

Evaluation of morphobiological, biomass and energetic characteristics of *Salix viminalis* L. and *S. dasyclados* Wimm. genotypes in short rotation plantations

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Three *Salix viminalis* and four *S. dasyclados* genotypes were studied in 2004–2007. The intensity of bush growth, the number of sprouts per bush, their slenderness and the dynamics of biomass production were evaluated. The analysis of data showed that the height of bushes differed every year. The highest bushes reached up to 578 cm (*S. viminalis* ‘Tora’) and 504 cm (*S. dasyclados* 9977) in height after four years of growth. There was a tendency of change of the number of sprouts per bush: the maximum number was reached during the second year of growth, while it decreased during the third and the fourth years. The thickest stems were characteristic of *S. dasyclados* (4.1 cm) and *S. dasyclados* × *S. viminalis* 04120 (3.5 cm) genotypes. The height of bushes, stem number per bush and slenderness correlate with the accumulated biomass. The biggest energetic value of biofuel was characteristic of *Salix dasyclados* 04122 (18.72 MJ/kg), *S. viminalis* ‘Tora’ (18.41 MJ/kg) and *S. dasyclados* 04123 (18.16 MJ/kg). The lowest calorific value was characteristic of the hybrid *S. dasyclados* × *S. viminalis* 04120. The obtained data show that *S. dasyclados* clones 04122 and 9977, *S. dasyclados* × *S. viminalis* 04120, and *S. viminalis* ‘Americana’ 9976 are the most valuable biomass producers.

Key words: *Salix*, clonal selection, morphology, biomass, short rotation, bioenergy

INTRODUCTION

Willow (*Salix* L.) species and their genetic potential are very important producers of biomass for energetic purposes. Some species belonging to Vimen Dum. section (*S. viminalis* L. and *S. dasyclados* Wimm.) can grow very fast and accumulate large amounts of biomass during a short period of time. Perspective willow genotypes are studied in many countries in order to find and evaluate the most perspective clones accumulating the biggest amount of biomass in short rotation plantations [1, 2]. Biomass productivity is mainly evaluated at the end of vegetation of two, three, and four years of growth cycles of willows [3, 4]. Anyway, there is a lack of data on the morphobiological characteristics and accumulation dynamics of biomass during separate cycles of growth.

The aim of this work was to study the morphobiological characteristics and peculiarities of biomass accumulation and their dynamics during a four-year cycle of selected *S. viminalis* and *S. dasyclados* genotypes and the evaluation of the energetic value of dry biomass.

MATERIALS AND METHODS

A research of the local *S. viminalis* clone 04116, cultural *S. viminalis* ‘Americana’ clone 9976 and ‘Tora’ (selected in Sweden,

supplier joint-stock company “Jūsų sodai”), three local clones of *S. dasyclados* (04122, 04123, and 9977) and *S. dasyclados* × *S. viminalis* hybrid’s clone 04120 was carried out in 2004–2007. The studies were carried out in the field collections and short rotation plantations of the joint-stock company “Vilda” (Alytus administrative district). The content of microelements and macroelements in the soil (mg/kg) was as follows: N-NO₃ – 15.9, K₂O – 86, P₂O₅ – 85, Ca – 1377, Mg – 250, Fe – 440, Zn – 1.5, Mn – 40, B – 0.6, and Cu – 1.1. The acidity (pH) of the soil was 6.2. Bushes were planted in rows in the field collection. The distance between rows was 70 cm and the distance between plants was 50 cm. The collection was established in turfy sandy loam soil.

The field was fertilized with potassium and phosphorus in autumn, while nitrogen was used in spring (the active substances were N₅₀, K₈₀ and P₆₀ (kg/ha)).

The dendrometric characteristics and biomass productivity of wood were evaluated at the end of vegetation or according to the cycles of usage after the cutting of bushes every year by standard techniques [5]. The obtained results were analysed using statistical methods [6].

Evaluation of the energetic characteristics of wood of short rotation was carried out according to the valid European standards accepted in Lithuania. The humidity of biomass was measured according to the standard CEN/TS 14774. The gross calorific value $q_{p,gr,d}$ of dry biomass was evaluated according to the standard CEN/TS 14918 [7]. A C4000 adiabatic calorimeter (produced by IKA) was used.

