Selection of willow clones for energy forests on exploited peatlands, utilising wastewater sludge

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The possibilities of 12 local and 14 introduced willow species and clones to grow on exploited peatland, utilizing wastewater sludge have been investigated. Most of all tested clones are growing in energy forests on arable mineral soil and 5 local willow species are naturally spread on peatlands. The investigations were carried out in the trails, established in 1993-1996 year on exploited peatland of the upper type, utilizing different doses of sludge (250-500 t/ha DM).

It was determined, that from 26 clones tested the bestones adapted to grow on acid exploited peatland is S.viminalis clone No. 2. High biomass production (11-12 t/ha s m) equal production of energy forests on mineral arable soils was obtained. A lot of willow clones grow on arable land and local willow species of peatlands are of low productivity under exploited peatlands conditions and not suitable for energy forests.

Key words: energy forests, willow clones, exploited peatlands, wastewater sludge.

Introduction

The growing of willows on peatlands is aimed at utilising them for nature protective purposes by applying wastewater deposits on exploited peatland. Willows perform not only protective function - biofiltration of harmful substances brought with wastewater sludge and their return to natural metabolism, but also provide economic benefit by producing biomass, a valuable energetic material.

A layer of peat up to 0.3 m and a thicker one left on exploited peatland pertains good absorbing properties of heavy metals, stops them from migrating into deeper soil layers and ground water. However, peat soils are infertile, of very acid reaction and even fertilised by wastewater sludge are suitable to grow only some willow clones.

In most European countries with great surplus of arable land willow clones selected for energy forests on cultivated soils are grown. Studies on growing them in exploited peatlands fertilized with wastewater sludge are carried out on a very small scale, for plantations in such areas fail to reach high biomass productivity (Aronsson P. and Perttu K.L., 1994). In Sweden, where selection of willows is conducted on a large scale (Ager A., Rannberg-Wastljung S., Thorsen I., Siren G., 1986, Ledin S. and Alriksson A., 1992), their clones are specialised according to site conditions.

The most widespread clones in energy forests are *S.viminalis* and *S.dasyclada* recommended to be grown on fertile mineral soils. Some willow taxons are described as suitable for growing on mineral and peat soils (Ledin S. and Alriksson A., 1992). In literature there are data on very productive clones from England - Burjatica Korso (syn. dasyclados Skvortsov, often called *Salix Aquatica Gigantea* clone 56) recommended for growing on wet and acid soils, exploited peatlands (Hummel F.C., Palz W., and Grassi G., 1989). This clone has accumulated 13 t/ha dm of the mean annual biomass increment on exploited peat soil fertilized with mineral fertilizers.

While working out the technology for growing energy forests on exploited peatlands, one of the main tasks is to define and recommend the most perspective willows and their clones for growing. They have to be adapted for growing under difficult peatland conditions.

Methods

Perspective willows for energy forests should comply to the following criteria (Hummel F.C., Palz W. and Grassi G., 1989):

- correspond to the soil;
- root well propagated by cuttings and be viable, for replanting is impossible;

- produce much biomass;
- grow especially intensively first year after cutting;
- sustain long-term regeneration capacity after several rotations;
- be resistant to pests and diseases under great density;
- be resistant to frosts, be suitable under our climatic conditions;
- pertain high energetic value.

Experiments for selecting perspective local and introduced willow clones for energy forests were established in 1993-1996 on high-moor and transitional peatlands utilising on them different dozes of wastewater sludge (250-500 t/ha dm).

On exploited high-moor peatland with left peat layer, of 0.5 - 1 m deep which was fertilized by wastewater sludge (360 t/ha dm), a trial of initial selection was started in 1993. There were planted 11 local and introduced willow clones as well as *Sambucus nigra* L. From local willows - *S.viminalis* clone No. 5 represents riverside sites, *S.acutifolia* - sandy sites, while other five - *S.myrsinifolia, S.pentandra, S.cinerea, S.aurita* and *S.rosmarinifolia* - marshland sites. They are adapted and most aften found under peatland conditions. All four species of introduced willows - *S.viminalis* clone No. 2, *S. schwerini* x *S.udensis, S.rigida, S.mollissima* are riverside willows.

Trials on peatlands were established on two sites with different peat layer depth, differing sludge application and growing duration:

1. The remaining peat layer is 0.5 m deep, wastewater sludge doze 500 t/ha of dry matter, age of their roots - 3 years (2/3).

