the genus *Salix*? It is surprising that the origin of such a widely cultivated, and scientifically experimented willow, has remained a mystery for 30–40 years. This willow is continuously referred to only with cultivar or variety name *S.* "Aquatica Gigantea", or *S.*

"aquatica", or *S.* "Grandis", but not with a proper scientific name like e.g. the other similar willow, osier, *Salix viminalis* L.

There is another high-yielding biomass willow, closely resembling *S.* "Aquatica Gigantea": *Salix dasyclados*. It was first described by Wimmer in 1849. The natural range of *S. dasyclados* is eastern; it is growing mainly in Siberia. Its northwestern boundary reaches the river Neva and the southeastern coast of the Kola peninsula. Finland or the Scandinavian peninsula do not belong to the natural range of *S. dasyclados*.

The willows named in the field research under *S.* "Aquatica Gigantea" and *S. x dasyclados* resemble each other by habitus so much that they must be close relatives. This resemblance has confused willow researchers, even willow systematists. But how close are they actually, or could they even belong just to one single species only? This also has been a continuous questionmark in the biomass willow research as well as in willow literature.

2. First observations of *S.* "Aquatica Gigantea" and main imports to Finland

By history *Salix* "Aquatica Gigantea" is connected to Denmark, to a Danish willow specialist and nursery man called Jensen. Jensen distributed this willow commercially in the late 1940's and in the early 1950's under designation *Salix* "Aquatica Gigantea No. 56".

In 1948 the pioneer in Finnish willow husbandry, Eeva Tapio (née Relander) paid a visit to Danish willow plantations. Based on this occasion she ordered in early 1950 for her field trials cuttings of a number of possibly suitable basket and hoop willow species and clones. At this import *S.* "Aquatica Gigantea" (or *Salix aquatica* as she called it) came to Finland.

S. "Aquatica Gigantea" was planted in 10 different sites all over Finland, in the experimental fields of the Agricultural Research Centre. The performance of the new species and clones was studied in a series of experiments between 1950–53 (Relander 1950, 1951, 1952, 1953a, 1953b, Tapio 1965). Tapio used clone numbers 65 and 90 for *S.* "Aquatica Gigantea" in the experiments carried out in Viikki Experimental Farm of the University of Helsinki. Whether these 2 clones were originally from different sources is, however, uncertain.

Tapio classified *S.* "Aquatica Gigantea" as hoop willow, i.e. it was suitable in producing raw material for hoops needed in manufac-

turing wooden drums. In her field experiments *S. "Aquatica Gigantea"* was continuously among the most productive species and clones. A special advantage was its good winter hardiness as compared to other tested willows, like *S. viminalis* L., *S. dasyclados* Wimm. and *S. x smithiana* Willd.

Tapio also recommended *S. "Aquatica Gigantea"* to be grown for windbreaks and hedges. In the mid-1950's she planted her original Danish import in the town of Mikkel, Central Finland, for hedge. These plants grew in 10 years into 8 metres high, forming a dense and beautiful hedge (Tapio 1965).

The second import to Finland of *S. "Aquatica Gigantea"* took place in 1953. The initiative came from Finnish forest industry, from R. E. Serlachius who was interested in finding new raw material sources for pulp milling (cf. also Die Papierweide 1956, Rudolph 1957). As a member of the board of directors of The Foundation for Forest Tree Breeding in Finland, Serlachius proposed to the chairman of that board, N. A. Osara, and to R. Sarvas of the Finnish Forest Research Institute that experimental planting of *Salix "Aquatica No 56"* should be initiated. This proposal led into purchase of 5000 cuttings from Denmark to the Finnish Forest Research Institute.

A population number R-53-075 was given to the import, since it was not known that cuttings of one single clone had been shipped. Later this number was changed into clone number DK 6352 (Hagman 1976).

Salix "Aquatica No 56" is male. It was planted in three experimental sites of the Finnish Forest Research Institute: in Ruotsinkylä, Lapinjärvi and Punkaharju. The still productive cutting orchard of *S. "Aquatica Gigantea"* in Ruotsinkylä Breeding Station has its origin in this 1953 import. Altogether

347 cuttings were planted in a clay field, where they adapted well. From this orchard numerous cuttings have been distributed into different field experiments in Finland (e.g. Pohjonen 1974, The PERA-project 1981). These same cuttings have also been distributed to Great Britain. There is a *S. "Aquatica Gigantea"* clone, designated "Korso", growing in Long Ashton Research Station willow collection, in Bristol. Korso is the railway station nearby Ruotsinkylä, at which the shipment originated.

In 1960's there were two imports of *Salix "Aquatica Gigantea"* to the Finnish Forest Research Institute. A female clone was received from Hungary, the origin of which was informed to be in German Democratic Republic. This female was designated a Finnish number H-D 3154. Hungarians delivered also another clone under the same name, but this other one is male. It was designated the number H-YU 3178. Into Hungary H-YU 3178 had come from Yugoslavia, from Nova Sadi Breeding Station (Hagman 1976). Both these clones were registered in Finland in 1967 (Rekisteröidyt . . . 1983).

