TEKA Kom. Mot. i Energ. Roln. – OL PAN, 2011, 11, 343–353

EVALUATION OF HARVEST OF ENERGETIC BASKET WILLOW[1]

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Summary. The aim of the investigations was the assessment of the size of harvest of five energetic basket willow clones at a plantation of the Forest Inspectorate Krzeszowice, the Forest Inspectorate Brodła branch, in the Malopolska voivodeship.

The article shows that in the years 2003, 2006 and in 2011 the highest crops of clone No. 1056 were obtained. Due to the extremely dry 2003 year the yield of this clone was evaluated as lower than in 2006. The 2011 harvest is estimated as lower than in 2006. The willow *Salix viminalis* is a plant which easily adapts to vegetation on any soil. The plant growing does not require any special cultivation treatment. By the establishment and maintenance of willow plantations it is possible to contribute to rural development, increase income and reduce unemployment in the country. Farmers are willing to undertake willow plantations if its sale at attractive prices is guaranteed.

The Polish market for biomass is formed slowly. To be able to develop fully and be profitable you need much more effort as well as technical and economic ventures.

In 2007 member countries of the European Union endorsed the "Climate package 3 x 20". By 2020 they plan 20-percent reduction in energy consumption, increase to 20% of energy produced from alternative sources and 20-percent reduction in CO_2 emissions. Europe is looking for alternatives to conventional energy sources, the combustion of which releases a greenhouse gas - carbon dioxide.

Key words: alternative energy, energetic plants, energetic willow, clone, harvest, "Climate package 3 x 20".

INTRODUCTION

In the last twenty years Poland has undergone profound economic transformation. Energy Policy of the European Union envisages providing a reliable, affordable and environmentally friendly energy supply. Poland is adapting to these patterns and looking for new and renewable energy sources. Among the energy crops the greatest chance belongs to the energetic willow *Salix viminalis*, which can grow both on rural land and on grassland. Willow is a plant with no special cultivation needs. It can grow both in very dry, poor in nutrients areas and in very humid and fertile ones.

Cultivation of willow *Salix viminalis* contributes to the introduction of new, attractive product on the market. A 4-year old willow plantation has a 14 times higher growth, than willow growing

[1] The paper has been prepared within the AGH – University of Science and Technology – statutory research work No 11.11.100.482

at the same time in a natural forest. If crops become widespread, then in the future they will be partially completed by wood harvested from forests [8].

Willow has a growing interest among farmers and small manufacturing companies. Farmers having land of low agricultural productivity may intend to grow the willows. Growing willow on marginal land meets the expectations of growers. It does not require large inputs of labor and is characterized by low energy consumption (low demand for fertilizers and pesticides), high productivity and the ability to use standard machines.

Farmers undertake willow plantations, and specialized companies process it to biomass. Apart from energetic value willow also has great ecological advantage. It can be used to protect the environment, among others to create buffer zones along routes or for the reclamation activities in post-industrial areas [ibid.].

ENERGY SOURCES

The term 'energy source' is understood as primary energy source (not processed) of fuel, nuclear, water, Earth's interior and wind energy, solar radiation and chemical reactions. The primary source of energy for Earth is the solar radiation, with which the power of about 178 PW reaches the Earth, of which approximately 30% is reflected by the atmosphere, and more than 45% is absorbed by the land and sea. The rest is consumed in the process of photosynthesis. Throughout the ages fossil fuels have been formed: coal, peat, crude oil and natural gas.

Huge demand for energy occurred in the era of the industrial revolution. In 1980 energy consumption increased 10 times, although the number of people increased by only 2.5 times. The increase in unit consumption per capita has still been growing.

In the second half of the twentieth century coal has ceased to be a major source of energy, especially in the developed countries. For ecological reasons, it has been replaced by the petroleum and natural gas. Electricity, which played a central role in the industry and the economy, is produced mainly in thermal power plants, water, nuclear and wind [3, 7]. Thermal power plants produce over 60% of global energy. Hydroelectric plants do not pollute the environment, but require appropriate terrain and a considerable potential of water, besides they incur large costs associated with the construction of dams. Hydropower is much cheaper than thermal plants. It is also better in terms of ecology. Hydroelectric power stations provide 21% of all the electricity in the world.

Depletion of energy resources and oil crises have led the world to looking for alternative energy sources. Compared with other countries in the EU, Poland has a large technical potential of biomass and considerable resources of geothermal energy.

BIOMASS

Biomass is organic matter produced in the process of photosynthesis from solar energy, carbon dioxide and water. The origin of the biomass can be varied: field crop production, the waste found in food industry, the waste wood as well as pulp and paper mills (12, 13, 17). The production has been started of biomass for energy purposes on special plantations of fast growing trees (willow, poplar), rape, topinambur [4, 5, 19], sunflower, mallow slime, fodder beet and grass (Miscanthus giganteus) [1, 2]. A significant source of biomass is waste from animal production and waste generated in municipal (sewage sludge, household waste, waste paper) (Tab. 1).

