

# Morphobiological characteristics and evaluation of productivity of *Salix* L. clones selected for short-rotation coppice

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Some morphobiological characteristics and productivity of ten selected *Salix* L. clones were studied in field collections during a five-year period of growth. The growth intensity of bushes, the number of sprouts per bush, their average length and diameter, peculiarities of slenderness of sprouts and their productivity were evaluated using the rotation of one-year-old sprouts.

*S. purpurea* L. × *S. viminalis* L. 9607, *S. integra* Thunb. × *S. kochiana* Trautv. 9606 hybrids and *S. viminalis* L. 'Americana' 9604, *S. viminalis* L. 9875, *S. purpurea* L. 'Rubra' 9649 clones had the most intensively growing sprouts.

*S. purpurea* L. 'Gracilis' (2354 thous. specimens per ha), *S. purpurea* L. 'Rubra' (1197 thous. specimens per ha) and *S. purpurea* L. × *S. viminalis* L. hybrid (991 thous. specimens per ha) produced the biggest number of twigs. The immunity to diseases and pests of the studied taxa, hybrids and their clones is discussed.

**Key words:** *Salix* L., clonal selection, morphobiological characteristics, short rotation, production of sprouts

## INTRODUCTION

The fast-growing crops of trees and bushes that are used for green stock have become widely recognized in the world practice. Willows are the most important bushes among leafy trees and bushes as they produce the biggest amount of biomass during the shortest period of time. Bioenergetic woody plants of short rotation are very important nowadays [1, 2]. Such plants are called the systems of ultrashort rotation or even the systems of wood grass in the literature [3]. Industrially produced sprouts of shortly rotated willows have deep traditions [4, 5]. According to the literature [6], *Salix triandra* L., *S. viminalis* L. and *S. purpurea* L. are traditional species used for production. Anyway, such assortment does not meet the requirements of the contemporary business.

A rich assortment of clones of willow taxa used for the production of industrial twigs was created in Lithuania. It was done with the help of clonal selection from native, introduced and adapted species of willows.

## MATERIALS AND METHODS

The research was carried out in 1996–2001. Clonal selection of promising short-rotated taxa of willows was done in natural habitats of Lithuanian flora according to the established criteria [7]. The introduced *Salix* L. species and their clones were grown and studied in the fields of the joint stock company "Pilvitis" (Dakiai district, Noreikupis environs).

The selected clones were planted in the collection of willows of the joint stock company "Vilda" (Alytus district, Miroslavas environs) in 1996. The collection was established on turfy sandy loam soil. The content of microelements and macroelements in the soil (mg/kg) was as follows: N-NO<sub>3</sub> 15,9, K<sub>2</sub>O 86, P<sub>2</sub>O<sub>5</sub> 85, Ca 1377, Mg 250, Fe 440, Zn 1.5, Mn 40, B 0,6, and Cu 1.1. The soil acidity (pH) was 6.2. The plants were planted in rows. The distance between rows was 70 cm, and the distance between plants was 25 cm.

The length of the planted cuttings was 25 cm. The field was fertilized with potassium and phosphorus in autumn, while nitrogen was applied in

spring (the active substances were  $N_{50}$ ,  $K_{80}$  and  $P_{60}$  (kg/ha)). The morphological and biological characteristics of bushes and the productivity of their sprouts were studied with the help of standard techniques [8]. The growth rate of bushes (evaluated as the height of sprouts at the end of vegetation), the number of sprouts per bush, their length, diameter and slenderness, and the output of twigs per hectare are the main morphological characteristics defining the productivity of shortly rotated clones of *Salix* L. taxa. These characteristics of selected clones are determined by genetic peculiarities. The analysis of data of ten clones of *Salix* L. taxa obtained during five years shows that their morphobiological characteristics, quality and productivity are different.

The obtained results were analysed using statistical methods [9]. The standard error of the mean, statistical significance and the coefficient of variation were calculated.

## RESULTS AND DISCUSSION

### 1. Biological diversity, provenance and morphological characteristics of clones of *Salix* L. taxa obtained by clonal selection

The *Salix purpurea* L. 9626 clone was discovered in the regional park of the Nemunas delta. One-year-old stems grow intensively, they are straight and elastic. The clone is insufficiently resistant to the gall makers *Pontania vesicator* (Bremi) (Hymenoptera, Tenthredinidae) and *Dasineura salicis* (Schrank) (Diptera, Cecidomyiidae).