In 1970's no recorded import of *S. "Aquatica Gigantea"* to Finland took place, but at the end of the decade interest again arose, now for energy forestry research. There was suddenly an acute shortage of a large number of homogenous cuttings, proved to be one clone. Therefore an additional import of the Danish clone No 56 was organised. In the spring 1980 P. J. Bäckström procured 100 000 cuttings from Denmark, and delivered them into the biomass research initiated in the Finnish Forest Research Institute (The PERA-project 1981). These cuttings were addressed with number "Denmark No 56", but whether this clone is really the same as Jensen's original one, is not absolutely sure.

3. *Salix "Aquatica Gigantea"* in short rotation forestry research

During late 1960's and early 1970's the concept of short rotation forestry was formulated. The key points in this concept were i) use of intensive cultural techniques to max-

imize forest tree yields and ii) reduction in the rotation times needed in conventional temperate or boreal forestry, sometimes up to 100 years, to clearly shorter periods, under 20

years or shorter, in the extreme case to even one year, i.e. to annual harvest.

The first reference to the short rotation forestry was made by McAlpine et al (1966), but a proper concept for these ideas was formulated by Schreiner in 1970. The key to the apparent silvicultural improvement was believed to lie on one hand in the application of advanced agricultural methods, and on the other hand in the concept of biomass, i.e. in utilizing the harvest as whole trees instead of stems alone.

The first Danish import of *Salix* "Aquatica No 56" into the Finnish Forest Institute can be regarded as an early anticipation of the forthcoming short rotation forestry research. But almost 20 years were to pass by, during which the interest in willows was faint in conventional silviculture. The new interest in the beginning of 1970's was, no doubt, due to experiments and concept formulation of short rotation forestry in the USA (cf. Fege 1981).

The short rotation forestry research initiative in Finland came from the University, from the Department of Silviculture. Three students (Malmivaara et al 1971) prepared a literature study, which could be regarded as a baseline study for the forthcoming Finnish willow research.

Next to the baseline study, field experiments with willows were established in 1973, simultaneously at Apukka, the Arctic Circle Agricultural Experimental Station near Rovaniemi, and at Hyytiälä, the summer camp for forestry students in the University of Helsinki. Although based on small-sized experimental plots, promising results were obtained at once. *S. "Aquatica Gigantea"* yielded best, a stem biomass yield of about 10 dry matter tonnes calculated as per hectare basis, was recorded in its first summer (Pohjonen 1974).

Larger-sized plots were established at Apukka during the next summer (1974), and the annual yields were maintained at their high level. In these first experiments the aim was to monitor the biomass production potential of some promising species using one year rotation only. The crop was established from the cuttings in the spring, and the biomass production – with and without leaves – was recorded in the autumn (cf. Pohjonen 1985).

Table 1. Finnish willow clones named as *Salix* "Aquatica Gigantea" with their different numbers or designations.

Number or designation	Remarks
No 65	Relander's import in 1950
No 90	Relander' import in 1950
Mikkeli	Relander's hedge in Mikkeli, either 65 or 90
No 56	Jensen's original <i>S. "Aquatica No 56"</i>
R-53-075	Population number for No 56
DK 6351	Renumbering of No 56 into Finnish system, DK for Denmark
Ruotsinkylä	Designation sometimes used for No 56
Korso	British designation for No 56, shipped apparently from Korso Railway Station
H-D 3154	Female clone, imported from Hungary (H), originally from DDR (D)
H-YU 3178	Male clone, imported from Hungary, originally from Yugoslavia (YU) Nova Sadi Breeding Station
Pa 7 Pälkäne	Foundation for Forest Tree Breeding in Finland, either Relander's No 65 or 90
Pa 75 Mikkeli	Foundation for Forest Tree Breeding in Finland, same as Relander's "Mikkeli"
Pa 275 Jyväskylä	Foundation for Forest Tree Breeding in Finland
Pa 297 Lieto	Foundation for Forest Tree Breeding in Finland, same as H-YU 3178
Denmark No 56	Danish import in 1980, apparently Jensen's original No 56
S78-47 Kälviä	S for Sweden
E 4856 Ruotsinkylä	Renumbering of DK 6351 and No 56
E 7317 Pälkäne	Renumbering of Pa7
E 7902 Urjala	Possibly Relander's No 65 or 90
K 2123 Kälviä	Renumbering of S78-47
V 761 Mikkeli	Renumbering of Pa 75
V 768 Jyväskylä	Renumbering of Pa 275
V 769 Lieto	Renumbering of Pa 297

At the same time as in the university of Helsinki, the short rotation forestry research was initiated in the Foundation for Forest Tree Breeding in Finland. Between 1973–1976 close to 400 willow clones from Southern Finland were chosen as basic material for breeding. The material was multiplied through cuttings, and 59 most promising clones were planted in spring 1975 into a comparative test. The accumulated biomass production was measured after three growing seasons, in autumn 1977. In this experiment *S. "Aquatica Gigantea"*, designated "Pa 297 Lieto", produced again most, on average of 15 tons dry matter per ha per year, the best plots producing even 20 tons/ha/a (Lepistö 1978a, Lepistö 1978b).

The latest, so far the strongest emphasis on *Salix "Aquatica Gigantea"* was given by the Finnish Forest Research Institute within the PERA project (1981, Hakkila 1985). This extensive four-part research project into the utilization and production of forest energy and energy forests, was started in 1978, partly as a continuation of the feasibility studies made by the Foundation for Forest Tree Breeding. The cultivation of fast-growing hardwoods, especially willows, was one of the four topics in the project. It was anticipated that abandoned agricultural land and worked-out fuel peat basins (cut-away peat-bogs) would make ideal cultivation sites.

