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Productivity and Biomass Parameters of Annual and Biennial Plantings of Willows in Latvia's Western Coastal Area

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Abstract:- The aim of the study is to evaluate the growth of willow clones in the northwestern region of Latvia. Already tested clones *(Tora, Torhild, Sven)*, clones cultivated in Europe and Scandinavia *(Tordis, Gudrun, Inger)*, new clone *Klara* and local Latvian *Salix burjatica, syn. dasyclados* were planted in Latvia's northwestern part close to the Baltic Sea. Morphological parameters – shoot height, sprouting point diameter was measured, number of sprouted shoots from cutting were counted, fresh shoots were weighed, moisture content of shoots were determined. Soil nitrogen content was analysed to find correlations with the main growth parameters. Data shows significant difference in all parameters between clones. Best results present with untested clones *Tordis, Inger* and already tested and more productive in Latvia, Tora. Tora had a high moisture content in comparison to others. Local *Salix burjatica* shows average yield and morphological results for current species clones and could be recommended for use for the admixture for biodiversity purposes.

Key-Words: Willow, salix spp., productivity, biomass.

1 Introduction

Wood is recognised as being the main self-renewing energy source used in Nordic countries. Most of the Nordic countries' fast growing tree species belong to the willow family. Wood chips from short rotation coppice stands, simple produced and ecologically safe are an alternative to fossil fuel energy material. Especially popular are those species of willow genus, which can be utilised in different ways (depending on market conditions) and which have characteristics of improving the growing environment, including soil [17], [2], [16], [15]. Since 1987, at least 24 varieties of willow (*Salix*) have been developed under the guidance of Dr. Stig Larsson; those clones now are plant protected for plant breeder's rights within the EU [7]. The breeding of willows has improved the yield by 60 per cent over a 20 year period, and today ten high yielding varieties can be found on the market. Since the demand of willows is expected to increase in both Sweden and the rest of Europe, continuous improvement of the plant material is of high importance from the perspective of yield and cost issues [10].

Plant material costs were one of main positions of establishing the budget of plantations, because of the expense of breeder's right protected plant material. Scientists of Estonia, Lithuania have conducted research trials for the testing of Swedish and other already tested clones, as well made new crosses to find new local clones of willows [3], [12], [13]. Large areas of willows were planted in Poland during the last few years, researchers working on new clones and following productivity under different stocks of plant nutrient elements, water availability and soil properties [14]. Scientists found that not only nutrients, but also ground water level regulation could be a key factor for bioenergy yield and economic efficiency at willow plantations [18].

Willows are multipurpose trees – scrubs with a wide variety of wood chemicals, mechanical properties and productivity. There is an opinion that energy plantations of willows are economically profitable when the average increase of biomass reaches at least 8-9 t ha^{-1} of dry material per vegetation season [12], [11]. It is the usual practice to cut short rotation willows after three or four years of growth, energy plantations of willows used for intensive culture (turnover cycle 1–2 years) are under discussion [12]. At first experimental trials in Latvia, clone *Tora,* in a two year rotation reached the same productivity as at a three year rotation [8]. The energy wood is just one option of use for willows; traditionally willows were used for baskets and furniture making, as well for the greening of cities and gardens. The bark of willows contains active substances known for their anti-inflammatory properties and is known as a phyto-therapeutic precursor of aspirin. Higher contents of active materials were determined in autumn 2-year-old willows [5].

The aim of the study is to evaluate the growth and moisture content of the biomass of *Salix* clones and local ones.

2 Problem formulation

To clarify, the productivity of willows selected in Sweden under Latvias conditions, already tested clones (*Tora, Torhild, Sven*), clones cultivated in Europe and Scandinavia (*Tordis, Gudrun, Inger*), new clone *Klara* and local Latvian *Salix burjatica (dasyclados)* were planted in the recommended position vertically in rows in the field collection in the Roja district 57.585138, 22.614464 – Latvia North West part, close to the Baltic Sea. The length of the planted cutting was 20-25 cm, the space between paired rows was 70 cm and between plants 50 cm, between double rows 1.50 cm [7], [12], [1]. The field was not fertilized; soil was tilled and cultivated in spring. Each clone was planted in two replications. Soil samples were taken from 0-20 cm, 20-40 cm, 40-60 cm depth, sampling points were chosen in a chess-board pattern in 3 zones distributed cross directionally to the willow rows, further described as zone 1, 2 and 3 (Fig.1). There was no agro-technical care.