2. Peat layer 0.5-1 m, sludge application 250 t/ha dm, age of willow stumps and roots 1 year (1/1).

On transitional peatland with peat layer of 0.5 m deep (sludge application 500 t/ha dm) 11 clones of the most productive local and introduced willows grown in Lithuania (Smaliukas D., 1996) on arable soils were planted. The following local willows were tested: 4 willows growing on riverside sites - *S.viminalis* clone No. 1, *S.viminalis* x *S.caprea, S.caprea* x *S.viminalis, S.purpurea* x *S.viminalis* and 2 growing on sandy sites - *S.daphnoides* and *S.acutifolia*. The following introduced willows were grown: S.viminalis clone No. 2, S.schwerini x S.udensis and S.viminalis clone No. 183.

On transitional peatland with peat layer of 0.5-1 m deep (sludge application 250 t/ha dm) *S.viminalis* clone No. 2, which is most perspective on peat soils and 8 clones introduced from Sweden: *S.viminalis* clones No. 7, 21, 101, 112, 183, 195, 915 and *S.dasyclada* clone No. 90 were planted. *S.dasyclada* was tested repeatedly. The growth of tested willows was compared to local *S. viminalis* clone No. 1.

In the trial of initial selection on high-moor peatland experimental variants were planted in rows, 50 specimens in each. Their rooting capacity, the current height and biomass increment were assessed by the usual biometric method. The mean stem mass on a stump (without leaves) was determined by weighing the stems of all stumps and dividing the amount by the number of stumps. The mass of stems was evaluated then in ton per hectare (t/ha). Dry mass (dm t/ha) was defined multiplying green mass by the coefficient of absolutely dry matter k=0.48.

In trials of repeated selection on transitional peatland (1994 and 1996) each variant was established with three randomly distributed replicates at 50-70 stumps. At the end of the vegetation period a total inventory of willows was conducted. The height of all stems on a stump, and diameter at 55 cm height were measured, percentage of rooting and number of stumps remaining per area unit were calculated.

Prior to trials on growing willows chemical analysis of the soil and wastewater sludge was conducted by usual methods. After L.Kubertavičienė (1991), high-moor peat is of very acid reaction (pH - 2.6-3.4), while judging by the amount of hydrolyzable nitrogen and mobile potassium and phosphorus it is very infertile. On transitional peatland with peat layer of 0.5 m deep unfertilized soil according to Forest fertilization reference book by R.Šleinys (1986) is of acid reaction (pHKCl - 3.6-4.3). It contains a small amount of hydrolyzable nitrogen (8.4-10.0 mg/100 g) and mobile phosphorus (P_2O_5 - 2.5-2.2 mg/100 g). On transitional peatland with peat layer of 0.5 m deep unfertilized fire-affected soil is of neutral reaction (pHKCl ~ 7.1). It contains greater amounts of hydrolyzable nitrogen (6.6 mg/100 g) and mobile phosphorus (P_2O_5 - 7.5 mg/100 g). In order to increase fertility of peatlands it is necessary to apply fertilizers and lime.

Wastewater sludge applied to fertilize experimental plantations according to granulometric content represents consolidated sand with great amount (16.4-30.2%) of organic matter. It is of neutral reaction (pHKCl - 6.6), contains great amount of humus (12.6-17.5%), substantial quantities of hydrolyzable nitrogen (53.3-79.2 mg/100 g) and mobile phosphorus (147-193 mg/100 g) and a small amount of mobile potassium (15.3-29.8%). Liming of peat soil is unnecessary when wastewater sludge is applied, however, due to a small amount of potassium it may require additional treatment with mineral potassium fertilizers.

Stem mass of willows was ascertained by a statistical sampling method, taking 25 stems of different thickness from each variant. Diameter and mass interrelation of model stems under strong correlation is expressed by the second degree regression equations. To find out stem mass of the most perspective S.viminalis clone No. 2 by diameter the following equation is used:

$$y=0.986x^{2.1519},$$

where y - stem mass, g; x - stem diameter (mm) at 55 cm height.

In accordance with measured stem diameters the total stem mass was calculated. By using the coefficient of absolutely dry matter (k=0.48) it was evaluated in tons per hectare (t/ha) of dry matter (dm).