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The bottom calorific value $q_{p,net,d}$ of dry fuel weight was used to compare the hard fuel. The bottom calorific value with some amount of humidity $q_{p,net,m}^w$ was evaluated for the practical purposes. Calculations were carried out according to the following formulas [8, 9]:

$$q_{p,net,d} = q_{p,gr,d} - 2441 \cdot \left(\frac{9 \cdot H_2}{100} \right), \text{kJ/kg},$$

$$q_{p,net,m}^w = \frac{q_{p,net,d} \cdot (100 - W) - 2441 \cdot W}{100}, \text{kJ/kg},$$

where 2441 is water evaporation heat at 25 °C, kJ/kg, $H_2 = 6.2$ (%) amount of hydrogen in dry biomass, W is the content of humidity of biomass, % (calculated for the fuel with the humidity of 40%).

RESULTS AND DISCUSSION

Salix viminalis is a widespread polymorphic species having a rich genetic potential in Lithuania [10]. *S. dasyclados* is a local species growing in valleys of big Lithuanian rivers. The genetic diversity of the latter species is poorly studied. Anyway, it has become one of the most perspective species in short rotation plantations.

The perspective of willow genotypes in short rotation plantations is mainly characterized by their biomass and calorific value. The productivity of biomass depends on many factors, such as the intensity of bush growth, the number of sprouts per bush, the slenderness and productivity of sprouts. The analysis of these morphobiological parameters is used in evaluating the productivity of willows as energetic biomass producers.

The growth intensity of bushes is a characteristic showing the viability of a genotype. The height of bushes in all the genotypes studied increased unevenly during the four years of growth (Fig. 1). The bushes grew intensively during the first year. *S. dasyclados* 9977 and *S. viminalis* 'Tora' developed the highest bushes (248 cm and 247 cm, respectively). The height of *S. viminalis* 'Tora' increased by 142 cm during the second year of growth and reached 390 cm in total, and *S. dasyclados* 04122–164 cm and 312 cm, respectively.

S. viminalis 'Tora' grew up most intensively during the third year (the increase of bushes was 140 cm per year; the total height reached 530 cm). *S. dasyclados* × *S. viminalis* 04120 increased by

103 cm and reached the height of 300 cm. According to a literary source [11], *S. viminalis* reaches 254–297 cm and *S. dasyclados* 239–273 cm after two years of growth. These clones reached 401–515 cm and 316–420 cm in height, respectively, during three years of growth. Our data showed that the genotypes studied grew up more intensively. The increase of the height of bushes was the slowest during the fourth year of growth. It varied from 23 cm (*S. dasyclados* 04123) to 97 cm (*S. viminalis* 'Americana'). The highest bushes reached up to 578 cm (*S. viminalis* 'Tora') and 504 cm (*S. dasyclados* 9977) in height after four years of growth.

The number of sprouts per bush is a biological characteristic influencing the accumulated biomass. *S. viminalis* and *S. dasyclados* bushes developed 1–3 sprouts per bush during the first year of growth (Fig. 2). Almost all genotypes (except *S. viminalis* 04116) produced the maximum number of sprouts (*S. dasyclados* 04122 – 11.7) during the second year of growth. The number of sprouts of all *S. dasyclados* clones decreased by 2–3 sprouts per bush during the third year (*S. viminalis* 'Tora' showed an obvious decrease to 2.9). Fungal diseases could cause a decrease of the sprouts. A slight increase of sprouts was characteristic only of the *S. viminalis* 04116 clone. Sprouts decreased in all the genotypes during the fourth year of growth, especially among *S. dasyclados* clones. The data showed the following tendencies of change of sprout number per bush: the maximum number is reached during the second year of growth, while it decreases during the third and the fourth years, with a conspicuous decrease during the fourth year.

Literature [12] and our data show that the height of sprouts, their number and slenderness correlate with biomass capacity. The diameter of stems of *S. dasyclados* genotypes varied from 1.0 cm to 1.4 cm during the first and the second years of growth (Fig. 3). The diameter of stems increased during the third year to 2.5 cm (*S. dasyclados* 9977). Its maximum was reached during the fourth year of growth. The thickest stems were produced by *S. dasyclados* 04122 (4.1 cm) and *S. dasyclados* × *S. viminalis* 04120 (3.5 cm).

Biomass accumulation is one of the most important parameters showing the perspectiveness of races and clones. *S. viminalis* genotypes accumulated more biomass than *S. dasyclados* during the first year of growth (Fig. 4).

