Yielding of selected plant species cultivated for energy purposes and their quality as a fuel

Hungarian-Polish Conference on Renewable Energy Resource

INSTITUTE OF SOIL SCIENCE AND PLANT CULTIVATION – NATIONAL RESEARCH INSTITUTE

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150 years of tradition in agricultural science in Pulawy

1862 – Technical Institute of Technology Agriculture and Forestry

1917 – National Research Institute of Rural Husbandry (PINGW)

1950 – Institute of Soil Science and Plant Cultivation (IUNG)

2005 – Institute of Soil Science and Plant Cultivation – National Research Institute (IUNG-PIB)

- **the oldest agricultural centre in Poland**
- **the second oldest agricultural centre in Europe (after Rothamsted)**

Main research problems concerning on crop cultivation for energy purposes

1. Production of raw material for energy utilization (biomass, biogas, bioethanol).
2. Analysis of low regulation for renewable energy production.
3. Analysis of availability and usefulness of soils for cultivation of energy plants.
4. Environmental aspects of cultivation of energy crops.
5. Agrotechnique and yielding of energy crops.
6. Economic analysis of energy crops cultivation.
7. Analysis of availability and usefulness of sideline agricultural products.

Crops in research

Biomass:	**Biogas:**	**Liquid fuels:**
Willow	Maize	Maize
Miscathus	Sorghum	Triticale
Virginia mallow	Rye	Rye
Black locust	Triticale	Sugar beet
Poplar	Sugar beet	Rape
Jerusalem artichoke	Jerusalem artichoke	
Red canary grass	Virginia mallow	
Sakhalin Knotweed	Red canary grass	
Prairie cordgrass *(Spartina pectinata)*		
Switchgrass		

Selected elements of agotechnique

Gatunek	Density of plants [tys./ha]	Fertilization [kg/ha]			Weed control	Diseases and insect pests
		N	P_2O_5	K_2O		
Willow	40	75	50	75	mechanical + herbicide	pesticides
Miskanthus	15	75	50	75	mechanical	no
Virginia mallow	10 20	75	50	75	mechanical + herbicide	pesticides

Willow - *Salix viminalis*

ADVANTAGES:

- **High yield – is about 10-19 t/ha in dry mass, is dependent from: condition of habitat, variety and frequency of harvest;**
- **usefulness 15-20 years;**
- **chip seedling (cutling) ;**

DISADVANTAGES

- **Humidity of collect biomass is near 50%;**
- **difficult mechanization of harvest;**
- **big water requirements, it requires good soils rather ;**
- **big threat by insects and diseases .**

One year willow

Three years willow

Establishment of plantation

Harvest of willow

Yields of willow harvested in every year (t d.m./ha) for different soils

Soil	2005	2006	2007	2008	2009	Mean
Heavy	12,8	11,1	12,7	17,3	16,8	14,1
Medium	10,8	11,5	12,4	13,7	15,9	12,9
Light	10,1	11,9	12,3	20,4	17,3	14,4
Mean	*11,2*	*11,5*	*12,5*	*17,1*	*16,7*	-

Biometric characteristics of the willow harvested every year (heavy soil)

Genotypes	Number of lives stems	Plant height [m]	Steam diameter [mm]	Number of lifeless stems
1023	**10,4**	**2,1**	**9,0**	**2,4**
1047	**9,6**	**2,0**	**9,2**	**4,4**
1052	**9,4**	**2,5**	**9,3**	**4,0**
1054	**14,5**	**1,9**	**7,4**	**1,4**
Gigantea	**13,0**	**1,9**	**8.9**	**3,8**
Tora	**9,3**	**2,3**	**10,5**	**3,0**
Torhild	**9,9**	**2,3**	**10,8**	**2,9**
Olof	**9,8**	**2,3**	**10,2**	**1,9**
Sven	**10,0**	**2,2**	**10,1**	**3,0**
Mean	**10,7**	**2,2**	**9,5**	**3,0**

