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IMPACT OF LASER BEAMS TREATMENT ON THE BIOMASS YIELD AND ENERGY VALUE OF MULTIFLORA ROSE

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ABSTRACT

The object of the paper was to determine the impact of laser beams treatment of the cuttings of multiflora rose on the yield of fresh and dry mass and the energy value. A one-factor field experiment was carried out in 2009-2013 in Mydlniki near Cracow. The impact of two doses of radiation of cuttings with laser beams on the yield, chemical composition and energy value of multiflora rose was investigated. As a result it was found out that radiation with laser beams did not influence the size of fresh yield of multiflora rose. However, bigger dose of laser radiation caused higher increase of dry mass concentration in the above-ground parts and a higher yield of dry mass. No significant impact of bio-stimulation of laser radiation of cuttings on the combustion heat and calorific value of multiflora rose was reported. A considerable content of sulphur in the multiflora rose biomass was reported.

Introduction

Combustion of fossil raw materials is a basic energy source in the modern world. Resources of these raw materials are limited and, according to the estimations, petroleum will suffice for approx. 50 years, whereas hard coal for 200 years (Szecówka, 2009). Thus, undertaking research on biomass from agricultural land as a renewable energy source is justified. Perennial energy crops in our country in 2010 occupied only 0.05% of the area of agricultural lands i.e. approx. 10,200 ha. Shrubby willow prevailed on the area of approx. 6,160 ha. According to the forecasts in 2020, in Poland, from 1.0 to 4.3 million ha of mainly poor soils of rye complexes will be designated under the crops of perennial energy plants (Czarnocka et al., 2012). Also multiflora rose, which does not react with a significant decrease of the crop-yield at the cultivation on light soils, is predisposed for plantings on these soils (Kieć et al., 2011). One of the forms of adjusting a multiflora rose to stress conditions which occur on light soils is a bio-stimulation of cuttings with a laser beam. Laser stimulation as well as magnetic field stimulation (Podleśny, 2004) or microwaves stimulation (Jakubowski, 2007) or an electric field stimulation (Marks, 2005) belong to the group of physical methods of stimulating seeds and germination material to better growth and as a consequence better yield. Works on the use of laser stimulation for the increase of cultivation plants yield was started in the 60s of the last century in the University in Almaty

(Injuszin et al., 1981). Koper (1994) and Koper et.al. (1997) have started a pre-sowing stimulation of seeds with laser beams. In the contemporary publications, results indicating a positive impact of radiation with laser beams on the potato tubers yield and flax seeds yield may be found (Dobrowolski et al., 1996). The review of the national and world literature shows that so far no research over the use of laser beams on the biomass yield of the above-ground parts of multiflora rose used for energy purposes have been undertaken.

The objective of the paper was determination of the impact of laser beams radiation of cuttings on the yield of fresh and dry mass of the above-ground parts of multiflora rose.

Material and methods

A one-factor field experiment in four replications was carried out in 2009-2013 in the randomised-blocks design in the Experimental Station of the Department of Agrotechnology and Agricultural Ecology of the University of Agriculture in Cracow located in Mydlniki next to Cracow (50°05` N, 19°51` E). A single experimental plot had the area of 10 m^2. The impact of two doses of radiation of cuttings with laser beams on the yield of fresh and dry mass of multiflora rose of Jatar variety was researched.

Irradiation of multiflora rose cuttings was carried out in 2009. Medical Laser D 68-1 emitting red light with the waves length of λ 672 nm and power 20 mW was used. Two times of interrupted exposition a) 3x3 seconds, and b) 3x9 s. were applied. The radiated cuttings were planted in spring 2009 in the spacing of 70x70 cm on the fluvioglacial brown soil of classified based onj the particle size-as loamy sands. The content of available forms of phosphorus and potassium was low, reaction was slightly acid (pH in KCl 5.93). No mineral, organic or natural fertilization nor chemical plant protection was applied. Due to weak growth of the rose biomass, the the first yield was harvested in winter 2013 for 4-year growths.