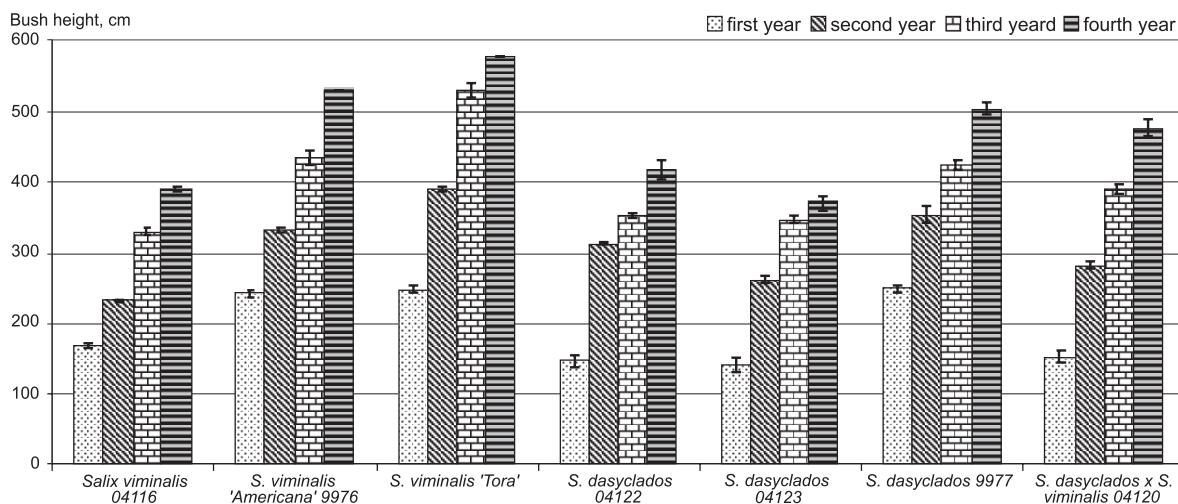


Fig. 1. Evaluation of growth intensity of some races and clones of *Salix viminalis* L. and *S. dasyclados* Wimm. in energetic plantations during four years of growth

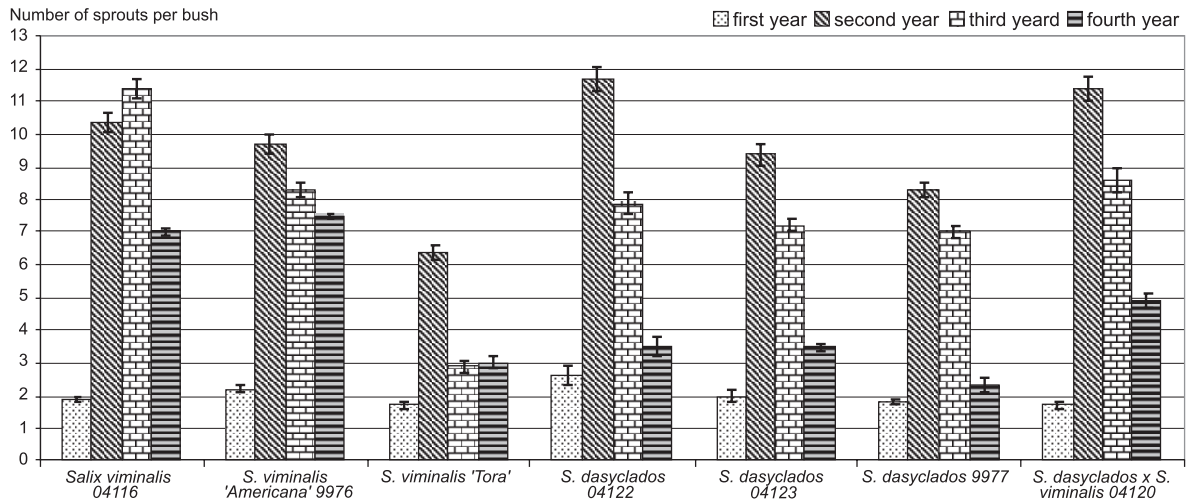


Fig. 2. Mean number of sprouts per bush of some races and clones of *Salix viminalis* L. and *S. dasyclados* Wimm. in energetic plantations during four years of growth