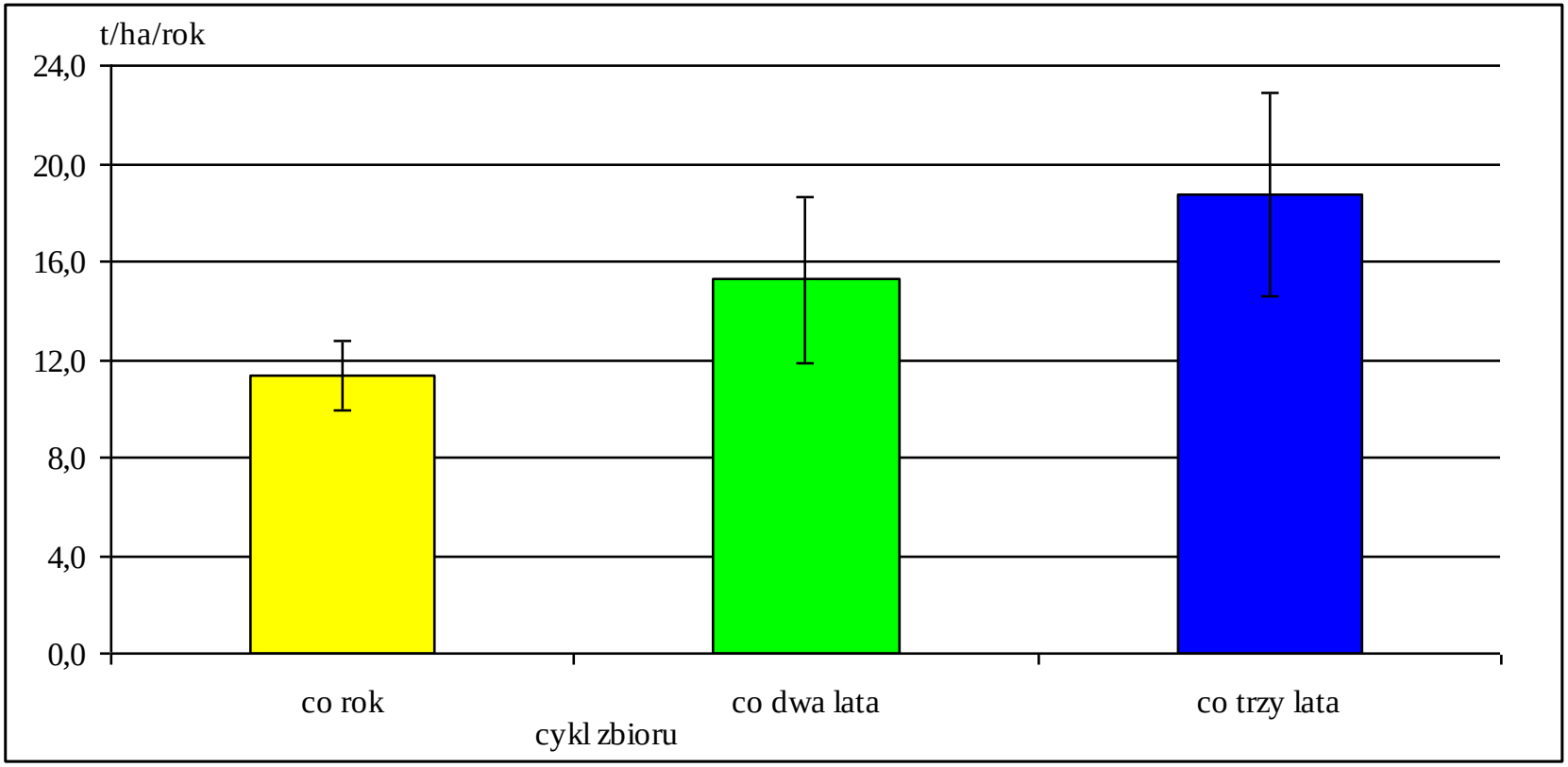
Relative yield of dry mass (%) for different genotypes of willow (2008)

Genotyp	Heavy soil	Light soil	Medium soil
1023	**88**	**102**	**118**
1047	**75**	**73**	**126**
1052	**77**	**73**	**91**
1054	**73**	**-**	**77**
Gigantea	**109**	**100**	**85**
Tora	**125**	**104**	**93**
Torhild	**122**	**127**	**90**
Olof	**117**	**111**	**120**
Sven	**111**	**108**	**100**
Średnio	**100**	**100**	**100**