The *S. purpurea* L. 'Lutea' 9631 clone was chosen from the industrial plantations of the joint stock company "Pilvitis". Its sprouts have a vivid yellow bark and its twigs are straight and elastic. The clone is resistant to diseases and pests.

The *S. purpurea* L. 'Rubra' 9649 clone was selected from the commercial plantations of the joint stock company "Pilvitis". The sprouts of the clone have a pink bark and their number is numerous in a bush. The twigs are of high quality. The clone is resistant to diseases and pests.

The *S. purpurea* L. 'Gracilis' 9611 clone was chosen from the industrial plantations of the joint stock company "Pilvitis" in Seređpius environs (Jurbarkas district). The clone has short leaves (4–6 cm in length), and this is the main difference from the typical *S. purpurea*. The clone has very numerous sprouts per bush in comparison to other *S. purpurea* taxa and their clones. The lowest height is 180–200 cm. The clone is not resistant to insect pests, especially to the leaf miner *Phyllocnistis saligna* (Z.) (Lepidoptera, Gracillariidae) and the gall makers *Pontania vesicator* (Bremi) (Hymenoptera, Tenthredinidae) and *Dasineura salicis* (Schrank) (Diptera, Cecidomyiidae) [10, 11].

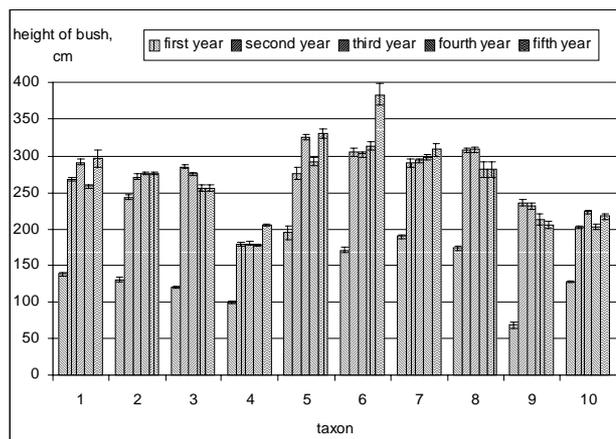
The *S. viminalis* L. 9875 clone was found in an osier-bed close to the Nemunas (Šakiai district). It has a very high bush (up to 330 cm) and long sprouts (up to 243 cm). The diameter of its twigs is larger (up to 1.1 cm) in comparison to the *S. purpurea* clones. The clone is sufficiently resistant to diseases and pests, but it could be attacked by the caterpillars of *Earias chlorana* (L.) (Lepidoptera, Noctuidae) [10, 11].

The *S. purpurea* L. × *S. viminalis* L. 9607 natural hybrid is common in native Lithuanian flora. The clone was chosen in Priekulė in the valley of the Minija river (Klaipėda district). The clone of the hybrid is viable and grows very intensively. Its bushes are higher and their twigs are longer in comparison to *S. purpurea*. The output of twigs is higher in comparison to *S. viminalis* L. The clone is sufficiently resistant to diseases and pests [10].

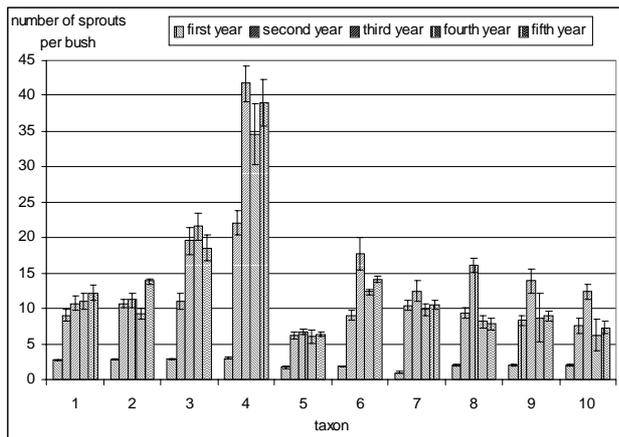
The *S. viminalis* L. 'Americana' 9604 clone was chosen from the industrial plantations of the joint stock company "Pilvitis". It is characterized by an intensive growth. The clone produces more twigs per bush in comparison to *S. viminalis*, so the output exceeds the typical species. It is more resistant to diseases and pests than *S. viminalis* [10].

The *S. integra* Thunb. × *S. kochiana* Trautv. 9606 hybrid was introduced to Lithuania from Russia in 1989. The clone was chosen from the joint stock company "Pilvitis" collections in 1996. Its growth is rather intensive. The quality of twigs is good, the wood is white and splendid. The clone is more resistant to diseases and pests than *S. purpurea*.