Due to earlier positive experience *Salix "Aquatica Gigantea"* was regarded from the very beginning of the PERA project as one of the main clones for larger-sized experimental plantations. In the beginning of the project a country-wide collection of all possible, fast growing willows in Finland was also organised. Within this collection the growing sites

of *S. "Aquatica Gigantea"* were mapped, and some clones, again with new numbers, were found (Table 1).

All in all, *Salix "Aquatica Gigantea"* has been recorded in Finland at least 23 times with a proper clone number or fixed designation. Part of the great number can be explained by unnecessary renumbering. But which of these clones originally belong to the one and same basic clone, is no more possible to accurately identify. As additional information on the clones it may be stated that:

- Pa clones belong to the collection organized by The Foundation for Forest Tree Breeding. Pa 7 (later E 7317) and Pa 75 (later V 761) are probably the same; they are originally Relander's clones.
- Clone V768 (formerly Pa 275) is a "Bee-willow" grown for apiculture in Jyväskylä city. It has also been given local nickname "American willow" by the owner, since it was imported, according to the owner, from United States. The exact origin of this clone has, however, remained unrevealed.
- Clone V769 (formerly Pa 297) is the same as H-YU 3178 (Rekisteröidyt . . . 1983), i.e. its origin is in Hungary. Later, during the collection of 1973–75 by The Foundation for Forest Tree Breeding it was found in a commercial nursery in the town of Lieto.
- Clone S78–47 (later K 2123) was found in Kälviä, near the Kannus Research Station of the Finnish Forest Research Institute. It was grown for apiculture. This clone is registered also in Sweden (S for Sweden).
- Clones E 7317 Pälkäne and E 7902 Urjala belong to the original Relander's clones (either No 65 or 90). Pälkäne is one of the Research Stations in the Research Centre of Agriculture in Finland, where Relander's clones have survived. In the town of Urjala a centre for willow cultivation was established by Paju Oy in the beginning of 1950's (Tapio 1965).

4. Observations of *S. dasyclados* in Finland

Salix dasyclados was a popular species in the basket willow husbandry in Europe already in the beginning of 1900's. But when the first cuttings of this species were actually imported to Finland, is not clear. During the years 1912 and 1913 about 10 promising willow

species were imported from the Soviet (Mäkinen 1913) to be investigated by their performance for possible basket willow husbandry. Most probably there was also *S. dasyclados* among these Russian clones. Mäkinen also gave some general guidelines about

the basket willow husbandry in Finland, and referred to future screening of his species. Survival and performance of his clones as well as their possible present day availability are not known.

S. dasyclados was known to Cajander (1917), but the short note in his fundamental text book is only an indication that it might have been grown in Finland during his times.

Great efforts to develop willow husbandry were made by Seth Nordberg during the years 1914–1930. Nordberg started his willow research (1914) by paying a visit to the Baltic countries, Germany and Denmark to familiarize himself with the subject, and he also imported several clones to Finland. In his travel report Nordberg (1914) mentions surprisingly well-developed Danish willow plantations which had been established with clones *S. dasyclados* x *purpurea* and *S. dasyclados* x *purpurea* x *viminialis* (according to Nordberg's description either of those Danish hybrids could be the present *S. "Aquatica Gigantea"* E4856, Danish No 56). Nordberg (1928) also praises *S. dasyclados* to be very productive when using a 2–3 years rotation.

In the light of Nordbergs' highly positive experience of *S. dasyclados* or its hybrids, it is surprising that he never mentioned to have actually imported it to Finland. But in 1923 he planted a similar hybrid in his experiment in Rovaniemi Forest School: *S. viminialis* x *cinerea*, i.e. the hybrid which is also named under *S. x dasyclados* (see Chmelar and Meusel 1979).

The first certain import of *Salix dasyclados* (certain under name of) was that of Relander in 1950. She imported two clones, *S. dasyclados* No 63 and *S. dasyclados* Duitse Dot No 125. Of these No 125 was more productive. As compared to Tapio's *S. "Aquatica Gigantea"*. *S. dasyclados* No 125 was as productive but matured earlier, which gave better winter hardiness. The promising clone No 125 has since Relander's experiments survived in the Research Station of Häme in Pälkäne and of Kymi in Anjala (both belonging to the Research Centre for Agriculture in Finland).

A willow under name of *Salix dasyclados* is growing in Finland as north as Oulu (Pohjonen 1977), in some parks of the town and even in one field ditch few kilometres south of Oulu, in Oritkari. The origin of these bushes is unknown, but it is related to some older

arboretal collections. The wild bushes in Oritkari have been explained with a temporary nursery which had operated on the site around 1960 (Heino 1982). *S. dasyclados* willows in Oulu were collected in the biomass experiments of Pohjonen (1977) under numbers No 9 Oulu, No 18 Oritkari and No 21 Ainola. Later they were renumbered (Table 2) and one of them was also included in the collection made by The Foundation for Forest Tree Breeding.