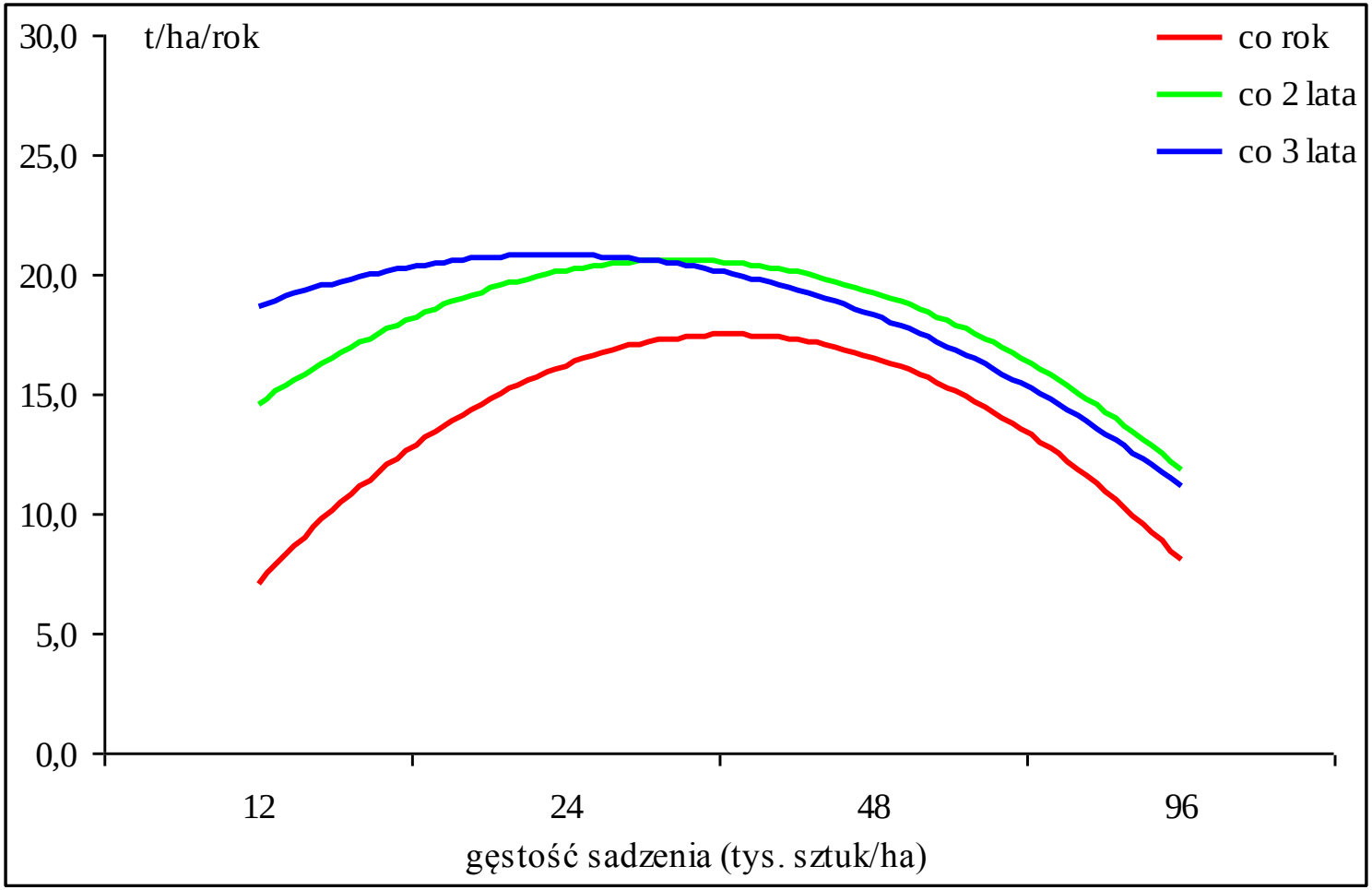
Yield of willow dry mass in depending on the frequency of harvest