Results

The data on initial selection (Table 1) have shown, that on high-moor peatland fertilized with wastewater sludge the best rooting capacity (89%) and growth are observed and the greatest biomass is accumulated by introduced riverside willow - *S.viminalis* clone No. 2. Stem height (213.7 cm) its one-year-old stumps with 2-year-old roots was by 34% greater (t=6.4) than that of local control *S.viminalis* clone No. 5. The best growing willow (*S.viminalis* clone No. 2) contains the greatest number of stems (15.1 units) per stump, while stem mass (12.3 t/ha dm) is 3.9 times larger than the control (*S.viminalis* clone No. 5).

Among unfertilized variants was also distinguished *S.viminalis* clone No. 2 by the best growth and greatest amount of the biomass. Stumps of almost all willow clones died off in an unfertilized variant (except some local species on marshland sites) because of a very acid reaction in the peat soil. This shows very unfavourable peatland conditions for willows as well as better adaptation of *S.viminalis* clone No. 2 to grow on exploited high-moor peatland. Much greater biomass productivity of this clone in the fertilized variant, as compared to unfertilized one, demonstrates its sensitivity to wastewater sludge application. Other riverside willow clones - *S.acutifolia, S.schwerini* x *S.udensis* and *S.mollissima* exhibited slight differences in stem height as compared to the control, however, their biomass productivity was low and comprised 1.5-4.1 t/ha dm.

Local marshland willows (*S.myrsinifolia, S.pentandra, S.cinerea, S.aurita* and *S.rozmarinifolia*) on high-moor peatland had low rooting capacity (27-56%), grew slowly and accumulated a small amount of the biomass. The height of their stems comprised 29-72% of the control variant, while stem mass - 0.9-2.5 t/ha dm. These species showed almost no reaction to wastewater sludge application and were sensitive to its overdosage. Therefore, marshland willows for energetic plantations on peatlands are completely unsuitable. *Sambucus nigra* on high-moor peatland grew quite well: its stem height

Table 1. The growth and biomass production by 1 year old stems from 2 year old stumes of local and introduced willow clones in exploited peatland (with sludge application 360 t/ha dm)

No.	Salix cultivars	Rootig capaciy, %	Stem height			Stem number from single stump			Stem mass		
			mean M±m, cm	t	%	mean M±m, m	t	%	from the stump, g	dm, t/ha	%
1.	S. viminalis cl. No 5 (control)	39	159.1±3.3	-	100	14.4±0.6	-	100	233	3.2	100
2.	S. acutifolia	36	154.6±3.8	0.9	97	4.8±0.2	12.8	33	125	1.7	53
3.	S. myrsinifolia	56	108.8±2.8	11.6	68	12.6±0.5	2.3	88	185	2.5	79
4.	S. pentandra	14	134.3±5.4	3.9	84	4.3±0.2	16.0	30	133	1.8	56
5.	S. cinerea	64	115.4±3.0	9.8	72	5.3±0.2	14.4	37	154	2.1	66
6.	S. aurita	39	92.2±4.3	12.3	58	6.1±0.3	12.4	42	121	1.7	53
7.	S. rozmarinifolia	27	69.1±3.4	19.0	29	5.2±0.2	14.5	36	68	0.9	28
8.	S. viminalis cl. No 2	89	213.7±7.9	6.4	134	15.1±0.6	0.8	105	900	12.3	386
9.	S. schwerini x S. udensis	80	156.4±5.4	0.4	98	5.2±0.2	14.5	36	110	1.5	47
10.	S. rigida	78	126.0±3.3	7.1	79	13.6±0.4	1.1	94	175	2.4	75
11.	S. mollissima	56	148.9±4.3	1.9	94	9.0±0.4	7.5	62	297	4.1	128
12.	Sambucus nigra	-	168.2±2.7	2.1	106	10.1±0.4	6.0	70	275	3.8	119
13.	S. viminalis cl. No 2 (not fertilized)	45	45.7±2.0	29.4	29	3.5±0.1	17.9	24	15	0.2	6

was even greater (6%) than the control, however, biomass productivity (3.8 t/ha dm) was insufficient for energy forests.