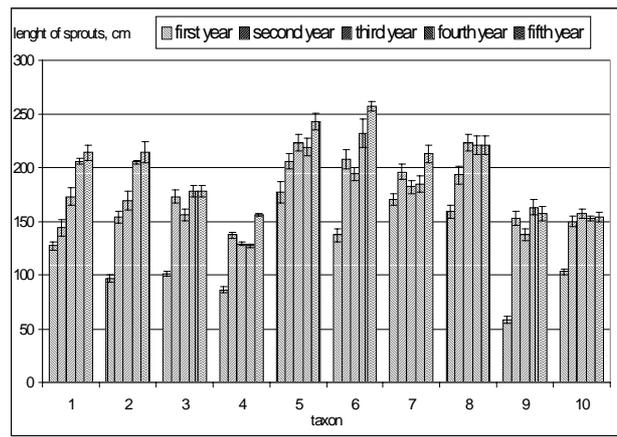
The *S. alba* L. ssp. *coerulea* 9636 clone was chosen from the valley of the Neris river close to the Verkiai osier-bed. It has a characteristic yellow bark. The clo-



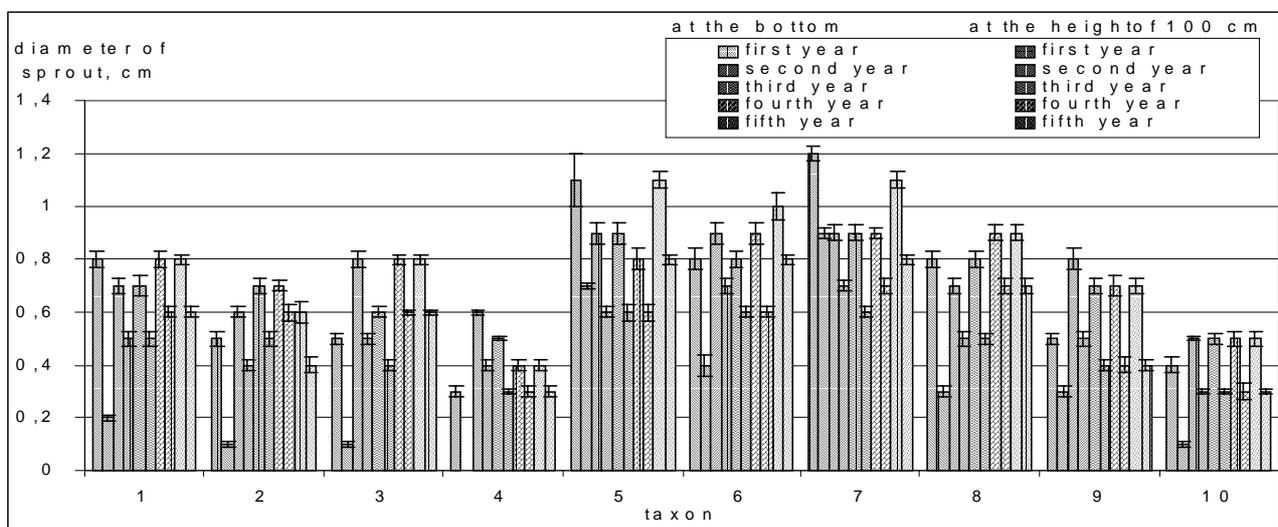
**Fig. 1.** Bush height variability of *Salix* L. clones during five years of growth: 1 – *S. purpurea* 9626; 2 – *S. purpurea* L. 'Lutea' 9631; 3 – *S. purpurea* L. 'Rubra' 6949; 4 – *S. purpurea* L. 'Gracilis' 9611; 5 – *S. viminalis* L. 9875; 6 – *S. purpurea* L. × *S. viminalis* L. 9607; 7 – *S. viminalis* L. 'Americana' 9604; 8 – *S. integra* Thunb. × *S. kochiana* Trautv. 9606; 9 – *S. alba* L. ssp. *coerulea* 9636; 10 – *S. ledebouriana* Trautv. 9643