Table 1. Characteristics of plants cultivated on energetic plantations [1]

biomethane yield (m^3/t d.m.)	production of biomethane (m^3/ha)	percentage of methane	production of biogas (m^3/ha)	cultivated plant
410	13530	85	15920	Miscanthus giganteus
410	9840	85	11580	Spartina pectinata
410	3280	85	3860	grass pasture
450	10800	83	13010	maize
410	6150	85	7240	alfalfa
840	18820	85	22140	beets (roots and leaves)
390	3120	75	4160	wheat (grain and straw)

t. d.m. - ton of dry matter

Unconventional energy sources play an important role in increasing the profitability of agriculture goods and in activation of the rural population. The particular usefulness of alternative energy sources for rural areas is due to the fact that the installations can be tailored to the needs of farmers and local communities. In the case of the wide rural areas may constitute a supplementary, economically attractive source of energy, relieving overburdened rural electricity network. The development of biofuels and biomass for heating purposes can be an incentive for the cultivation of plants for non-food purposes [9, 17].

WILLOW *SALIX VIMINALIS*

Willow *Salix viminalis* (Fig. 1) as an energy plant has raised a lot of interest, because of the high yielding. Type of *Salix* includes over 300 species that occur as trees, shrubs or dwarf shrubs. Shrub willow species are used mainly for basket-work, but fast-growing forms are assigned for energy purposes. It is possible to obtain a change in the form of certain species, depending on cultivation. Some of them (sallow) may exist in two forms simultaneously. Willows have low soil requirements, but most grow in wetlands and near watersources.

Fig. 1. Willow *Salix viminalis* [own material]

During the first period after setting up of plantations, willow *Salix viminalis* requires special care. Fast-growing weeds choke the young seedlings, even when the field in the year before planting was well prepared. Plant Protection Institute in Poznan recommends the use of herbicide, before the shoots start to grow.

Herbicide doses are dependent on the nature and development stages of weeds. These treatments can be performed during the growing season of plants after the earlier application of protectors that cover the young shoots. If chemical weed control method does not afford the desired results, it can be destroyed by mechanical means. Spacing should be expanded twice, before a strong root system of weeds is formed [14]. In the first year of growing, plants have a root system, which throughout the years develops into intense increments.

The greatest demand for minerals in the plants appears in the second year, because then there is the greatest weight gain. In subsequent years of growing the plants you do not need to apply almost any agricultural practices. Demand for fertilizers is decreasing, because they collect nutrients from the organic litter layer formed of fallen leaves [10].

The energy value of willow is comparable to pulverized coal. As we know, willow is an ecological product, so it has completely organic combustion parameters. Such characteristics make it like the fuel of the future [18].

For many years in Poland there is cultivation of willow for basket-work or honey-yielding aims, thanks to early flowering period. Crops willow *Salix viminalis* and *Salix purpurea* started about 20 years ago in order to use the energy [11]. These species are characterized by very rapid and large increase in biomass, as well as disease resistance (scab, gangrene of shoots) and harmful insects.

After the first year of growing, shoots should be cut at the height of 3 cm above the soil surface, so that they have dormant buds. If the cut bars correspond to the standards, they can be used for new plantings. In the following years harvest is made each year, whether the plants are intended for fuel pellets, the cuttings to increase the plantation or cuttings for sale. If we make a harvest every 2 or 3 years, the resulting biomass is used for heating purposes and for production of chipboard. After harvesting willow plantations should be intensively fertilized to get crops faster. Exploitation of the plantation may last up to 30 years. After the liquidation of the plantation, soil should be renovated [15, 16].

For single collection they use combine harvester or sheaf-binders. To cut willow stems on small plantations you can use special sickle (Fig. 2) or hand mower blades: exhaust or tractor.

Fig. 2. The employee of the Forest Inspectorate Brodła cuts the stems with the special sickle [own material]

PURPOSE AND METHODS

The task of the research study was to assess the economic benefits of growing willow *Salix viminalis* in Forest Inspectorate Brodła (municipality Alwernia), 30 km west of Krakow (Fig. 3). Experimental plantation was established on sandy soils.