Genotypes	1 year cycle			**Sum of the 3 years= 100%**	**3 years cycle**	
	2004	2005	2006		t/ha	%
Heavy soil						
1023	16,6	12,6	10,0	**39,2**	**54,9**	**140,0**
1047	14,1	12,7	12,8	**39,6**	**47,4**	**119,7**
1052	17,2	13,7	10,1	**41,0**	**48,0**	**117,0**
1054	10,8	12,4	11,5	**34,7**	**46,8**	**134,9**
Humidity (%)	50,1	50,3	51,4	**50,6**	**47,5**	**-**
Medium soil						
1023	13,4	11,0	11,2	**35,6**	**40,8**	**114,6**
1047	12,7	9,4	11,2	**33,3**	**45,6**	**137,0**
1052	13,1	10,8	10,8	**34,7**	**40,2**	**115,8**
1054	14,0	12,1	12,7	**38,8**	**45,6**	**117,5**
Humidity (%)	50,2	49,9	51,6	**50,7**	**45,7**	**-**

Dry matter yield on average for seven genotypes of willow harvested in 1, 2 and 3-year harvest cycles (Stolarski i in. 2006)



Yielding of willow in depending on plant density and frequency of harvest, on average for the 5 varieties (Stolarski 2009)



Poplar *(Populus Sp.)* – First year of growth

2 years Poplar

Plantation established with long stem

Poplar plantation established with long stem in first year growth

Usefulness of black locust for cultivation in marginal soils

Black locust *(Robinia pseudoacacia)* – I year growth

Black locust after first year growth

Miscanthus

Origin - Japan, China and Indochina - type of photosynthesis C4.

ADVANTAGE:

- **big potential yield;**
- **period of use 15-20 years;**
- **possible of utilization traditional agricultural machinery for harvest;**
- **small fertilization requirements.**

DISADVANTAGE:

- **Reproduction only fragmentation of rootstock or production seedling with method in vitro;**
- **Dangerous of to freeze, especially in first year after planting from in vitro cultures;**
- **high cost of seedling (2,8-4,2 thousand Euro/ha).**

Genotypes of miscanthus in research:

Giganteus - *M. sacchariflorus* i *M. sinensis*

M7 - *M. sinensis* klon Gofal,

M40 - *M. sinensis* klon Silver Feather,

M105- *M. saccharif. (*Robustus) i *M. sinesis*

M114 - *M. sacchariflorus* klon Robustus,

M115 - *M. saccharif.* Robustus i *M. sinensis*,

M117- *M. sacchariflorus i M. sinensis.*


Giganteus
M 7
M 40
105
M 114
M 115
M 117
Giganteus
M 7
M 40
M 105
M 114
M 115
M 117

Plantation of miscanthus in spring

Harvest of miscanthus

Harvested miscanthus

Yields of miscanthus (t d.m./ha) for different soils

Soil	2005	2006	*2007*	*2008*	*Mean*
Heavy	**19,2**	**15,6**	***15,8***	***21,0***	***17,9***
Medium	**20,7**	**16,7**	***21,0***	***16,0***	***18,9***
Mean	***20,0***	***16,2***	***18,4***	***18,5***	**-**

The biometric characteristics of miscanthus harvested in late autumn, the average of the years 2007 and 2008 for both soil

Genotypes	Number of stems	Steam diameter [mm]	Plant height [cm]	The share of leaves in d.m. yield (%)
Giganteus	48	7,6	259	28,2
M7	108	5,7	216	39,2
M40	76	5,3	218	41,0
M105	63	5,6	196	39,6
M115	92	5,5	226	36,4

Relative yield of dry mass (%) for different genotypes of miscanthus (2004-2007)

Genotypes	Heavy soil		Medium soil	
	t/ha	%	t/ha	%
Giganteus	*17,2*	109	*17,0*	94
M 7 – Gofal	*18,3*	116	*19,9*	110
M 40 – S.F.	*12,0*	76	*15,1*	83
M 105	*14,6*	92	*16,6*	76
M 115	*17,0*	108	*21,9*	121
Mean	*15,8*	*100*	*18,1*	*100*
Humidity (%)	35 - 54		35 - 45	

Yield of miscanthus cultivated in heavy soil in depending of harvest time.