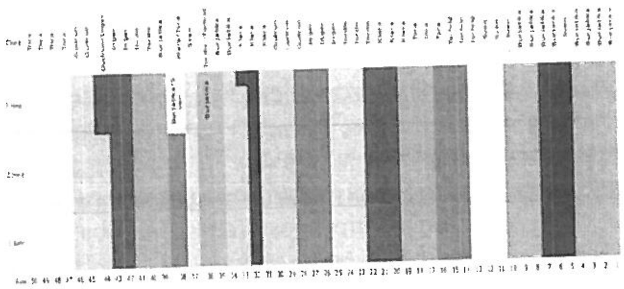

Fig. 1. Design of field trial.

The sampling and measurement of shoots was done in the same place and nearby, where the sampling of soil was done following the visually different growth rates of the willows.

Soil chemical analyses were done at the LSFRI Silava Forest environment lab. Soil samples were prepared for analyses according to the LVS ISO 11464 standard. The content of N ($N\text{-}NH_4^+$, $N\text{-}NO_3^-$) was determined by spectrophotometry. All results were validated according to the validity tables provided by the ICP Forests [4].

Comparative analyses of dendrometric characteristics and dry biomass of stems was carried out. Stem height, shoots diameter (at sprouted point and at 0.55 cm height) were measured. Numbers of sprouted shoots from cutting, fresh shoots were weighed and the moisture content was determined. The average dry weight per sprouts grown up from cutting and possible productivity per ha are presented. Dendrometric parameters – in biennial shoots at sprouting point diameter and diameter at 0.55 cm are measured only for larger stems. Measurements of shoots were done at the end of vegetation.

The obtained results were analysed using descriptive statistical methods, one way with ANOVA and correlation analysis using SPSS software.

3 Problem solution

Cuttings in the experimental field were planted in two replicates under naturally different availabilities of nitrogen, the average content of nitrogen in the soil was $N\text{-}NO_3^-$ (1.15-4.72 mg kg^{-1}) and $N\text{-}NH_4^+$ (4.12-17.1 mg kg^{-1}). Figures below show that there were various contents of N in the field trial in the first replicate (1-21 rows) and second (24-50 rows) (Fig. 2).

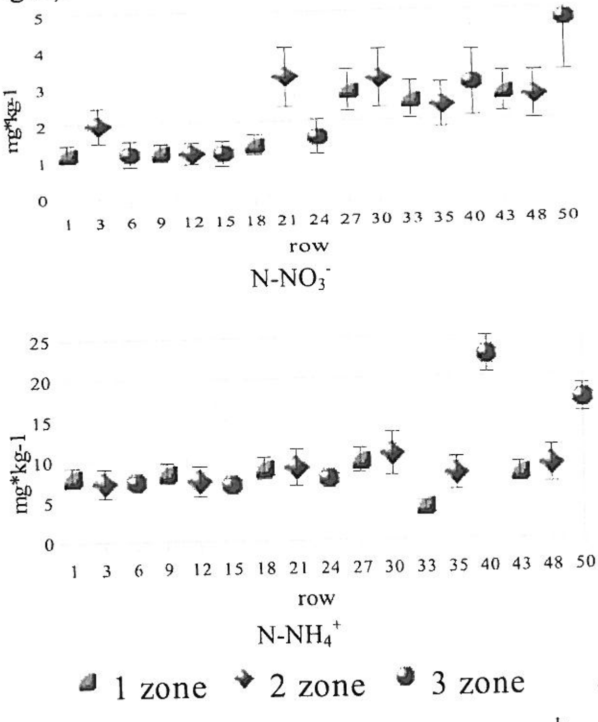

Fig. 2. Average content of nitrogen (mg kg^{-1}) at experiment trial soil depth from 0-60 cm.

The results of soil analysis show that not only nitrogen, but also the relative moisture of soil had different values and were higher in the second replication (Fig. 3).

There were significant difference between zones of nitrogen $N\text{-}NO_3^-$ content ($p=0.02$) and

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tendencies to having different water availability (p=0.06) where shoots were collected, but no significant differences for average growth conditions of each clone, because rows of replications were in a cross position.

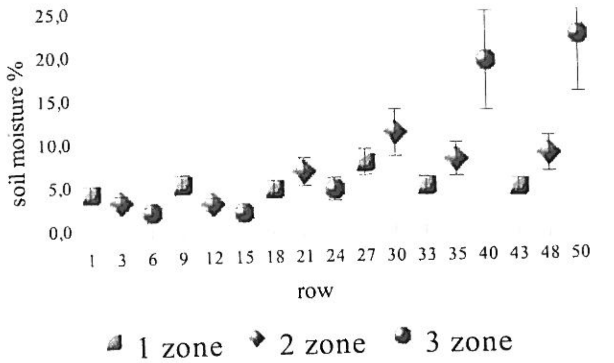

Fig. 3. Average relative soil moisture content (%) at experiment trial soil from 0-60 cm.