On transitional peatland with 0.5 m layer of peat (sludge application 500 t/ha dm) sufficiently great biomass productivity of the most perspective clones was obtained. The highest biomass increment in 2-year-old stems (Fig. 1, Table 2) has been accumulated by *S.viminalis* clone No. 2 - 25 t/ha dm, *S.schwerini x S.dasyclada* - 23.3 t/ha dm, as well as by local *S.viminalis* clone No. 1 (control) - 22 t/ha dm. These most productive clones in the second year after cutting

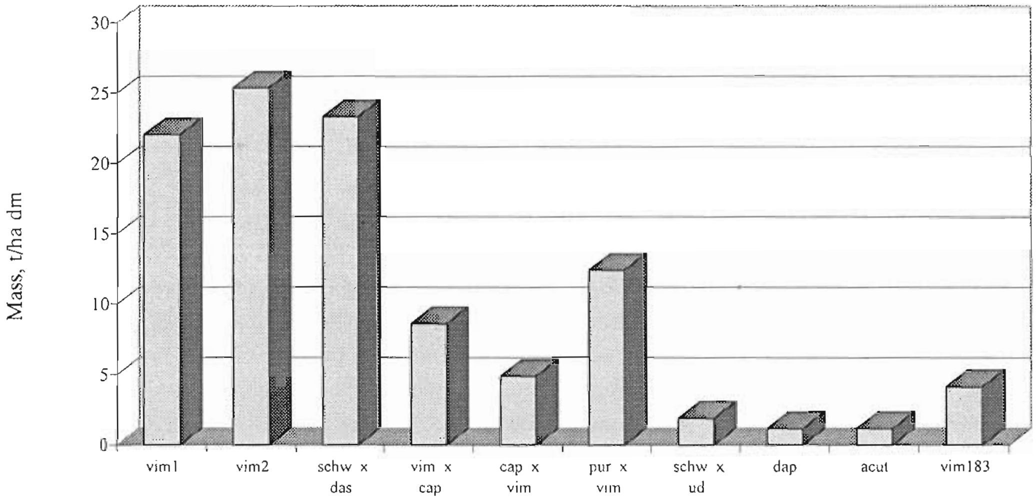

Fig. 1. Biomass production of 2 year old willow stands in exploited peatland with 0.5 m layer of peat (with sludge application 500 t/ha dm)

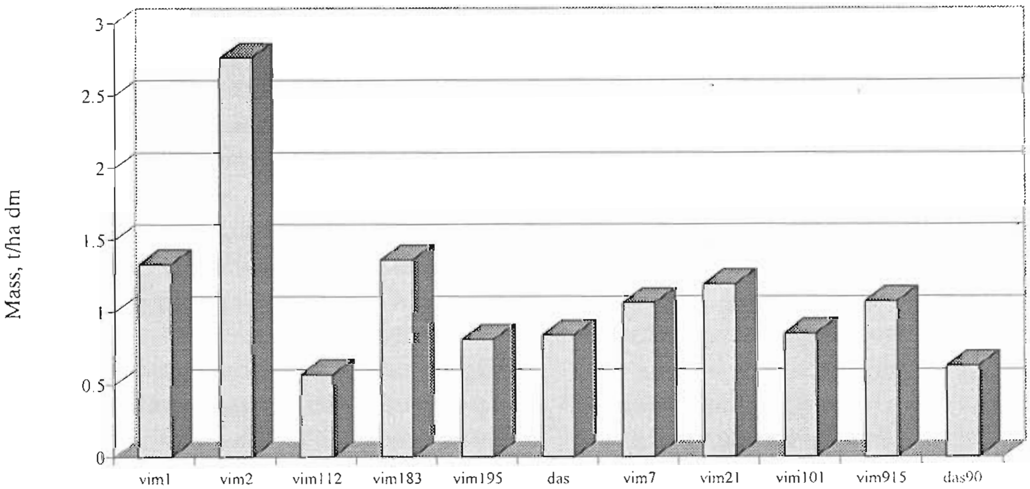

Fig. 2. Biomass production of 1 year old willow coppice on exploited peatland with 0.5-1.0 m layer of peat (with sludge application 250 t/ha dm)

Salix cultivars

vim 1	- S. viminalis clone No 1	vim x cap	- S. viminalis x S. caprea
vim 2	- S. viminalis clone No 2	cap x vim	- S. caprea x S. viminalis
vim 7	- S. viminalis clone No 7	pur x vim	- S. purpurea x S. viminalis
vim 21	- S. viminalis clone No 21	das	- S. dasyclada
vim 101	- S. viminalis clone No 101	das 90	- S. dasyclada clone No 90
vim 112	- S. viminalis clone No 112	schw x das	- S. schwerini x S. dasyclada
vim 183	- S. viminalis clone No 183	schw x ud	- S. schwerini x S. udensis
vim 195	- S. viminalis clone No 195	acut	- S. acutifolia
vim 915	- S. viminalis clone No 915	dap	- S. daphnoides