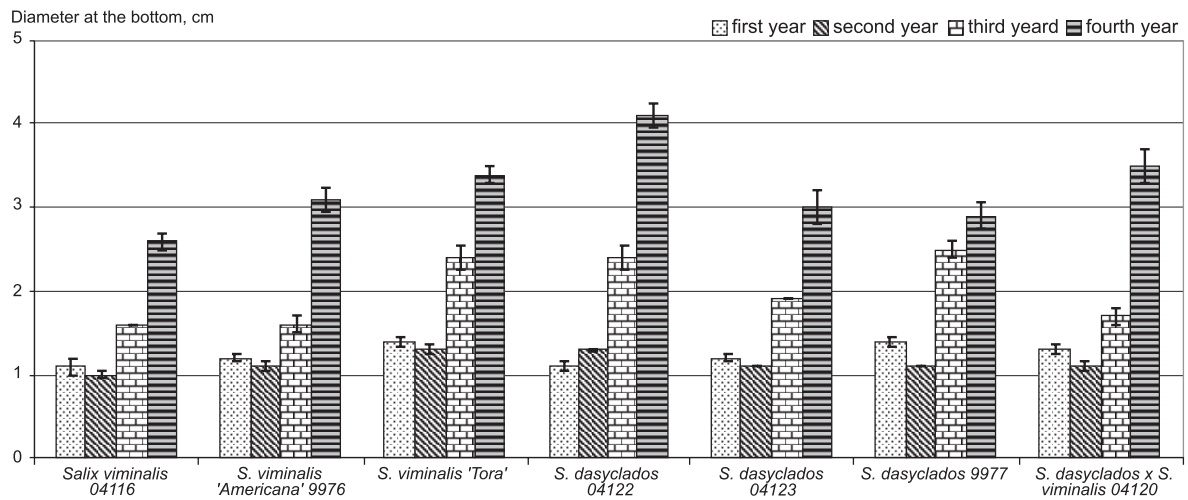


Fig. 3. Slendering of sprouts of some races and clones of *Salix viminalis* L. and *S. dasyclados* Wimm. in energetic plantations during four years of growth

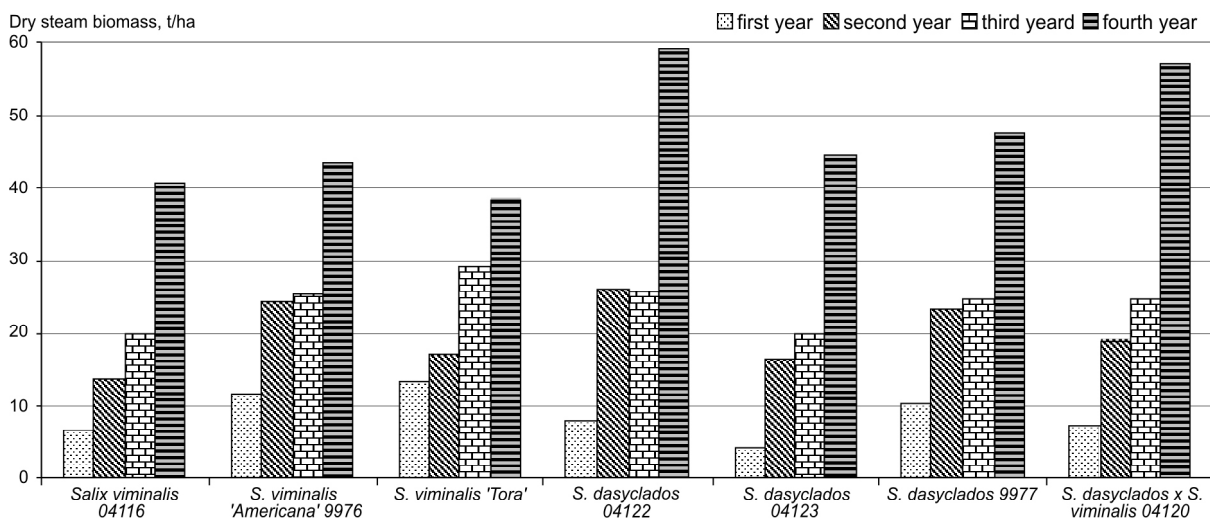


Fig. 4. Evaluation of biomass accumulation of some races and clones of *Salix viminalis* L. and *S. dasyclados* Wimm. in energetic plantations during four years of growth

Table. Evaluation of energetic characteristics (hard fuel) of some races and clones of *Salix viminalis* L. and *S. dasyclados* Wimm. in short rotation plantations

Species, race and number of a clone	Ash-content of absolutely dry biomass, %	Gross calorific value at constant volume, q p,gr,d MJ/kg	Net calorific value at constant pressure, q p, net, d MJ/kg	Net calorific value of biofuel (humidity 40%), q p,net,m MJ/kg
<i>Salix viminalis</i> 04116	0.73	19.13	17.77	9.68
<i>S. viminalis</i> 'Americana' 9976	0.85	19.47	18.11	9.89
<i>S. viminalis</i> 'Tora'	0.85	19.78	18.41	10.07
<i>S. dasyclados</i> 04122	0.96	20.08	18.72	10.26
<i>S. dasyclados</i> 04123	1.06	19.52	18.16	9.92
<i>S. dasyclados</i> 9977	0.80	19.01	17.65	9.61
<i>S. dasyclados</i> × <i>S. viminalis</i> 04120	0.79	18.95	17.59	9.58