Animal damages recognised for clones was very different, with a high significance level (p<0.000), less damaged clones were *Gudrun*, *Inger*, *Tora* and *Salix burjatica* (Fig. 4).

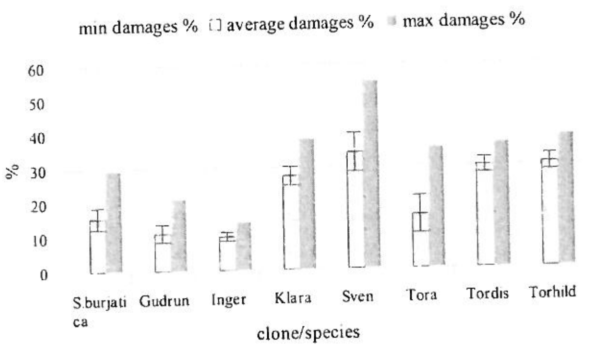

Fig. 4. Number of shoots damaged by animals at the first year.

The data showed that willows had different dendrometric characteristics. Those differences are significant in the first and second year. The average height of annual bushes varied from 61.64cm *(Gudrun)* to 105.29cm *(Torhild)* and the difference was significant p=0.009, but there were no significant differences between stem diameters at sprouting point p=0.055, just tendencies. In the second season, the best growth results were in the plantings of *Tordis* – shoot height reached 252.50 cm, but *S. burjatica* saw slower growth (stems were just 119.69 cm long on average). A biennial shoot's dendrometrical parameters differ significantly in second year as well; the height of shoots were significantly different p=0.002, measurement results of stem diameter at sprouting point did not significantly differ. Since the second year, there are significant differences of shoot biomass grown up from one cutting (p=0.05) (Fig. 5).

The number of stems from 1.83 to 2.80 per stump in the first year and 1.58-2.02 stems from one cutting survived in the second year. The diameter of stems from 0.6 to 1.7 cm, finally *Gudrun*, *Klara* and *Inger* had more stems but *Tora* and *Torhild* had less. The average dry weight (for moisture content, 55%) of stems were from 0.58 (*Gudrun*) to 4.02 *(Tora)* kg per bush grown from one cutting in the second year, and it weakly correlated with the number of stems from cutting (r=0.42) but a stronger correlation was with the height of the stem (r=0.89) and diameter of the shoot spouting point (r=0.88).

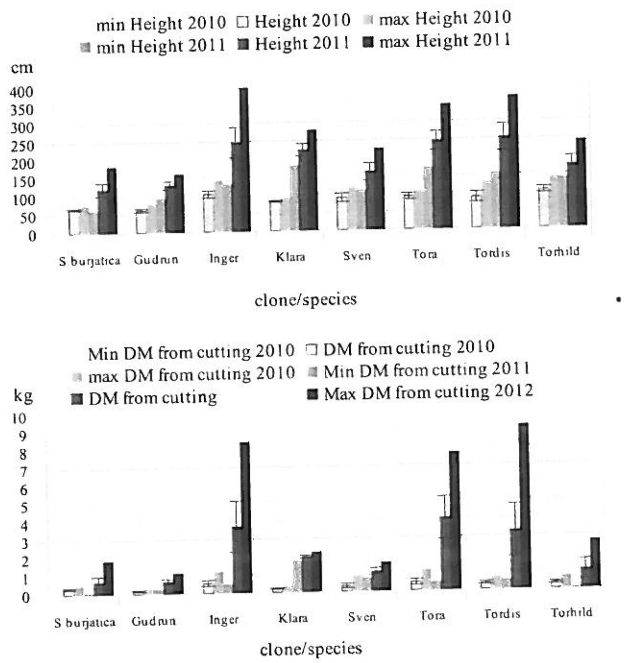

Fig. 5.Growth and dry biomass data for the first two years.