At the end of 1970's a number of Finnish *S. dasyclados* clones was collected by the PERA-Project, similarly than with *S. "Aquatica*

Table 2. Finnish willow clones named as *Salix dasyclados* with their different numbers of designations.

Number or designation	Remarks
<i>S. x lanceolata</i>	Probably <i>S. dasyclados</i> see Nordberg (1923)
No 63	Relander's import in 1950
Duitse Dot No 125	Relander's import in 1950
H-NL 3159	Import from Netherlands through Hungary to Finnish Forest Research Institute.
OU-9	Pohjonen's collection (1977), later with number P 6009
OU-18	Pohjonen's collection (1977), later with number P 6011
OU-21	Pohjonen's collection (1977), later with number P 6012
Pa 75	Also with name <i>S. "Aquatica Gigantea"</i> Later renumbered as V 761
Pa 436	One of the clones from Oulu: P 6009, P 6011 or P 6012, later renumbered as P 6287 Oulu
E 6707 Pälkäne	Relander's No 63 or Duitse Dot No 125 renumbered
E 7894 Orimattila	Hedge in Southern Finland, also known as "Pennala"
P 6009 Oulu	Renumbering of OU-9
P 6011 Oritkari	Renumbering of OU-18
P 6012 Ainola	Renumbering of OU-21
P 6287 Oulu	Renumbering of Pa 436
V 761 Mikkeli	Also with name <i>S. "Aquatica Gigantea"</i> , and with number Pa 75

Gigantea". Grouping them under either *S. "Aquatica Gigantea"* or *S. dasyclados* did not follow any pattern. The earlier name was usually accepted. In some cases, morphological and ecological similarities (like frost hardiness) were used as basis for grouping.

All in all, *Salix dasyclados* has been recorded in Finland at least 16 times (Table 2) with a proper clone number or fixed designation. As with *S. "Aquatica Gigantea"*, it is no more possible to accurately identify which of these clones might belong to one and single original clone.

As additional information on the clones it may be stated that:

- E 7894 Orimattila (also known as "Pennala") was received from a private garden hedge, the origin of which remained unknown.
- V 761 was collected from the hedge in Mikkeli planted by Tapio (1965). Tapio calls this same clone *S. "Aquatica Gigantea"*. The clone of Mikkeli has also been distributed under number PA 75 (Lepistö 1978) and No 075 (in Sweden).

5. Opinion about the systematic location of *S. "Aquatica Gigantea"* and *S. dasyclados*

When the first *S. "Aquatica Gigantea"* cuttings were distributed from Denmark, there was no clear opinion what it is, or what are the actual willow species behind the clone. Tapio (1965) noticed that there was no information in the willow literature on the clone that she received in 1950. So she postulated that the clone had been propagated by starting with a single plant selected from a mixed stand. Tapio, however, did not consider *S. "Aquatica Gigantea"* to be a hybrid, rather she spoke about species *Salix aquatica*.

In the mid fifties there existed a theory that Jensen's clone No 56, is a specific (male) selection derived from a hybridization programme (Die Papierweide 1956, Rudolph 1957, Stott 1981). At this time the name *S. "Aquatica Gigantea"* emerged. One of the combinations suggested in the 1950's for its parentage was *S. cinerea* x *caprea* x *viminalis* (Stott 1984).

The hybrid theory might have its roots in the earlier willow research made before Jensen's time: in the hybridization studies of Nilsson (1918) and subsequent cytological investigations made on these hybrids by Håkansson (1929, 1938, 1955). Of particular interest are Nilsson's artificial hybrids between *Salix viminalis* and *Salix caprea*. By description these hybrids did greatly resemble the present *S. "Aquatica Gigantea"* (Zsuffa et al. 1984).

A curiosity in Nilsson's hybridization

studies was that he later (1935) described a series of his sterile *viminalis* x *caprea* F2 hybrids as "gigantea" types because of the unusually large size of their leaves and stems, and their superior vigour. A cytological analysis by Håkansson had earlier (1929) revealed that these "gigantea" type hybrids were triploids.

In the sixties and seventies there was only little interest in the origin of *S. "Aquatica Gigantea"*. Neither Rechinger (1964), Skvortsov (1968), Meikle (1975), Jalas and Suominen (1978) nor Chmelar and Meusel (1979) mention a word of it in their otherwise comprehensive presentations.

In the boom of forest energy and energy forest research in the early 1980's, *S. "Aquatica Gigantea"* became almost synonym with energy plantations. An interest in its systematical background also arose. Austrian Neumann (1981) notifies it under name *S. x aquatica* hort., reflecting the opinion of hybrid background and nature of a cultivar for horticultural purposes. Neumann mentions the hybrid background to be complicated, in which *S. cinerea* L., *S. daphnoides* Vill. and *S. viminalis* L. could be involved.

In a Finnish encyclopedia of plants (Kasvien . . . 1982) an opinion is presented that *S. "Aquatica Gigantea"*, cultivated as energy willow, is probably a form or a hybrid of *S. triandra* L. This theory is, however, vague and loosely given: neither origin nor arguments are presented.

Canadian Robertson (1984) paid an extensive study tour to the most important biomass willow plantations and collections in Europe in the beginning of 1980's. He analyzed the essence of *S. "Aquatica Gigantea"* as a putative hybrid. He found two especially vigorous clones *S. x aquatica "Gigantea"* and *S. x aquatica "Korso"*. In the Salicetum at Brno, Czechoslovakia the cultivar "*Aquatica Gigantea*" was considered a cultivar of *S. dasyclados* Wimm.