Table 2. The growth and biomass production by 2 year old stems from 3 year old stums of willow clones on exploited peatland with 0.5 m

No.	Salix cultivars	Rootig capaciy, %	Stem height			Stem diameter at 55 cm aboveground		
			mean M±m, cm	t	%	mean M±m, mm	t	%
1	S. viminalis cl. No 1 (control)	100	311.6±2.5	-	100	13.9±0.2	-	100
2	S. viminalis x S. caprea	95	219.2±4.5	14	70	13.7±0.3	0.3	99
3	S. caprea x S. viminalis	83	171.7±2.9	36	55	11.7±0.2	7.2	84
4	S. purpurea x S. viminalis	96	278.4±2.8	8.8	89	11.6±0.2	9.8	84
5	S acutifolia	85	230.2±9.6	8.2	74	12.1±0.5	3.4	87
6	S. daphnoides	94	209.2±7.8	12.4	67	9.8±0.4	8.6	76
7	S. viminalis cl. No 2	95	303.6±4.9	1.4	97	15.1±0.4	3.1	109
8	S. schwerini x S. dasyclada	98	333.9±5.3	3.8	107	18.0±0.4	9.9	130
9	S. dasyclada	92	229.9±4.9	15	74	13.9±0.4	0.2	99
10	S. schwerini x S. udensis	76	202.5±7.7	13.4	65	11.2±0.5	5.0	81
11	S. viminalis cl. No 183	90	175.3±3.4	32	56	10.1±0.3	10.9	73

produced especially significant annual biomass increment - from 4.8-8.1 t/ha dm (1995) up to 17-18 t/ha dm (1996). Better adaptation of the clones to grow on exploited peatland is demonstrated by their rooting capacity (95-100%) and a great number of the remaining stumps (26.1-33.3 thous./ha). A greater (15%) biomass increment of *S. viminalis* clone No. 2 than that of the control was preconditioned by 9% thicker stems (t=3.1) and by 31% greater number of them (t=3.1) on a stump. In comparison to the control, slightly lower height of stems of *S. viminalis* clone No. 2 was due to browsing by animals in winter time. Willow hybrid *S.schwerini* x *S.dasyclada* (morphologically more similar to *S.dasyclada*), as compared to *S.viminalis* clone No. 1, had by 7% higher stems (t=3.8) and by 30% greater stem diameter (t=9.9), although the number of stems per stump was less (t=4.6). It was observed, that *S.schwerini* x *S.dasyclada,* apart from most *S.viminalis* clones and *S.dasyclada,* was disliked and undamaged by animals, which had direct impact on stem quality, spreading of diseases and biomass productivity.

All the other willow clones (Table 2) grown on transitional peatland due to unfavourable soil conditions grew poorly and accumulated low or average biomass increment. Especially bad rooting capacity, growth and survival in the second year were demonstrated by willows - *S.daphnoides* and *S.acutifolia* on sandy sites. Biomass increment of their two-year-old stems comprised 1.2 t/ha dm. Both *S.viminalis* x *S.caprea* and *S.caprea* x *S.viminalis*, failed to show expected high biomass productivity although on cultivated sandy soils these clones have especially thick stems and high biomass increment. They were severely damaged by fungi diseases and biomass increment of their 2-year-old stems comprised 8.6 and 4.7 t/ha dm. Good rooting capacity of *S.viminalis* x *S.caprea* and *S.caprea* x *S.viminalis* cuttings was obtained after soaking them in heteroauhin solution. Without biostimulators these clones show poor rooting, which is a great disadvantage. *S.dasyclada* demonstrated a low biomass increment as well. However, in our trials on arable lands with sod-podzolic gley soil this taxon is one of the most productive. Poor rooting capacity, poor growth and extensive thinning out due to root rot on overmoistured peat was shown by *S.schwerini* x *S.udensis*. Thus accumulated small biomass in 2-year-old stems was 1.9 t/ha dm. Over 2 years biomass increment of *S.purpurea* x *S.viminalis* was insufficient - 12.4 t/ha dm which is also more perspective on arable and with sandy soils. An important variant was the growth of the most popular willow for energetic plantations in Sweden - *S.viminalis* clone No. 183 (Ledin S. and Alriksson A., 1992). On transitional peatland the height of its stems comprised hardly 56%, while mass - 19%, as compared to the control.