The productivity of the current trial was lower than presented at fertilized plantations, but approximately the same as in Sweden, Estonia and Lithuania - no fertilized fields [17], [3], [12]. In our results, calculating from one cutting dry mass (DM) to Swedish planting density (20 000 cuttings per ha, presented by Larsson S.) we could theoretically reach 80 $T_{ODM}ha^{-1}$ by planting 20 000 per ha, but in fact, there usually had been planted no more than 15 000 cuttings and those surviving on an industrial scale are approximately 70%, that means that, in a field, there were 10 500 plants left, as a result, we should calculate the yield as half less than showed in Table 1. The yield of the annual shoots in Norway from the field established in 2005 ranges from 1.2 T_{DM} ha^{-1} in *Aage* and 2,9$T_{DM}ha^{-1}$ in *Tordis* are similar to Latvian conditions [6]. Highest yielding varieties including the *Tora* (12.8$T_{ODM}ha^{-1}$ yearly) with an increase of their yield in the second rotation by between 20-40%; in our experiment, the yield increment varied from 51-88% (Table 1). Newly released varieties such as *Sven* and *Torhild* have on occasion yielded over 12$T_{ODM}ha^{-1}$ yearly but generally fall into the range between 10-12$T_{ODM}ha^{-1}$ yearly [10].

Table 1. Calculated to 20 000 cuttings ha^{-1} yield of willows at experimental trial

clone	*S. burjatica*	*Gudrun*	*Inger*	*Klara*	*Sven*	*Tora*	*Tordis*	*Torhild*
Annual $T_{ODM}ha^{-1}$	6.6	3.2	11.2	4.2	6.4	9.5	7.3	6.9
Biennial $T_{ODM}ha^{-1}$	13.7	13.4	73.9	39.0	22.1	80.6	65.8	21.2
Increase of yield %	51.5	76.2	84.8	89.3	71.2	88.2	89.0	67.5

In the Latvian experimental trial *Sven* was not one of the more productive clones as previously, as in current experiment. The better growth rate in the current experiment was held by *Tora*, *Inger* and *Tordis*, in other previous experiments *Torhild* was the most productive in that field [9]. The *S. dasyclados* variety *Loden* (9.66 $T_{ODM}ha^{-1}$yearly) is a short, broad-leaved willow with an acceptable yield. It has the added benefit of adding genetic diversity to a mixture [10], for the same reasons, in Latvia the *Gudrun* or *S.dasyclados* may be recommended. Biannual plants show bigger differences of productivity, especially in the height of stems (Fig. 5) and number of survived cuttings depending on water availability which shows the coefficients of the Pearson correlation (r=0.35) and soil nitrogen content (r=0.43). The significant factor for the height of stems is the clone (p=0.002), but the correlation is weak (r=0.38), because only some clones had significant differences from each other, the same correlations are recognised in the research of other scientists [6], [12].

Correlation analysis of willow clone growth parameters and yield with soil properties in the current trial showed that there are significant correlations in 2010 between height of annual shoots and yield (r=0.53), soil moisture (r=0.38), $N\text{-}NO_3^-$ (r=0.39) and clone (r=0.41). Diameter of shoots correlated with yield (r=0.81), but soil moisture content (r=0.41), $N\text{-}NH_4^+$ (r=0.31), $N\text{-}NO_3^-$ (r=0.46) had a weak correlation.

In the second year, 2011, there were no correlations of shoot height and diameter to the soil moisture and content of N, but a weak correlation appeared between the number of shoots from cutting with soil moisture content (r=0.36) and $N\text{-}NH_4^+$ (r=0.43). In both seasons, the soil moisture content correlated with $N\text{-}NH_4^+$ (r=0.78) and there was a covariance of both parameters to productivity of the plantation.

Despite the correlation of productivity with soil moisture, there is no correlation of shoots biomass moisture relations to the soil properties and stem characteristics; stem moisture were significantly correlated only with clone (r=0.62) (Table 2).

Table 2. Biannual stem moisture content % of most productive clones.

clone	*Inger*	*Klara*	*Sven*	*Tora*	*Tordis*	*Torhild*	*Average*
Moisture %	53.4	53.6	53.4	57.5	55.4	56.4	55.0
Standard error of mean	1.6	1.2	2.2	1.0	1.0	1.2	1.7

Average moisture content of biannual willow of *Inger*, *Klara* and *Sven* were lower than for another clones. *Tora* had larger productivity, but also a higher moisture content in the stem, so it may be recommended to decrease moisture content of the biomass before using it for energy production, because it is related to heat capacity.

4 Conclusion

Clones *Tora, Inger, Gudrun* and *Salix dasyclados* were less preferred by game animals and could be recommended for planting in the plantations close to forest areas with a high animal density.