A fresh mass yield and the content of dry mass were determined (in 105°C), and heat of combustion and the calorific value were measured according to Polish Norm PN 81/G 04513 pursuant to DIN 51731 in the calorimetric bomb AC-350. The ash content was determined with a weight method – Polish Norm PN-G-04512. The carbon and hydrogen content was carried out with the Shefield method – Polish Norm PN-G-04521, the total sulphur content was determined with the combustion method in high temperature – Polish Norm PN-ISO 351.

The obtained results were statistically analysed with the use one-factorial analysis of variance (ANOVA) for the design of randomised blocks, where the period of irradiation was a factor (two levels). Significance of differences between the mean values was estimated with Tukey's test at the level of significance P=0.05.

Results and discussion

Treatment with laser beams did not cause differentiation of fresh mass yield of multiflora rose. Only tendency to higher by 4% yielding at a higher dose of irradiation with laser beams occurred (fig. 1a). The analysis of variance proved simultaneously significantly higher yield of dry mass on objects (plots) treated with laser radiation (fig. 1b) in comparison to control, by 0.66 t ha^{-1} for a lower radiation dose and by 1.42 t·ha^{-1} for a higher radiation dose. It was caused by a higher accumulation of dry mass per unit and simultaneously by lower water content in biomass formed from cuttings radiated with a laser in comparison

to the control object (field) (fig. 2). Rose shoots treated with a longer time of laser beams radiation were characterized by significantly higher dry mass content (by 3.1%) compared to the control.

The results obtained in the research are similar to the results of laser radiation of energy willow cuttings, where the increase of dry mass content in the willow leaves was reported (Jakubiak and Śliwka, 2009). According to Karu (1990) bio-simulation of plants with laser light results in absorption of radiation energy quantum by photoreceptots, which consist in cell organelles and active biological compounds. Laser radiation particularly stimulates enzymes which are responsible for cycles of energy changes in cells, which influence the synthesis and utilization of ATP (Cenian et. al., 2005). In the development cycle of plants, it shows usually in the form of speeding earlier growth stages and with the increased resistance to stress factors such as e.g. salinity (Dobrowolski et al., 2012; Jakubiak and Śliwka, 2006). A positive effect of physical stimulation may be observed in the later growth stages – plants are higher, have a higher yield of vegetative and generative parts (Podleśny and Pietruszewski 2006). In the research average dry mass content in multiflora rose biomass amounting to 54.7% (fig. 2) was similar to analogous value for energy willow (Stolarski et al., 2008). Average yield of multiflora rose dry mass in the fourth year after planting was 21.43 $t \cdot ha^{-1}$ (fig. 1b). It resulted from the fact that fertilization and plant protection was not applied and the field soil, on which radiated cuttings were planted, was of low agronomic category. Such an approach to agrotechnology of multiflora rose followed from the assumption that this plant was predisposed to be cultivated in sandy soils, which prevail in Poland and which possibly may be used in future for cultivation of energy plants. Assuming harvesting of rose in a two-year cycle, it is justified to decrease the obtained dry mass yield by half that is to 10.7 $t \cdot ha^{-1}$. Assuming this value for comparative purposes, it should be stated that such yield is similar to an average dry mass yield of energy willow harvested annually (Dubas, 2004). However, it is almost two times lower than average yield of Virginia mallow *Sida hermaphrodita* (Kalembasa and Wiśniewska, 2006) and by average of 20% lower than yields of Manitoba maple *Acer negundo* (Frączek, 2009). However, it should be emphasised that yields of mentioned plants were obtained on better soils and with fertilization. Thus, comparison should include economic indexes e.g. costs of production 1 GJ of thermal energy, which are decisive for use in the practice of research results (Bieniek and Żołnierz-Rusinek, 2008).

The analysis of variance did not prove a significant impact of laser irradiation of cuttings on the heat of combustion, calorific value and chemical composition of multiflora rose biomass (Table 1). Thus, a result part of the paper presents average values. Average value of the heat of combustion was 18, 573 $kJ \cdot kg^{-1}$and the calorific value 17,078 $kJ \cdot kg^{-1}$. Similar values of the heat of combustion and the calorific value for multiflora rose are presented by Stolarski et al. (2008). Presented parameters are similar to analogous data of energy willow (Stolarski et al., 2008). Average ash content in multiflora rose biomass was 2.4%, volatile parts 6.28%, carbon 46.2%, hydrogen 5.79% and sulphur 0.08%. These values, except for sulphur, are similar to analogous data of energy willow (Stolarski et al., 2008). Sulphur content in multiflora rose biomass was almost two times higher than in the quoted research.