Robertson also noted that two willows were remarkably similar: *S. x calodendron* and *S. x aquatica*. The background of *S. x calodendron* is very complicated. Meikle (1952) for instance considered it a triple hybrid between *S. caprea x cinerea x viminalis*. *S. calodendron* and *S. x aquatica* should be considered hybrids of similar parentage.

S. "Aquatica Gigantea" No 56 is all male. The rooting of cuttings is very easy; it is most logical that this Jensen's original selection is a single clone which was taken in one stem or bush. But more *S. "Aquatica Gigantea"* clones than this one were actually distributed because there is at least one, probably two or more female clones of *S. "Aquatica Gigantea"*. One, H-D 3154, is growing in the collections of the Finnish Forest Research Institute. The other (designated "Germany") is growing in Long Ashton Research Station.

In Long Ashton the female clone flowers later and has more upright growth habit than the male *S. "Aquatica Gigantea"* (Stott 1981). Most probably this female clone of Long Ashton is the same as the female H-D 3154 in the Finnish Forest Institute. It is not known whether also the female *S. "Aquatica Gigantea"* was distributed originally by Jensen or someone else.

Possibly *S. "Aquatica Gigantea"* could be a product of a selection mix (i.e. a selection of mixed hybrids) but the more likely explanation is that these willows are merely male and female selections, selected from a natural population (Stott 1981).

How was the name *S. "Aquatica Gigantea"*, or *S. aquatica*, or *S. "Grandis"* invented? What is behind the vernacular and superfluous expressions? Probably "water willow" (in Finnish "vesipaju") was originally grown in wet sites (Tapiro 1965).

The most logical explanation for the names is that of Stott (1981). The selection was

perfected by commercial horticulturalist from a natural population: the best clone was selected for marketing. Naturally the sale had to be boosted with a suitable name, like "Gigantea" or "Grandis". Who is the father or mother of these names is not, however, known – maybe it was Jensen influenced by Nilsson's studies (1935).

S. dasyclados has synonyms in the older willow literature, like *S. stipularis*, *S. acuminata*, *S. longifolia* and *S. serotina* (described by several authors, see Skvortsov 1968). In the earlier days it was also mixed with *S. viminalis* L., or considered sub-species of it like *S. viminalis* var. *nitens* Turcz of *S. viminalis* var. *splendens* (non Turcz.) Lundström. Russian Nasarov (1936) named it as *S. burjatica*.

Is *Salix dasyclados* pure species or a hybrid *S. x dasyclados*? There seems to have prevailed a long-standing confusion in the willow systematics about this matter.

Originally Wimmer (1849) described it as a pure species. But in the early days of willow hybridization studies it was soon described as hybrid (e.g. Kerner 1860, Wichura 1865). The hybrid hypothesis for *S. dasyclados* has since then been slightly dominant:

in favour of of pure species:	in favour of hybrid:
Meikle 1952	Rechinger 1964
Rehder 1967	Chmelar and Meusel 1979
Skvortsov 1968	Bean 1980
	Neumann 1981

For hybrid origin Rechinger (1964) gives *S. caprea x cinerea x viminalis*, Chmelar and Meusel (1979) *S. cinerea x viminalis*, Bean (1980) states "oceanic hybrid" and Neumann (1981) gives *S. caprea x cinerea x viminalis*.

The notable dimensions of *Salix dasyclados* may reflect its position among the other willows. In its natural range it is distinguished by its tree-like growth amidst the remaining vegetation of the valleys, represented by low beds of osier (*S. viminalis*). For a willow, *S. dasyclados* attains remarkable dimensions. For example, in the Pechora basin (Izhma river) *S. dasyclados* trees have been found which attain a height of 20 metres and a trunk diameter of 80–90 cm (Sidorov 1978).

6. Similarities and differences between *S. "Aquatika Gigantea"* and *S. dasyclados*

By morphology *S. "Aquatika Gigantea"* and *S. dasyclados* are very similar. Their bark is yellow-brownish or brownish. The young shoots are densely pubescent, greyish and woolly, subsequently almost glabrous. The leaves are up to 20 cm long, oblong-lanceolate or from lanceolate to obovate lanceolate. The colour of the leaves is dark green and dull above; from beneath slightly pubescent, soft-pubescent and glaucescent, with prominent veins. The catkins are large, staminate up to 4.5 cm, pistillate up to 5.5 cm long. The catkins are developing earlier than leaves.

However, there are clear differences between different *S. "Aquatika Gigantea"* and *S. dasyclados* clones in the field research. The susceptibility to rust (*Melampsora* sp.) and to frost damage clearly varies from clone to clone. Also even if the morphological features of a single individual in a clone named under *S. "Aquatika Gigantea"* and in another individual named under *S. dasyclados* match perfectly each other, there may be differences in the stand, for instance in the colour of the canopy when the two neighbouring stands are looked towards sun, e.g. between clones with Finnish clone numbers *S. "Aquatika Gigantea"* No. V769 and *S. dasyclados* No. V761.