Local *Salix burjatica* in comparison with clone *Gudrun* selected from *S.dasyclados syn. burjatica* shows a similar and, in the first year, even better productivity and morphological results and could be recommended as an admixture for biodiversity targets as well as buffer zone.

Near to the Baltic Sea, coastal areas with a marine climate yielded better growth results with clones *Tora, Inger, Tordis, Klara*, but because of a larger quantity of stems and thicker shoots, more productive were *Tora, Inger* and *Tordis*.

The average height of the most productive clone biennial shoots was 245-252cm, average number of shoots was close to 2. Average moisture content of biennial shoots was 55%, moisture content at clone level varied significantly from 53.40% to 57.49%.

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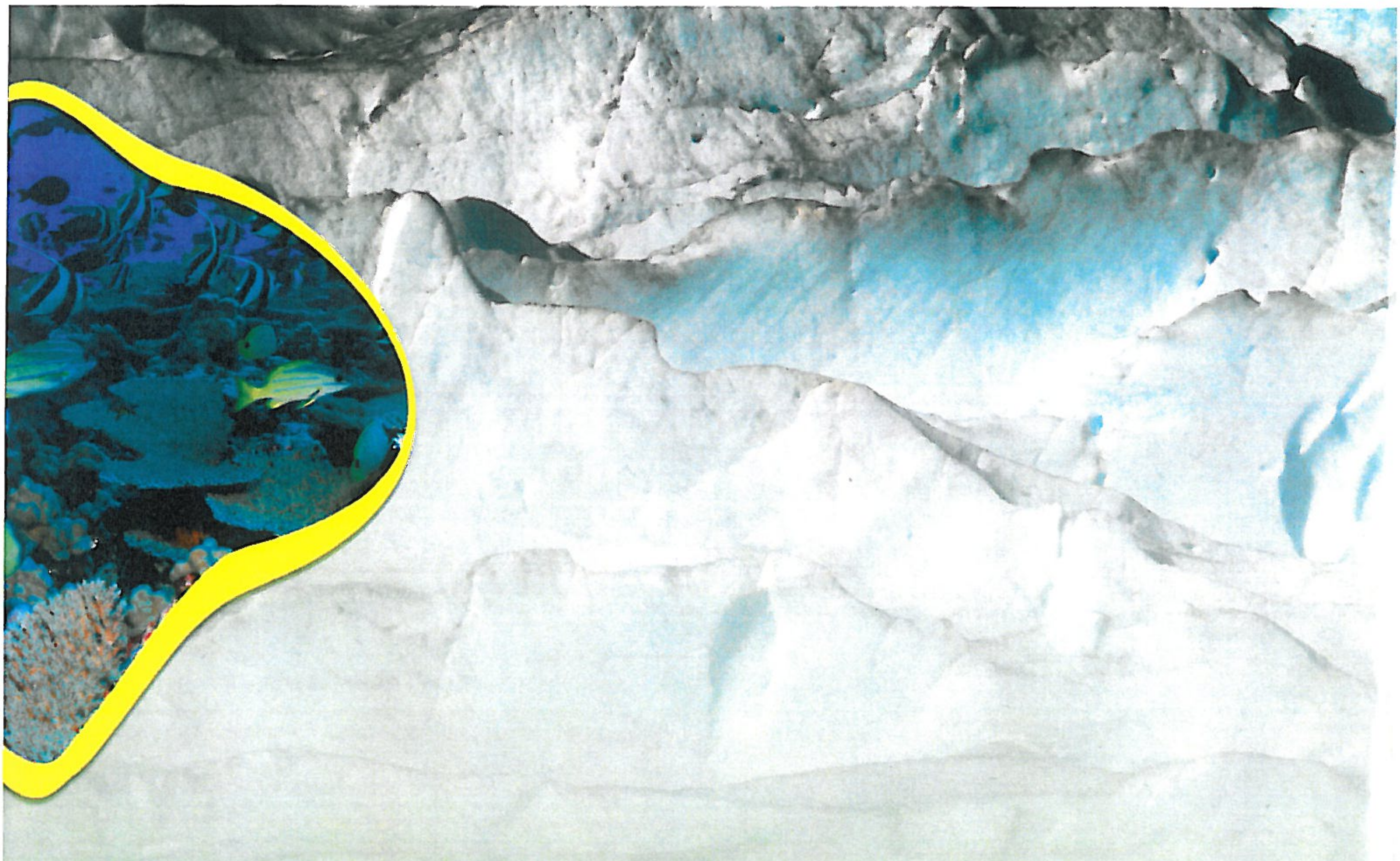

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