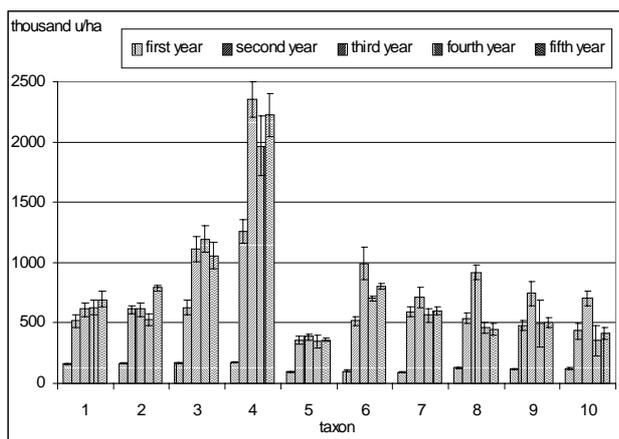
**Fig. 2.** Variation of the number of sprouts per bush of *Salix* L. clones. For explanation, see Fig. 1



**Fig. 3.** The average length of sprouts of *Salix* L. clones during five years of growth. For explanation, see Fig. 1



**Fig. 4.** Slendering of sprouts of *Salix* L. clones during five years of growth. For explanation, see Fig. 1



**Fig. 5.** Number of sprouts (thousand/ha) of *Salix* L. clones during five years of growth. For the explanation, see Fig. 1

ne is good for wicker-works; it has a characteristic colour and its twigs with bark are used for weaving.

The *S. ledebouriana* Trautv. 9643 clone was introduced to Lithuania from Russia in 1982. The clone was chosen from the collections of the joint stock

company “Pilvitis” in 1996. It has thin (up to 0.5 cm in diameter) and sufficiently long twigs, so it is suitable for subtle weavings. The clone is insufficiently resistant to gall makers.

**2. Morphological characteristics and productivity evaluation of clones.** The collection of short rotated clones of *Salix* L. taxa was established in April 1997. All selected clones are characterized by a very active rhizogenesis. In spite of a different rate of growth, the naturalization of sprouts reached 100 percent. Twigs of willows that are used for wicker-works industry should be rotated during one year (rarely during two years if it is necessary to get a frame material for stick furniture). Sprouts of willows are usually cut after the end of growth. The quality and the output of the material are evaluated.

The results show that all the taxa studied and their clones have some uniform peculiarities (Fig. 1). The height of bushes becomes different and fluctuates from 69 cm (*S. alba* L. ssp. *coerulea* 9636) to 195 cm (*S. viminalis* L. 9875) during the first year of growth. The growth of bushes is influenced by different acti-

ity of rhizogenesis of different species. Willows belonging to the Vimen Dum. section have the highest bushes. The majority of clones reach their typical height in the second year of growth, while some clones become highest after five years of growth. *S. purpurea* L. × *viminalis* L. 9607 (384 cm) and *S. viminalis* L. 9875 (330 cm) were the highest clones in the collection. Three clones belonging to Purpureae A. Skvorts. section were lower, while *S. purpurea* L. 'Gracilis' 9611 was the lowest one (150–205 cm in height).

The taxa studied and their clones produced different numbers of sprouts per bush (Fig. 2). This biological characteristic is very important from the practical point of view. It influences the output of twigs directly. *S. purpurea* L. 'Gracilis' 9611 and *S. purpurea* L. 'Rubra' 9649 clones had the biggest number of sprouts per bush. The average number of sprouts per bush reached up to 41.7 and 21.5, respectively, after three years of growth. The number of sprouts per bush increased during the second year of growth, while some taxa produced the biggest number during the third year of growth. Such results are influenced by favourable meteorological conditions as well.

The length and diameter of sprouts of the clones studied were different. These characteristics are very important as they show the category of commercial twigs. The longest twigs are the most valuable, so the clones were compared according to the average length, their diameter and slendering. The number of short sprouts becomes smaller when the root system of bushes becomes stronger, so older bushes produce longer sprouts (Fig. 3).

The studied clones could be grouped into three groups according to the average diameter of sprouts (Fig. 4): 1) the thickest sprouts are characteristic of willows belonging to Vimen Dum. section (*S. viminalis* L. 9875, *S. viminalis* L. 'Americana' 9604, *S. purpurea* L. × *S. viminalis* L. 9607 and *S. integra* Thunb. × *S. kochiana* Trautv. 9606); 2) taxa belonging to Purpureae A. Skvorts. section (*Salix purpurea* L. 9626, *S. purpurea* L. 'Lutea' 9631, *S. purpurea* L. 'Rubra' 9649 and *S. alba* L. ssp. *coerulea* 9636) have medium sprouts; 3) *S. purpurea* L. 'Gracilis' 9611 and *S. ledebouriana* Trautv. 9643 have the thinnest sprouts. The biggest slendering of sprouts was determined during the first year of growth. This characteristic varied starting from the second year of growth and depended on the biological and genetic peculiarities of clones.