On transitional peatland with 0.5-1 m layer of peat, applying ecologically allowable doze of wastewater sludge (250 t/ha dm), a low biomass increment of all tested clones - 0.6-2.8 t/ha dm (Table 3, Fig. 2) was obtained. Soil conditions with a deeper layer of overmoistured peat were especially unfavourable for growing willows. In comparison to the control (*S.viminalis* clone No. 1) *S.viminalis* clone No. 2, selected by us, had greater stem height (t=5.3), diameter (t=6.7) and biomass (208%). Extremely unfavourable conditions have revealed ability of *S.viminalis* clone No. 2 the to grow on peat soils. Local *S.viminalis* clone No. 1 under more difficult growth conditions was lagging behind (concerning bio-mass increment) from the most perspective *S.viminalis* clone No. 2 by comparing to the experiment of 1994 (application 500 t/ha). This shows, layer of peat (with sludge application 500 t/ha dm)

Stem number in the stump			Density, plants,	Stem mass increment dm, t/ha		Stem mass		
mean M±m,units	t	%	10^3/ha	in 1995	in 1996	from the stump, g	dm, t/ha	%
3.5± 0.1	-	100	33.3	4.8	17.0	1378	22.0	100
2.5± 0.2	4.4	70	20.2	3.4	5.2	882	8.6	39
2.5± 0.1	5	73	22.6	3.0	1.9	450	4.9	22
4.7± 0.3	4.2	134	25.0	2.6	9.8	1034	12.4	56
2.3± 0.2	9.8	48	6.4	0.9	0.3	374	1.2	5
1.7± 0.1	4.6	66	5.6	0.8	0.4	431	1.2	5
4.6± 0.3	3.1	132	26.1	8.1	17.3	2024	25.4	115
2.3± 0.1	4.6	67	27.0	5.3	18.0	1798	23.3	106
2.7± 0.1	5.6	77	21.6	3.6	4.6	788	8.2	37
2.2± 0.2	5.9	64	10.3	1.2	0.7	385	1.9	9
4.2± 0.4	1.6	119	23.5	1.9	2.3	367	4.2	19

that *S.viminalis* clone No. 1, as most clones on mineral sites, is more sensitive to soil fertility than *S.viminalis* clone No. 2.

In literature there are data on Swedish *S.viminalis* clones No. 21, 101, 112, 183 and 195, tested by us which have grown on special soils (Ledin S. and Alriksson A., 1992). *S.viminalis* clone No. 112 (specialized on mineral sandy soils) tested was smallest according stem height (t=3.3), diameter (t=5.1) and biomass accumulation (43%). On cultivated soils in our trials *S.viminalis* clone No. 112 grew well and was among the most perspective ones. *S.viminalis* clone No. 183 (specialized on sandy loam and peat soils) according to stem height, diameter and biomass displayed insignificant differences from the control. The following clones have similar specialization in respect to soil: *S.viminalis* clones - No. 21 (wet organic soil), No. 195 (organic soil), No. 101 (tolerates low pH values). The greatest biomass was accumulated by *S.viminalis* clone No. 21 (89% as compared to the control). The biomass of *S.viminalis* clones No. 195 and 101 comprised only 63-64% as compared to the control. On peat soil *S.dasyclada* clone No. 90 (47% compared to the control) and *S.dasyclada* grown in Lithuania (63% compared to the control), are unproductive which is one of the most perspective on arable lands with mineral soils.

The biomass of all tested Swedish clones was more twice less as compared that of *S.viminalis* clone No. 2. Most of the clones (except *S.viminalis* clone No. 183) were less productive than the control *S.viminalis* clone No. 1.