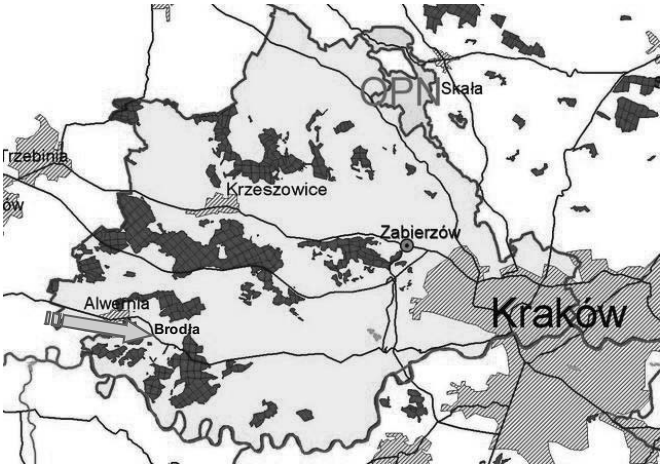

Fig.3. Location of Forest Inspectorate Brodła

Inoculated willow clones were marked by numbers: 1051, 1052, 1054, 1056, 1059, 1007, 1015 and 1033rd. In an experimental nursery (Fig. 4 and 5) planting of seedlings was carried out in six rows: at 50 cm, a length of 10 meters for each clone. Seedlings were distributed at 33 cm.

The aim of the study was the choice of clone whose yield is the largest and the most profitable. The study was realized in 2003, 2006 and in 2011. Subject to annual growth were clones with the following numbers: 1051, 1052, 1054, 1056 and 1059th.

Fig. 4. The experimental energy willow plantation in the Forest Inspectorate Brodła

Fig. 5. Author of the article near clone 1052

Both in 2003 and in 2006 a study was started from measuring the height of plants of 50 samples of each clone. The thickness of individual clones shoots was measured at the height of 100 cm plants (Tab. 2). Mean thickness of stems of each clone was calculated. The mass of individual shoots of 100 clones (t/ha) was accepted for the determination of the estimated one-year yield of individual clones (Tab. 3).

Table 2. The results of calculations of average thickness of clone shoots [own preparation]

clones	average shoot thickness [mm]
1051	6,9
1052	4,17
1054	8,6
1056	10,2
1059	9,6

Table 3. The results of the mass investigations (2003 r.)

	no. clone	member of shoots	mass [kg]
1	1051	100	14,5
2	1052	100	9,8
3	1054	100	20,5
4	1056	100	21,6
5	1059	100	16,4

In 2011 the study was limited to 15 random shoots of each clone and their height (Fig. 6) and thickness (Fig. 7 and 8). During the fieldwork it was found, that the highest shoots (average height 305 cm) belonged to clone No. 1056. This clone also had the thickest stems (Tab. 4). It can be concluded that the yield from planting clone No. 1056 will be the highest.

Fig. 6. Assessment of shoots by the author of article. The highest has a clone No. 1056

Fig. 7. Visible differences in thickness of stems of different clones; in the foreground clone No. 1056

Fig. 8. The thickest stems of clone No. 1056

Table 4. The results of investigations of the plants' height in 2011 (the empirical data)

clone no.	average height of shoots in cm	average shoot thickness (mm) at the height of 100 cm
1051	255	16
1052	267	17
1054	286	18
1056	305	22
1059	270	13
1007	not measured	not measured
1015	not measured	not measured
1033	not measured	not measured

RESULTS AND DISCUSSION

Based on the investigation [20] it was found, that in the first year of cultivation annual growth of thickness was 7 ÷ 13 mm. Measuring in 2003 showed that clone 1056 had the thickest stems (Tab. 3). One hundred shoots of clones number 1056 and number 1054 achieved the largest weight: 21,6 kg and 20,5 kg. After the weight test there were counted the shoots on the surface of 1 m^2. Since in the nursery the willow grew at the spacing of 0.5 m, the surface area of 1 m^2 included two rows. On this basis the estimated yield (in tons per 1 hectare) of individual clones in 2003 and in 2006 was calculated (Fig. 9 and 10).

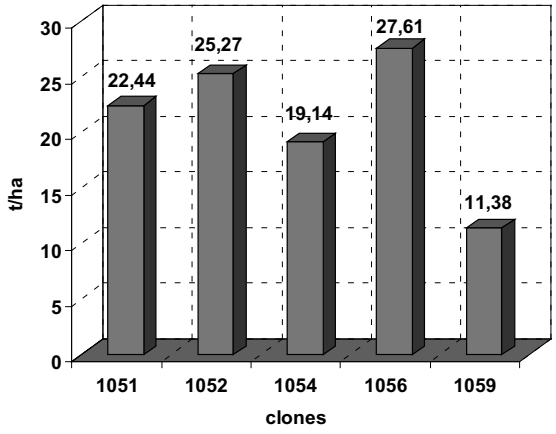

Fig. 9. Graphic interpretation of estimated yield in tons per 1 hectare of willow clones in 2003 [own preparation]