The output of twigs per hectare is the main commercial characteristic of the productivity of clones. The output of twigs is very small during one year of growth. It depends on the taxon and varies from 91.0 thous. ha (*S. viminalis* L. 'Americana' 9607) to 171.0 thous. ha (*S. purpurea* L. 'Gracilis' 9611) (Fig. 5). The output of twigs increases greatly during the second year of growth and produces a valuable material for industry. The productivity of some taxa and their clones increased during the third year of growth and

reached the maximum output. That could be explained by very favourable meteorological conditions. The results show that *S. purpurea* L. 'Gracilis' 6949 is one of the most productive clone (Fig. 5). The maximum output of twigs was 2354 thous. of specimens/ha during a five-year period. *S. purpurea* L. 'Rubra' 9649 produced 1197, *S. purpurea* L. × *S. viminalis* L. 9607 – 991.8 thous. specimens/ha. The selected clones were more productive than populations of clones grown in the plantations of the joint stock company "Pilvitis" [12]. The output of *S. purpurea* L. was 719.4, *S. purpurea* L. × *S. viminalis* L. – 656, and *S. integra* Thunb. × *S. kochiana* Trautv. – 746.6 specimens/ha.

## CONCLUSIONS

1. Ten selected clones of *Salix* L. taxa have a different intensity of growth of bushes, the number of sprouts per bush, characteristic morphobiological peculiarities and productivity.

2. *S. purpurea* L. × *S. viminalis* L. 9607, *S. viminalis* L. 9875 and *S. integra* Thunb. × *S. kochiana* Trautv. 9606 clones are the most intensively growing bushes and have the longest sprouts.

3. Some clones are characterized by the biggest number of sprouts per bush and are most productive: *S. purpurea* L. 'Gracilis' 9611 (41.7 spec. per bush and 2354 thousand spec. per hectare), *S. purpurea* L. 'Rubra' – 21.5 and 1197 spec., respectively, *S. purpurea* L. × *S. viminalis* L. 9607 – 17.7 and 991 thousand per hectare during five years of growth.

4. The output of twigs is the highest during the second and the third years of growth in a rotated culture. It varies during the fourth and fifth years and depends on the taxon and clone. Meanwhile, the productivity is high during the fifth year of growth.

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#### TRUMPOS APYVARTOS ÞELDINIAMS SELEKCIONUOTŲ *SALIX* L. KLONŲ MORFOBIOLOGINĖS SAVYBĖS IR PRODUKTYVUMAS

##### Santrauka

Tyrimai atlikti 1996–2001 m. AB „Vilda“ gluosnių kolekcijose (Alytaus r. Mirosłavo apyl.).

Taikant vienerių metų atpalinėjusių ūglių (vytelių) apyvartos rotaciją nustatytas krūmų augimo intensyvumas, išauginamų atpalinėjusių ūglių kiekis krūme, jų vidutinis ilgis ir skersmuo, išauginamų vytelio nulaibėjimo pobūdis ir produktyvumas. Nustatyta, kad selekcionuoti ir tirti 1–5-aisiais auginimo metais dešimties *Salix* L. taksonų klonai skiriasi krūmų augimo intensyvumu, išauginamų krūme atpalinėjusių ūglių kiekiu, jų morfologiniais rodikliais ir produktyvumu. Intensyviausiu krūmų augimu išsiskyrė bei ilgiausias vyteles išaugino *S. purpurea* × *S. viminalis* 9607, *S. viminalis* 9875 ir klonai, taip pat *S. integra* Thunb. × *S. kochiana* Trautv. 9606 hibridas. Daugiausiai atpalinėjusių ūglių krūme išaugino ir didžiausia vytelio ideoiga (tūkst. vnt./ha) pasiūymėjo taksonai *S. purpurea* L. ‘Gracilis’ 9611 – 41,7 ir 2354, *S. purpurea* L. ‘Rubra’ – 21,5 ir 1197, *S. purpurea* L. × *S. viminalis* L. 9607 – 17,7 ir 991 atitinkamai.

Taikant vienerių metų apyvartos rotaciją vytelio ideoiga ryškiausiai padidėjo antraisiais ir trečiaisiais auginimo metais. 4–5-aisiais auginimo metais ji varijuoja priklausomai nuo taksono ir jo klono, tačiau ir penktaisiais išlaiko aukštą produktyvumą.