Genotypes	Autumn harvest (XII.2007)		Spring harvest (III.2008)	
	Yield t.d.m./ha	*Humidity (%)*	*Yield t.d.m./ha*	*Humidity (%)*
Giganteus	19,9	51	15,1	28
M7	22,5	55	16,8	31
M40	17,3	55	12,5	30
M105	19,4	52	13,3	34
M115	25,4	58	18,6	30
Mean	*20,8*	*54*	*15,4*	*30*

Virginia mallow (fanpetals) *(Sida hermaphrodita Rusby)*

Origin – North America.

ADVANTAGE:

- **low content of ash and N;**
- **harvest– late autumn – winter (humidity 25-30%);**
- **possibility cultivation in weak soils.**

DISADVANTAGE:

- **low able of seed to germination**
- **big threat by diseases.**

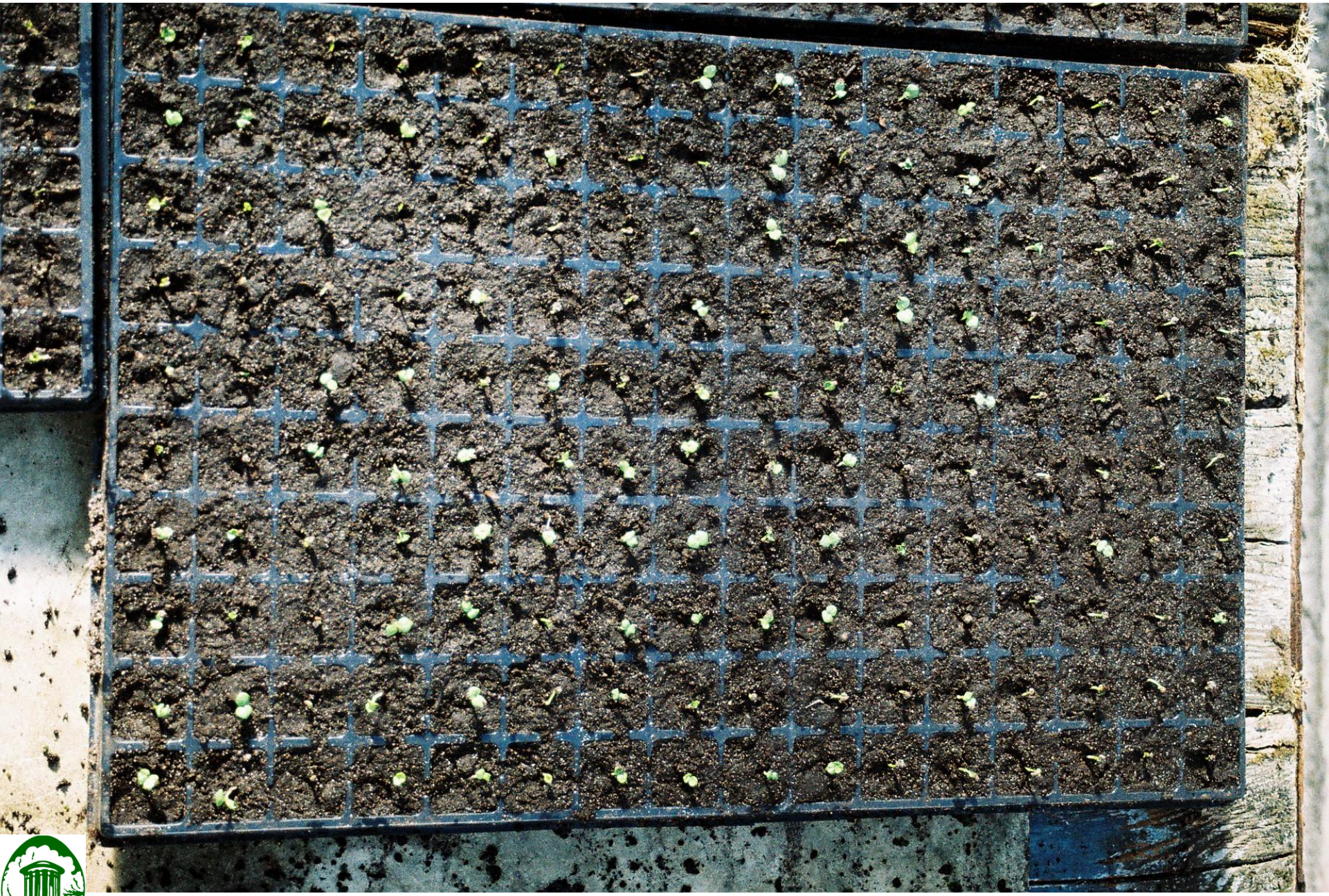
Yields of virginia mallow (t d.m./ha) for different soils