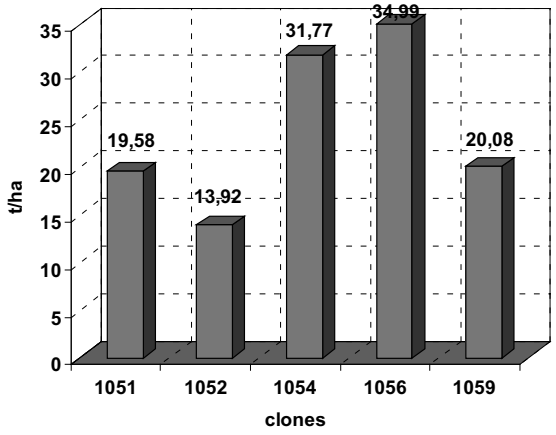

Fig. 10. Graphic interpretation of estimated yield in tons per 1 hectare of willow clones in 2006 [own preparation]

In 2011 the highest yield is expected for clones 1056 (approximately 35 tons) and 1054 (approximately 32 tons).

CONCLUSIONS

In 2003 and 2006 the highest yield was estimated for the planting of willow clone No. 1056. Therefore, to establish the potential of energy plantations you need cuttings of this clone. Willow *Salix viminalis* is a perennial which grows on almost any soil. But it has a high demand for water. The year 2003 was poor in rain, so it was estimated that the yield of willow was small: 27 t/ha [13]. However, in 2006 the estimated yield increased substantially: to 35 t/ha. Large demand of willow for water does not mean that you can overdo it. That happened in 2010, when following long rain the whole plantation was in the water for weeks. This fact may in turn cause lower yields.

A medium-sized area (0.5 ha) appropriate for the cultivation of willow *Salix viminalis* can supply each farm with fuel for all the year. A significant aspect of the rationale for setting up plantations of fast-growing willow and timber harvesting for energy purposes is the use of fallow land or land polluted by industry and thus excluded from the production of food raw materials [6]. In addition, a new product in form of chips, briquettes and pellets is introduced to the market.

In March 2007 at the summit of the European Union, the member countries endorsed the „Climate package 3 x 20". This document is a response to rising fuel prices and energy and finding alternatives to conventional energy sources, the combustion of which releases the greenhouse gas - carbon dioxide. By 2020 they assume 20-percent reduction in energy consumption and increase to 20% of energy produced from alternative sources, as well as 20-percent reduction in CO_2 emissions.

Poland has one of the largest in the EU countries potential for renewable energy resources. To be able to use it, there should be increased funding in research and technology development, and a system of funding projects should be created. This work is mainly inspired by the European Union, which for many years has supported the development of renewable energy sources.

The author would like to express sincere thanks to mgr. inż. Krzysztof Smaga [20], the employee of the Forest Inspectorate Krzeszowice, the Forest Inspectorate Brodła branch, for help in field studies, consultation and valuable suggestions.

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OCENA PLONOWANIA WIERZBY ENERGETYCZNEJ

Streszczenie. Celem badań była ocena wielkości plonowania pięciu klonów wierzby energetycznej z plantacji w Nadleśnictwie Brodła, woj. małopolskie. W artykule wykazano, że zarówno w latach 2003, 2006, jak i w 2011 najwyższe potencjalne plonowanie uzyska się z posadzenia klonu nr 1056. Ze względu na bardzo suchy 2003 rok plonowanie tego klonu oceniono jako niższe niż w 2006 r. W 2011 r. zakłada się słabsze zbiory niż w 2006 r. Wierzba *Salix viminalis* jest rośliną przystosowaną do wegetacji na dowolnym gruncie, a jej uprawa nie wymaga szczególnych zabiegów agrotechnicznych. Przez zakładanie i prowadzenie plantacji wierzby energetycznej można przyczynić się do rozwoju wsi, zwiększenia dochodów i zmniejszenia bezrobocia na wsi. Rolnicy będą chętnie zakładać plantacje wierzby energetycznej, jeśli będzie gwarancja sprzedaży po atrakcyjnych cenach.

Polski rynek biomasy powstaje powoli. Aby mógł się w pełni rozwinąć i być opłacalnym, potrzeba jeszcze wielu starań i przedsięwzięć technicznych i ekonomicznych.

W 2007 r. kraje członkowskie Unii Europejskiej zatwierdziły „Pakiet klimatyczny 3 x 20". Do roku 2020 zakłada się 20-procentową redukcję zużycia energii, wzrost do 20% udziału energii produkowanej ze źródeł niekonwencjonalnych oraz 20-procentową redukcję emisji CO_2. Europa poszukuje alternatywy dla konwencjonalnych nośników energii, których spalanie powoduje emisję gazu cieplarnianego – dwutlenku węgla.

Słowa kluczowe: energetyka alternatywna, rośliny energetyczne, wierzba wiciowa, klony, plonowanie, „Pakiet klimatyczny 3 x 20".