Discussion

By applying wastewater sludge, which according to granulometric content represents sand, an artificial fertile soil layer is formed. However, only a few riverside willow clones can grow more or less well on it. Of 26 willow clones tested only *S.viminalis* clone No. 2 grew well under these conditions. Its great annual biomass increment (12 t/ha dm) equals the amount of the biomass grown in energetic plantations on arable mineral soils. Ability of *S.viminalis* clone No. 2 to grow on peat soils is best revealed under unfavourable conditions, when its biomass increment on 0.5-1 m peat layer by 2-5 times exceeds that of other 10 willow clones tested in energy forests. Therefore, energy forests on exploited peatlands fertilized with wastewater sludge may be established only from selected willow clones, specialized to grow on peat soils.

A valuable clone on peat soils is *S.schwerini* x *S.dasyclada*. On transitional peatland with peat layer of 0.5 m after having applied 500 t/ha dm it accumulated greater annual biomass increment (11 t/ha dm). However, its ability to grow under difficult conditions, when peat layer is deeper and less (ecologically allowable) amount of sludge is applied, is not yet investigated. Insufficiently adapted to growing on exploited peatlands is local S.viminalis clone No. 1: it accumulated greater biomass under higher application rate (500 t/ha dm), however, under difficult conditions - in a trial with deeper peat layer (0.5-1 m) and application rate 250 t/ha dm - it was lagging behind of the most perspective S.viminalis clone No. 2.

Most perspective on cultivated soils local and introduced riverside willow clones grew poorly even on abundantly fertilized exploited peatland. Under such conditions especially unsuitable are riverside clones perspective on sandy soils. In accordance with foreign sources (Proceedings, 1987) the most perspective on peat soils are *S.dasyclada* clones. However, tested

Table 3. The growth and biomass production of 1 year old willow coppice on exploited peatland with 0.5-1.0m layer of peat (with sludge

No.	Salix cultivars	Rootig capacity, %	Replicates	Stem height			Stem diameter at 55 cm aboveground		
				mean M±m, cm	t	%	mean M±m, mm	t	%
1	S. viminalis cl. No 1		1	152.5±3.3			5.9±0.2		
			2	144.2±3.4			5.4±0.2		
			3	140.6±2.7			5.3±0.2		
		87	vid.	145.8±3.2	-	100	5.5±0.2	-	100
2	S. viminalis cl. No 2		1	185.1±2.8			8.2±0.2		
			2	159.1±3.4			6.8±0.2		
			3	166.9±4.1			7.0±0.2		
		84	vid.	170.4±3.4	5.3	117	7.3±0.2	6.7	133
3	S. viminalis cl. No 112		1	134.7±4.2			4.3±0.2		
			2	126.3±4.3			4.2±0.1		
			3	123.8±4.4			4.6±0.1		
		78	vid.	128.2±4.3	3.3	88	4.4±0.1	5.1	79
4	S. viminalis cl. No 183		1	133.0±2.3			5.7±0.2		
			2	139.3±2.1			6.2±0.1		
			3	134.2±2.9			6.2±0.2		
		85	vid.	135.5±2.4	2.6	93	6.0±0.2	2.1	109
5	S. viminalis cl. No 195		1	131.3±3.0			6.4±0.2		
			2	121.3±7.1			5.5±0.2		
			3	124.7±3.2			4.4±0.2		
		71	vid.	125.8±4.4	3.7	86	5.4±0.2	0.4	98
6	S. dasyclada		1	121.1±4.1			6.1±0.3		
			2	115.5±3.5			6.2±0.2		
			3	155.3±3.2			8.4±0.3		
		90	vid.	130.6±3.6	3.2	90	6.9±0.3	4.4	124
7	S. viminalis cl. No 7	65		144.8±8.2	0.1	99	5.2±0.3	0.8	95
8	S. viminalis cl. No 21	88		142.9±3.8	0.6	98	5.3±0.2	0.8	96
9	S. viminalis cl. No 101	65		133.8±4.8	2.1	92	5.3±0.3	0.7	96
10	S. viminalis cl. No 915	83		132.0±4.2	2.6	90	5.3±0.2	0.7	97
11	S. dasyclada cl. No 90	70		102.1±4.3	8.2	70	5.0±0.2	1.8	91

S.dasyclada and especially Swedish introduced *S.dasyclada* clone No 90 grew poorly and had small biomass increment. Swedish *S.viminalis* clones No 21, 101, 112, 183 and 195, specialized on organic or peat soils, were not productive either.

Local marshland willows are best adapted and naturally grow on exploited peatlands. Since their needs in soil fertility are somewhat low they slightly react to wastewater sludge application. They are very unproductive, most of them have poor rooting capacity, thus they are not perspective for energy forests.