It was Stott (1981) who noticed that there are too large morphological differences in clones from the same species, to be explained with population variation. In Long Ashton Salicetum there is a West European type of *S. x S. dasyclados* (female hybrid), as well as North European type of *S. dasyclados* (which he considered a pure species). They do not appear to enough fit each other. Instead, Stott noticed that the North European type of *S. dasyclados* was much nearer to *S. "Aquatika Gigantea"* clones of Finland and Sweden.

In *S. "Aquatika Gigantea"* and North European *S. dasyclados* the stipules are particularly conspicuous, broad based and withering before falling. The West European hybrid *S. x dasyclados* of Long Ashton does not have notable stipules and the leaves lie in a conspicuous almost two ranked arrangement presented in the same flattened horizontal plane at right angles to the light. Also very short, often pinkish, side shoots are produced by *S. x dasyclados* during the season. Most of these side shoots wither and fall around August. *S. "Aquatika Gigantea"* leaves are not two ranked and it never produces side shoots.

7. Postulation of Stott (1981)

The observations made in the Salicetum of Long Ashton led Stott (1981) to postulate that there are two different biomass willows among the clones of *Aquatika - dasyclados* complex. These willows are nearby each other, they are often mixed, but are of different origin. As a working solution he suggested that a distinction between *Salix x dasyclados* Wimm. (West-European hybrid) and *Salix dasyclados* Skvorts. (North-European species) should be made.

Salix x dasyclados Wimm. should, according

to Stott, denote the vigorous female hybrids *S. x viminalis x caprea x cinerea*, famous basket willow in Western Europe, with 2 ranked leaves, few stipules and side shoots present. It is growing in Long Ashton Research Station Collection in Great Britain as well as in De Pannekoek Collection, in Utrecht in the Netherlands.

Salix dasyclados Skvorts. would denote a pure species from Old Prussia, Brandenburg, Poland, Urals and Siberia. It is a species resembling *Salix viminalis* L., but having wide

and very long leaves, hairy stem and conspicuous persistent stipules. *S. dasyclados* Skvorts. is present in the form of variants – in Finland e.g. as V761 Mikkeli, P6011 Oulu, in Sweden as selections 056, 075. A notably vigorous Danish selection *Salix* "Aquatica Gigantea" would also belong to this species.

Stott's postulation (1981) means that all the Finnish and Swedish willows closely resembling *S. "Aquatica Gigantea"* should be grouped under one scientific name *Salix dasyclados* Skvorts., which is a true species of Siberian and East European origin, but which should not be mixed with a female hybrid of *Salix* x *dasyclados* Wimm. Relander's import of 1950, Duitese Dot No 125 was apparently this Wimmer's hybrid.

Stott's suggestion (1981) fits well with Skvortsov's (1968) note about the essence of the Russian type of *S. dasyclados*. There had been a long discussion in Russia, that this is not a species but a hybrid between *S. viminalis* L. and one of the willows from the section *Capreae*, most probably *S. cinerea*. In fact the shoots and leaves of Russian *S. dasyclados* superficially have a form that seems to be intermediate between *S. viminalis* and *S. cinerea*; in *S. dasyclados* there are generally striations on the wood, a feature that is particularly strikingly expressed in *S. cinerea*.

8. *Salix burjatica* Nasarov

Stott's postulation (1981) was on a right track, since his hypothesis of two different origins was later confirmed by Chmelar (1982). Chmelar based his deduction on chromosome numbers. Neumann and Polatschek (1972) had found out that Wimmer's *S. x dasyclados* is a triploid with chromosome number $2n = 57$, a cross between *S. viminalis* L. ($2n = 38$) and *S. cinerea* L. ($2n = 76$); *S. caprea*, as Stott (1981) had suggested, should be dropped away from its parentage.

On the other hand Chmelar himself had earlier (1979) verified that the chromosome number in the Russian type of *S. dasyclados* is $2n = 76$, i.e. the same as in *S. cinerea*. *S. dasyclados*, as used by Russian authors, would

However, with more attentive examination, Skvortsov found this intermediate position of *S. dasyclados* to be imaginary. Russian *S. dasyclados* grows in good conditions into a tree which reaches a height of 20 metres and trunk diameter of 90 cm; these are indices which are quite unthinkable for the supposed parents. The form the buds and the pubescence of the leaves of *S. dasyclados* does not resemble the *Vetrix* type willows at all. Neither is there anything of *S. cinerea* in the flower of *S. dasyclados*. Referring to these observations Skvortsov concludes that "morphology provides no serious proof on the hybrid nature of *S. dasyclados*".

To provide still more convincing proof of his theory of pure species, Skvortsov refers to the colossal range of *S. dasyclados* in Eurasian nature, with a series of Asian relatives: the Siberian *S. sajanensis* Nasarov (especially close), the Tyan-Shan *S. argyracea* E. Wolf and the Himalayan *S. obscura* Anderss. Throughout its range *S. dasyclados* also occupies a definite place in nature, including completely virgin lands. It has normal reproduction by seeds, with no form of hybrid segregation. All of this, states Skvortsov finally, makes the proposition that *S. dasyclados* is a hybrid or a complex of diverse hybrids, altogether unlikely.

therefore be a pure Eurasian species, which Chmelar (1982) noticed to be unknown in collections; its correct name should be *Salix burjatica* Nasarov (1936).