In the available literature there is no research results concerning production efficiency of bio-stimulation with a laser of multiflora rose cuttings. One should thus assume, that the presented results are one of the first ones, which quantify the impact of laser beams irradiation of multiflora rose cuttings on the content of dry mass and cropping of this energy plant.

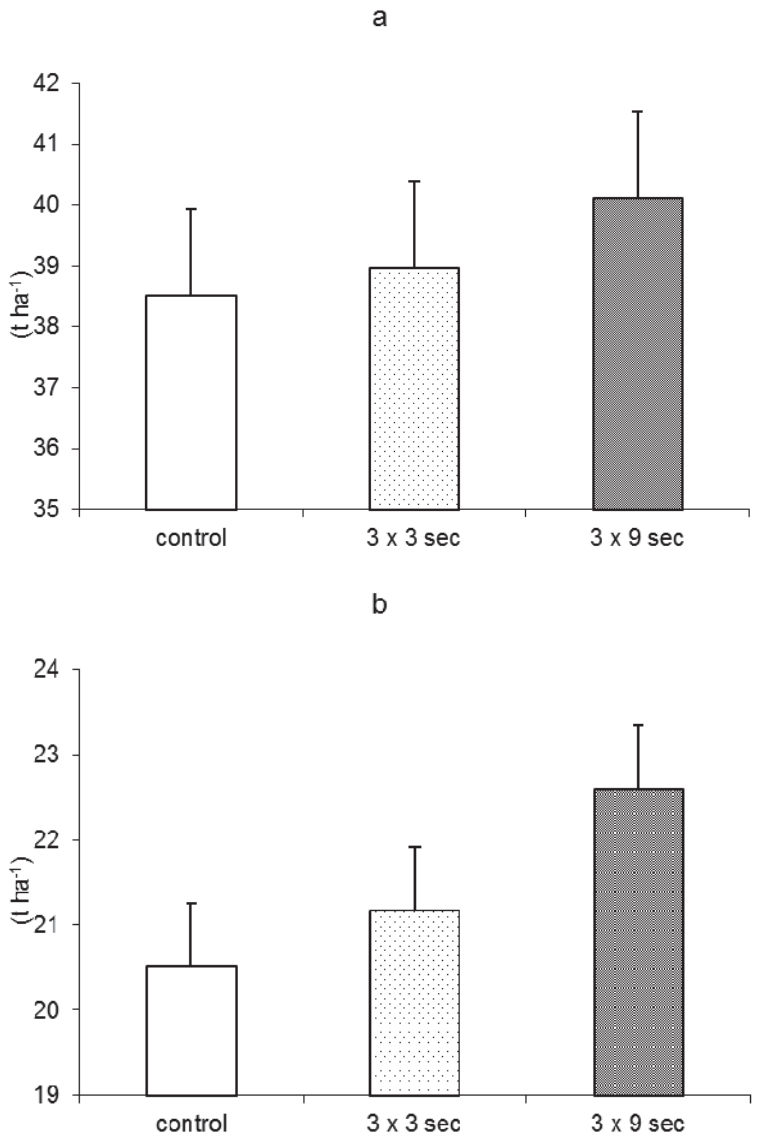

Figure 1. Yield of multiflora rose biomass treated with laser irradiation (average + SD): a) fresh mass yield (t·ha^{-1}), insignificant difference, b) yield: dry mass (t·ha^{-1}); P=0.05; LSD = 0.737