S. dasyclados 04122 and *S. viminalis* 'Americana' produced the biggest amount of biomass (26.1 t/ha and 24.4 t/ha, respectively). The increase of biomass was small during the third year. It was influenced by unfavourable meteorological conditions (precipitation was low during March and June; in July – 9.6 mm only). The increase of biomass of *S. dasyclados* clones was obvious after four years of growth (reaching up to 44.4–59.1 t/ha). The amount of biomass of *S. viminalis* races and clones was 38.5–43.5 t/ha of dry matter after the a four-year cycle. *S. viminalis* 'Tora' biomass decreased due to the damaged or dead sprouts. According to the literature data [4], *S. viminalis* and *S. dasyclados* genotypes accumulate 24.6 to 38.1 t/ha of dry matter during four years of growth.

The evaluation of the energetic value of absolutely dry biomass showed its variation from 17.59 MJ/kg to 18.72 MJ/kg (Table). The highest energetic value of biofuel was characteristic of *Salix dasyclados* 04122 (18.72 MJ/kg), *S. viminalis* 'Tora' (18.41 MJ/kg) and *S. dasyclados* 04123 (18.16 MJ/kg). The lowest calorific value was shown by the hybrid *S. dasyclados* × *S. viminalis* 04120. Anyway, willow biomass is much more valuable as biofuel in comparison with some other plants (e.g., the calorific value of *Quercus robur* with the bark is 18.20 MJ/kg, of *Picea abies* with the bark 18.80 MJ/kg, of grasses from 17.00 MJ/kg (*Cannabis* sp.) to 17.70 MJ/kg (*Zea* sp.) [13]).

Analysis of the results showed that *S. dasyclados* clones 04122, 04123 and 9977, *S. viminalis* 'Americana' 9976 and *S. viminalis* 'Tora' were most valuable according to the energetic value of dry biomass.

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SALIX VIMINALIS L. IR S. DASYCLADOS WIMM. GENOTIPŲ, AUGINAMŲ TRUMPOS APYVARTOS ENERGETINIUS ŽELDINIUS, MORFOBIOLOGINIŲ, BIOMASĖS IR ENERGETINIŲ SAVYBIŲ ĮVERTINIMAS

Santrauka

2004–2007 m. trumpos apyvartos želdiniuose auginti ir tirti trys *Salix viminalis* ir keturi *S. dasyclados* genotipai. Išaiškinta krūmų augimo intensyvumo, stiebų skaičiaus krūme, jų skersmens ir stiebų biomasės produktyvumo dinamika per ketverių metų auginimo ciklą.

Nustatyta, kad per ketverius auginimo metus visų tirtų genotipų krūmų aukštis netolygiai didėja, o metiniai prieaugiai skirtingų genotipų krūmų skiriasi. Aukščiausius krūmus išaugino *S. viminalis* 'Tora' – 578 cm ir *S. dasyclados* 9977 – 504 cm. Išryškėjo stiebų kiekio gluosnių krūme kitimo tendencija: antrais auginimo metais susiformuoja maksimalus jų kiekis (*S. dasyclados* 04122 – 11,7, *S. viminalis* 04116 – 10,4), trečiais ir ketvirtais metais stiebų skaičius mažėja ir labiausiai sumažėja ketvirtais auginimo metais. Didžiausio skersmens stiebus išaugino *S. dasyclados* (4,1 cm) ir *S. dasyclados* × *S. viminalis* 04120 (3,5 cm). Mūsų tyrimų duomenimis, krūmų stiebų aukštis, jų skaičius krūme ir skersmuo tiesiogiai siejasi su sukauptu biomasės kiekiu. Didžiausia biokuro energetinė vertė išsiskyrė *Salix dasyclados* 04122 – 18,72 MJ/kg, *S. viminalis* 'Tora' – 18,41 MJ/kg ir *S. dasyclados* 04123 – 18,16 MJ/kg. Mažiausio kaloringumo biomasę išaugino *S. dasyclados* × *S. viminalis* 04120. Pagal biomasės išeigą vertingiausi yra *S. dasyclados* klonai – 04122, 9977 ir *S. dasyclados* × *S. viminalis* 04120 bei *S. viminalis* 'Americana' 9976, jų biomasės išeiga ketverių metų auginimo ciklo pabaigoje sudarė 43,5–57,0 t/ha sausosios medžiagos. Apibendrinus gautus tyrimo rezultatus galima teigti, kad pagal sausosios biomasės energetinius rodiklius vertingiausi yra *S. dasyclados* klonai – 04122, 04123, 9977, *S. viminalis* 'Americana' 9976 ir *S. viminalis* 'Tora'.