In the trial of repeated selection in 1996 it was difficult to evaluate the rate of the absolute biomass increment over the first year after rooting, because in plantation of that age it was usually very low. Knowing, that highly productive energy forests on arable lands gave biomass increment in the first year up to 3.8-4 t/ha dm, their increment on exploited peatland, which comprises 2.8 t/ha dm, is quite satisfactory.

Conclusions

1. Most willow clones perspective on arable land with mineral soils grow poorly and fail to meet the requirements for biomass productivity under unfavourable conditions of exploited peatlands. Of 26 tested local and introduced willow clones only *S.viminalis* clone No. 2 is perspective for energy forests. It accumulated the greatest annual biomass increment - 12 t/ha dm.

2. Ability of the selected perspective S.viminalis clone No 2 to grow under unfavourable conditions of exploited peatlands is especially obvious when peat layer is thicker (0.5-1 m) and application of wastewater sludge is less (ecologically allowable doze 250 t/ha dm). In this case biomass increment of S.viminalis clone No 2 was 2-5 times greater than that of other 10 willow clones grown in energy forests.

3. Local marshland willows due to low rooting capacity and biomass productivity fail to meet the requirements for energy forests.

application 250 t/ha dm)

Stem number in the stump			Density, plants 10^3/ha	Stem mass		
mean M±m, units	t	%		from the stump, g	dm, t/ha	%
2.1±0.1				79		
2.1±0.1				105		
2.0±0.1				156		
2.1±0.1	-	100	24.86	113	1.3	100
2.6±0.1				173		
2.2±0.1				259		
2.2±0.1				288		
2.3±0.1	1.3	111	24.0	240	2.8	208
2.5±0.1				45		
3.2±0.2				45		
2.5±0.1				68		
2.7±0.2	3.1	131	22.28	53	0.6	43
2.6±0.1				84		
3.6±0.2				93		
2.2±0.1				177		
2.8±0.1	4.2	137	24.31	118	1.4	106
2.3±0.2				79		
1.9±0.1				79		
2.0±0.1				94		
2.1±0.1	0.1	99	20.33	84	0.8	63
1.6±0.1				56		
1.6±0.1				45		
1.4±0.1				105		
1.5±0.1	3.6	73	25.72	69	0.8	63
1.9±0.2	0.9	91	18.57	119	1.1	80
2.2±0.2	0.5	105	25.14	99	1.2	89
2.1±0.2	0.0	100	18.57	95	0.9	64
2.2±0.2	0.5	105	23.71	94	1.1	80
2.2±0.2	0.5	106	20.00	66	0.6	47

4. The results of willows selection tests have shown, that biomass increment of the most perspective clone on exploited peatland fertilized with wastewater sludge is equal to the amount of the biomass in energy forests growing on arable mineral soil.

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ОТБОР ИВ ДЛЯ ЭНЕРГЕТИЧЕСКИХ НАСАЖДЕНИЙ НА ВЫРАБОТАННЫХ ТОРФЯНИКАХ ПРИ УТИЛИЗАЦИИ ОСАДКОВ СТОЧНЫХ ВОД

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Резюме

Изучено возможности выращивания на выработанных торфяниках, при утилизации осадков сточных вод, 12 местных и 14 интродуцированных видов и клонов ив. Большинство испытанных ив предназначены для выращивания энергетических насаждений на окультуренных почвах, 5 видов являются естественно произрастающими представителями болотистых местопроизрастаний. Исследования произведены в 1993-96 г. заложенных опытах на торфяниках верхового и переходного типа применением различных доз (250-500 т/га сухого вещества) осадков сточных вод.

Установлено, что в неблагоприятных условиях торфяных почв из испытанных 26 клонов ив может произрастать *Salix viminalis* клон № 2. Получен большой средний годовой прирост его биомассы (12 т/га с в) не уступает приросту биомассы энергетических плантаций, созданных на окультуренных минеральных почвах. Большинство на окультуренных почвах выращиваемых ив, а также ивы болотистых местопроизрастаний на выработанных торфяниках растут плохо, накопляют небольшое количество биомассы и не отвечают требованиям продуктивности энергетических насаждений, поэтому являются неперспективными.

Ключевые слова: энергетические насаждения, виды и клоны ив, выработанные торфяники, осадки сточных вод.