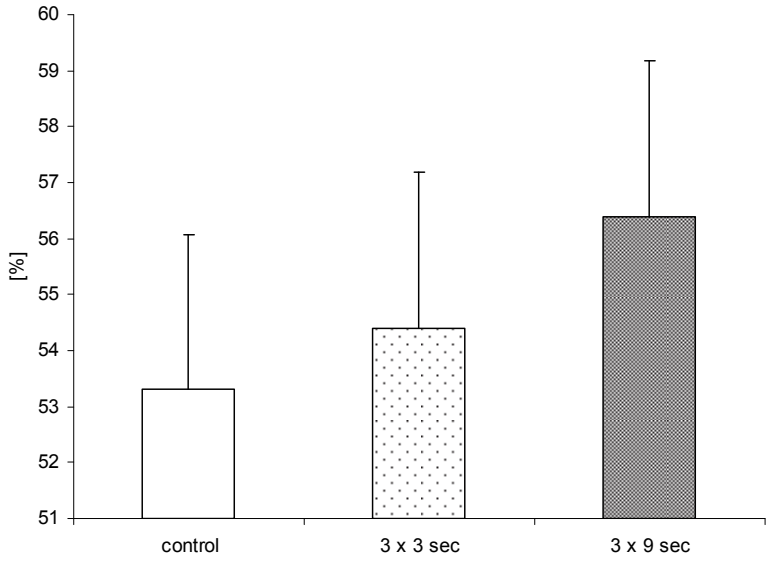

Figure 2. Dry mass content (%) in multiflora rose shoots (average +SD); P=0.05; LSD = 2.78

Table 1
Heat of combustion, calorific value and composition of multiflora rose

Item	Control	Laser beam treatment		Mean
		3 x 3 seconds	3 x 9 seconds	
Heat of combustion, ($kJ \cdot kg^{-1}$)	18568	18.574	18.577	18.573
LSD $_{\alpha=0,05}$		n.s.		
Calorific value, ($kJ \cdot kg^{-1}$)	17068	17.081	17.085	17.078
LSD $_{\alpha=0,05}$		n.s		
Ash content, (%)	2.4	2.4	2.5	2.4
LSD $_{\alpha=0,05}$		n.s		
Volatiles content, (%)	6.26	6.30	6.29	6.28
LSD $_{\alpha=0,05}$		n.s		
Carbon content, (%)	46.2	46.2	46.3	46.2
LSD $_{\alpha=0,05}$		n.s		
Hydrogen content, (%)	5.78	5.78	5.81	5.79
LSD $_{\alpha=0,05}$		n.s		
Sulphur content %	0.07	0.09	0.08	0.08
LSD $_{\alpha=0,05}$		n.s		

LSD – Least significant difference; n.s. – non significant

Conclusions

1. Laser beams treatment of multiflora rose cuttings did not cause significant diversity of yielding of multiflora rose fresh mass.
2. Cuttings treated with a higher dose of laser radiation caused higher content of dry mass in the above-ground parts and the increase of multiflora dry mass yield.
3. Laser beams treatment of multiflora rose cuttings did not influence significantly the heat of combustion and calorific value of multiflora rose.

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WPŁYW NAŚWIETLANIA PROMIENIAMI LASERA NA PLON BIOMASY I WARTOŚĆ ENERGETYCZNĄ RÓŻY WIELOKWIATOWEJ

Streszczenie. Celem pracy było określenie oddziaływania naświetlania promieniami lasera sadzonek róży wielokwiatowej na plon świeżej i suchej masy oraz wartość energetyczną. Przedmiotem badań było jednoczynnikowe doświadczenie polowe przeprowadzone w latach 2009-2013 w Mydlnikach k. Krakowa. Badano wpływ dwóch dawek naświetlania sadzonek promieniami lasera na plon, skład chemiczny i wartość energetyczną róży wielokwiatowej. W wyniku badań stwierdzono, iż naświetlanie promieniami lasera nie wpłynęło na wielkość plonu świeżej masy róży wielokwiatowej, jednakże większa dawka promieniowania laserowego spowodowała wyższy przyrost suchej masy części nadziemnych oraz większy plon suchej masy. Nie stwierdzono istotnego wpływu biostymulacji promieniowaniem laserowym sadzonek na ciepło spalania i wartość opałową róży wielokwiatowej. Stwierdzono znaczną zawartość siarki w biomasie róży wielokwiatowej.

Słowa kluczowe: biostymulacja laserowa, ciepło spalania, skład chemiczny, róża wielokwiatowa