Later Stott (1984) agreed with Chmelar's deduction. To avoid confusion and ambiguity with the name *dasyclados* he also prefers the species name *Salix burjatica* Nasarov to his earlier suggestion *Salix dasyclados* Skvorts. The name *Salix* x *dasyclados* Wimm. would remain for the West European hybrid.

Interesting, although only academic question is whether Wimmer ever knew or saw at all the Russian type *S. burjatica*, which had been so often misdesignated under his name. Originally Wimmer described (1849) his

species as a true species, but it was suspected to be a hybrid already 1860 by Wichura and 1865 by Kerner. Soon afterwards the name *dasyclados* presented by Wimmer was taken over by Russian willow scientists (Chmelar 1982).

Skvortsov, who for one reason or another still (1968) used the species name *Salix dasyclados* Wimm. for the Eurasian type, notes that it is not possible to answer positively the

question, whether Wimmer's species belonged to their (Russian) species. Therefore, approaching this matter strictly formally, it is possible to rename the Russian species, or stick to Nasarov's definition (1936). But why Skvortsov did not accept Nasarov's name *S. burjatika* is unclear; instead he prefers similar dual solution than that in Stott's postulation (1981).

9. Conclusion

Collection of all Finnish (also Swedish) clones of biomass willows with evident morphological, ecological and cultivational similarities with the original Danish *S. "Aquatica Gigantea"*, under one species, under name *Salix burjatika* Nasarov would clarify the present confusing situation. According to this solution we would be dealing with a normal population, with normal variation as to different characteristics. With the populational variation we can explain why for instance clone P6011 Oulu is more winter hardy than the others, why V769 is more susceptible to rust than the others, and why there are differences in biomass productivity, too.

The name "*Aquatica Gigantea*" or "*Aquatica*" can live, but it must be regarded as a variety name only. The proper marking would be *Salix burjatika* var. *Aquatica* (or var. *Aquatica Gigantea*). But in order to respect Jensen's original selection this variety name should be used for the Danish selection only, for the numbers Denmark No 56, E4856 Ruotsinkylä, 056 (in Sweden). According to the practical definition of variety in modern plant husbandry – variety is the result of plant breeding, released with a special name to commercial market – Jensen's nomination for this selection fulfills the requirements of a variety.

The true *Salix x dasyclados* Wimm., female hybrid of *S. x viminalis x cinerea*, is one of the most famous West-European basket willows. So far, it has apparently been introduced in Finland only by Relander, when she imported in 1950 the two clones, *S. dasyclados* No 63 and *S. dasyclados* Duitse Dot No 125. Especially No 125 would still be worth of further studies.

A close resemblance of the different improperly named willows, has confused the biomass research. The researchers have, however, learned to live with this confusion by stressing the importance of clones and proper clone selection. According to this approach, the proper name of the species is secondary. A properly marked, registered and described good clone is the basic unit for the practical applications. Such approach will no doubt lead into commercial varieties which after all is the ultimate aim in biomass willow breeding.

But without knowing the background of different clones in the systematics, the breeding works unefficiently and at random. Many of the possible, potentially promising hybrids which might come into the mind of the breeder, might have already been produced by the nature herself. Proper understanding of systematics would make the clone and hybrid elimination programmes quicker.

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Total of 62 references

Seloste

Vesipaju (Salix "Aquatice Gigantea") ja vannepaju (Salix x dasyclados) energiapajututkimuksissa

Vesipaju, *Salix "Aquatice Gigantea"*, on eniten kokeiltu energiapaju. Pääosa sen nykyisistä kloneista on peräisin Tanskasta, viljelijältä nimeltään Jensen, joka myi vesipajun pistokkaita 1940-luvun lopulta lähtien. Suomeen ensimmäiset vesipajun pistokkaat toi vuonna 1950 koripajukokeisiin Eeva Tapio (o.s. Relander). Pistokkaat viljeltiin Maatalouden tutkimuskeskuksen koasemille, mistä niitä on levitetty koristeistutuksiin ja myöhemmin 1970- ja 1980-luvulla lyhytkiertoviljelyn ja energiaviljelyn kokeisiin.

Vesipajun pistokkaita tuotiin varhain myös Metsäntutkimuslaitokseen: R. Erik Serlachiuksen ehdotuksesta Tanskasta ostettiin 5000 kappaletta pajun *Salix "Aquatice No 56"* pistokkaita, jotka viljeltiin Ruotsinkylään,

Lapinjärvelle ja Punkaharjulle. Varsinkin Ruotsinkylän viljely oli onnistunut; pistokkaita sieltäkin on levitetty runsaasti eri tutkimuksiin, viimeksi klooninumerolla E4856.

1960-luvulla Metsäntutkimuslaitokseen tuotiin kaksi uutta vesipajukloonaa. Unkarista saatiin klooni numeroltaan H-YU 3178; Unkariin klooni oli kulkeutunut Jugoslaviasta, Nova Sadin jalostusasemalta. Unkarista tuotiin myös toinen klooni, H-D 3154 (alunperin Itä-Saksasta). Muista aikaisemmin ja myöhemmin tuoduista ja viljeltyistä vesipajuista poiketen H-D 3154 on emiklooni.