Soil	Plant density pieces/ha	2005	2006	2007	2008	Mean
Heavy	**10 000**	**10,0**	**10,3**	**9,3**	**8,2**	**9,4**
	20 000	**20,8**	**20,4**	**17,1**	**13,8**	**18,0**
Light	**20 000**	**20,5**	**12,9**	**11,1**	**21,1**	**16,4**
Medium	**10 000**	**9,0**	**11,4**	**9,6**	**7,9**	**9,5**
Mean		**15,1**	**13,8**	**11,8**	**12,8**	**-**
Humidity (%)		25,5 – 27,5	21,3 – 29,3	24,5 – 28,7	17,6 – 19,3	

Virginia mallow

Established of plantation:

1. **Sowing seeds directly into the ground - poor germination (very small seeds (mass 1000 seeds is 2-3g), the large proportion of seeds with a hard cover.**
2. **Seedling production.**
3. **Vegetative cuttings from the distribution of carp.**



The calorific value of biomass

Characteristic	unit	Pine wood	Willow	Sida	Miscanthus	Red canary grass
Calorific value	*MJ/kg*	*18,8*	*18,0*	*17,4*	*17,3*	*17,5*
Ash	%	0,8	1,2	1,9	2,8	7,3
N	%	0,1	0,7	0,22	0,22	1,4
P	%	0,003	0,07	0,02	0,01	0,14
K	%	0,01	0,31	0,34	0,27	2,6
Na	%	0,01	< 0,004	< 0,005	< 0,005	< 0,004
Si	%	0,22	0,02	0,001	0,08	0,33
Cl	%	0,009	0,02	0,01	0,02	0,09 – 1,12 **
Cd	mg/kg	0,26	1,59	0,21	0,07	0,02
Pb	mg/kg	2,38	0,1	0,36	0,53	0,2
Zn	mg/kg	37,6	83,0	34,2	21,5	22,9

Profitability of the production of biomass for energy purposes (loco field) depending on the species of plants, yield and sales price

Crop / Specyfication	**Willow**		**Miscanthus**	**Virginia mallow**
	3 years harvest	1 years harvest		
Costs of production zł/ha/year	1945	2912	3425	2977
Yield t.d.m./ha/year	**10** (8-12)	**9** (7-11)	**12** (9-15)	**9** (7-11)
Costs of production (zł/t/year)	**194** (243-162)	**324** (416-265)	**285** (381-228)	**331** (425-271)
Price of biomass sales (zł/t)	**288** (256-320)			
Profit / Loss (zł/t/year)	**128** (69-177)	**19** (-90 - 100)	**43** (-71 - 124)	**35** (-99 - 94)
Profit / Loss (zł/ha/year)	**1282** (548-2129)	**169** (-615-1079)	**503** (-626 -1820)	**104** (-680 -1013)

Summary

1. **Yields of perennial crops grown for energy purposes are very different. Its depending on the quality of soil, weather conditions and crop management.**

2. **In the experiments the highest yields were obtained from miscanthus with the limits 17-18 t DM / ha. Willow yield fluctuated depending on the variety and frequency of harvest from 11 to 17 t / ha / year, and virginia from 9 to 16-18 t / ha depending on plant density.**

Summary

3. **Potentially, the production of biomass for heat and power can be used several species of plants, but in light of past studies, in Polish conditions the main will by shrubs and tress in short rotation.**

4. **Agricultural production for energy purposes must be evaluated by economic, energy, and environmental criteria (water balances, greenhouse gas balance, biodiversity, landscape, etc.).**


Thank you for attention

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