PERA-projektin (Puu energiaraaka-aineena) kenttäkokeisiin tuotettiin Tanskasta, Jensenin viljelmiltä keväällä 1980 vesipajun pistokkaita lisää 100 000 kpl. PERA-

projektin kloonikeräyksessä inventoitiin myös kaikki muut maassamme kasvavat vesipajuviljelmät. Kaiken kaikkiaan vesipaju todettiin viljellyksi omalla numerolla maassamme ainakin 23 kertaa (taulukko 1).

Salix x dasyclados Wimm., Suomessa vannepajuksi kutsuttu, on vesipajun ohella menestynyt hyvin energiapajukokeissa. Vannepaju oli suosittu koripajuna jo 1900-luvun alussa; tämän totesivat mm. Cajander 1917 ja Nordberg 1928. Ensimmäisen kerran vannepajun toi maahamme (nimellä *Salix dasyclados*) kuitenkin vasta Tapio vuonna 1950. Kaksi kloonina: No 63 ja Duitse Dot No 125 viljeltiin vesipajun ohella koripajukokeisiin.

Vannepajun nimellä kulkevia kloonieja on levinnyt koristepajuna maassamme etelärannikolta Oulun korkeudelle asti; sieltä löydettiin kolme kloonina SITRAN kokeisiin vuonna 1976. PERA-projektissa inventoitiin myös maamme vannepajuesiintymät. Se todettiin viljelyn omalla numerolla ainakin 16 kertaa (taulukko 2).

Toisiaan paljon muistuttavien vesipajun ja vannepajun lajitausta on ollut hyvin sekava. Etenkään vesipajua ei ole kyetty suomalaisissa tai ruotsalaisissa energia- ja biomassatutkimuksissa määrittämään. Sitä on pidetty yleisimmin hybridinä, joka monistettiin sekakasvustosta valitusta yksilöstä. Kaikki vesipajut eivät kuitenkaan ole yhtä ainoaa kloonina, koska sekä hede- että emikloonit tunnetaan. Hybriditeorian mukaan vesipajun kantalajeiksi on ehdotettu mm. *S. viminalis* L., *S. caprea* L., *S. cinerea* L., *S. daphnoides* Vill. ja *S. triandra* L.

Myös käsitykset vannepajusta ovat vaihdelleet. Alunperin (1849) Wimmer kuvasi sen omana lajinaan, mutta jo varhain sitä alettiin epäillä hybridiksi, joko harmaapajun ja koripajun risteymäksi *S. cinerea* x *viminalis* tai kolmoishybridiksi *S. x caprea* x *cinerea* x *viminalis*. Vesi- ja vannepajulle ehdotetut kantalajit kuuluvat siis samaan joukkoon.

Vuonna 1981 Stott huomasi Long Ashtonin pajukokelmassa Englannissa, että vaikka hänen keräämänsä ja

viljelemänsä vesi- ja vannepajukloonit muistuttavat huomattavan selvästi toisiaan, ne voidaan jakaa morfologisten ominaisuuksien perusteella kahteen ryhmään. Länsi-eurooppalaisen ryhmän kloonit (kaikki emikloonieja) Stott oletti kuuluvan alkuperäiseen Wimmerin hybridiin: *S. x dasyclados* Wimm. Tämä hybridi on Länsi-Euroopan maineikkaimpia koripajuja. Kaikki itä-eurooppalaisen ryhmän kloonit (sekä hede- että emikloonieja) Stott oletti sen sijaan kuuluvan puhtaaseen lajiin jonka hän ehdotti nimettäväksi venäläisen Skvortsovin mukaan: *S. dasyclados* Skvorts. Jensenin alkuperäinen vesipajukloonin No 56, kuten myös lähes kaikki muut suomalaiset vesi- ja vannepajun nimellä kulkevat kloonit (esim. E4856 Lieto) kuuluivat Stottin mukaan tähän itä-eurooppalaiseen lajiin.

Stottin esittämä teoria sai tukea jo vuonna 1982, kun Chmelar totesi omiinsa ja muiden suorittamiin kromosomitutkimuksiin perustuen että läntinen ja itäinen ryhmä voidaan todella erottaa. Läntinen hybridi *Salix x dasyclados* Wimm. on triploidi, jonka kromosomiluku on $2n = 57$. Mitä ilmeisemmin se on koripajun ($2n = 38$) ja harmaapajun (kromosomiluku $2n = 76$) välinen risteymä *S. x viminalis* x *cinerea*. Tätä hybridiä eivät liene Suomessa kokeilleet muut kuin Relander, kun hän toi vuonna 1950 maahan kloonit *S. dasyclados* No 63 and *S. dasyclados* Duitse Dot No 125.

Itä-eurooppalaisen lajin kromosomiluku on $2n = 76$. Välttääksemme nimisekaannuksen hybridipajun *Salix x dasyclados* Wimm. kanssa itä-eurooppalaista lajia tulisi kutsua nimellä *Salix burjatica* Nasarov, venäläisen Nasarovin mukaan joka kuvasi sen vuonna 1936.

Jos lajike määritellään nimen saaneeksi, kaupallisesti levitetyn valinnan tai jalostustyön lopputulokseksi, tanskalaista hedekloonina "Aquatica Gigantea" tai "Aquatice No 56" voi pitää pajulajikkeena, jonka Jensen valitsi itä-eurooppalaisen pajulajin *Salix burjatica* Nasarov kasvustosta.