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Effect of Pre-Sowing Laser Treatment of Seed on the Biomass Yield and Energy Value of *Lavatera Thuringiaca* L. Plant

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Summary. The aim of the study was to evaluate the effect of pre-sowing seed stimulation of Thuringian Mallow (*Lavatera thuringiaca* L.) with He-Ne laser light of different exposure times on the crop yield as well as on energetic parameters such as calorific value and combustion heat. Seeds were subjected to laser light with an exposition time of 0, 1, 5, 10, 15 and 30 minutes. Measurements were carried out independently on mature plants from the first and second vegetation year. The results varied between the samples, which indicated possible impact of laser radiation on the resultant weight and calorific value of various experimental combinations. For plants from the second vegetation year the statistical differences in calorific value, combustion heat and crop mass were found between samples characterized by different exposition times: between sample irradiated for 30 min (L30) and 1 min (L1) as well as between sample L30 and sample irradiated for 5 minutes (L5). For plants after the first vegetation year the statistically significant differences in calorific value and combustion heat were found for sample with exposition time of 15 minutes (L15) and control sample, for sample L15 and sample L5 as well as between samples L15 and L30. For all the samples from the second vegetation year the increase in combustion heat and calorific values were detected as compared to control. Thus, after the application of certain parameters of laser radiation to the processing of seeds, the plant can be more useful for energetic purposes through more efficient crop.

Key words: renewable energy, biomass, Thuringian Mallow, combustion heat, calorific value, laser radiation.

INTRODUCTION

Thuringian Mallow (*Lavatera thuringiaca* L.) is a perennial plant of the *Malvaceae* family naturally occurring in the area of Eurasia [11]. It is resistant to adverse environmental conditions. This plant is insensitive to cold and has little habitat requirements such as low requirements of water. Under favorable conditions it tillers well and can reach heights of up to 2 m. This plant can to be used as feed or fiber and is also a good perennial honey plant [13]. *Lavatera* flowers are characterized by a favorable content of flavonoids and may be used in the pharmaceutical industry [10]. Due to the fact that it is a perennial plant, it may be particularly useful for energy purposes, as it can give a relatively high biomass in a wide range of environmental conditions, positively influencing the structure and soil fertility at the same time [12]. The advantage of this plant is the efficient production of seeds, which unfortunately are characterized by a low ability to germinate under natural growing conditions. This is probably due to the possibility of seed dormancy for a relatively long period of time and the fact that when sown into the ground they may lie for up to five years before germination.

Therefore, environmentally safe treatments for improving seed germination, such as scarification, are often used [13] as well as physical treatments such as laser radiation, constant or variable electric and magnetic fields, ultrasound, ionizing radiation or microwave radiation [1, 4, 5, 9]. There are a number of scientific reports, indicating the effect of laser radiation on various organs and tissues at both animals and plants [7]. In order to improve the quality of seed material and thus achieve a higher yield of crops, usually short exposition times to laser radiation are applied in order to induce processes of bio-stimulation. Prolonged exposure to this treatment may cause adverse genetic changes and, consequently, cause mutations [14].

Laser stimulation in the case of plants contributes to the increase in their bio-energetic potential, which contributes to stimulating activities of phytochrom and phytohormone. This can lead to the activation of the fermentation process, and therefore stimulate the physiological and biochemical reactions [6]. The effect of laser stimulation is dependent on the emitted wavelength, power, and time of irradiation of material.

The above-mentioned factors can accelerate the germination process and affect the crop yield.

Daylight is necessary to activate the most important process in plant life – photosynthesis.

Plants used for energy crops should be characterized by efficient conversion of solar radiation into biomass [2] and a large annual growth under minimal habitat requirements and good adaptation to the climatic conditions in Poland [3].

Renewable energy sources will not replace conventional sources, but they can be complementary sources. The *Lavatera* variety *Uleko* used in this study is suitable for planting intended for the production of energy biomass. Depending on the soil type and fertilizer, the yield of dry weight of 15–35 t ha^{-1} can be obtained. The advantage of this plant is also a relatively low cost of plantation establishment – approx. 2 kg of seeds are required for 1ha. The chemical composition of *Lavatera* wood is similar to hardwood [15]. There are no reports in the literature on the effects of laser irradiation on the yield and energy value of the plant. These characteristics were examined for the *Rosa multiflora* [8], but in the reported studies the authors reported no statistically significant impact of this factor.

The aim of this study was to preliminary analyze the influence of pre-sowing laser irradiation of seeds on the mass of grown plants as well as to evaluate energetic parameters such as the calorific value and the combustion heat of the *Lavatera thuringiaca* shoots. Measurements were made for two independent experimental groups of plants subjected to pre-sowing laser light radiation: plants from the first and second year of vegetation.

MATERIALS AND METHODS

The experimental material consisted of plant shoots of *Lavatera thuringiaca* variety *Uleko* collected independently after the first and second vegetation year. Plants from the first vegetation year were planted in 2015 year while plants from the second vegetation year in 2014. Field experiments were conducted on experimental farm at Felin (51° 13' 21.9"N, 22° 37' 55.85" E). The tested shoots belonged to plants grown from seeds subjected to pre-sowing treatment with He-Ne laser light (wavelength of 632.8 nm and the power density of 6 mW cm^{-2}) and the exposition times of 0 (control), 1, 5, 10, 15 and 30 minutes sown in 2014 and 2015, respectively, for plants from the second and first vegetation year. The experiment was performed for the five stimulated combinations and the control sample as randomized blocks with four replicates. The crop was obtained from experimental plots, each with an area of 1 m^2. Fresh weight of 10 plants from each 1 m^2 was obtained from randomly selected plants from each experimental combination and each repetition, i.e. from 6x4 = 24 m^2 for the first vegetation year and 6x4 = 24 m^2 for the second vegetation year. After reaching full maturity stage, the plant material was collected and subjected to mass analysis. For the measurements ground shoots of Thuringian Mallow obtained from each of the five combinations and the control sample in four replications were used. Dry weight of each combination was obtained by drying the samples in an oven at 105°C for 24 hours prior to measurements. For the determination of wet and dry weight 4 independent measurements from any combination were used. For the calculation of energy parameters 12 independent measurements of each experimental combination were used.

The heat of combustion and calorific value was determined by using LECO AC600 calorimeter equipped with ACWin application. Before the measurements, test specimens were dried to the same moisture content of 5 % and subjected to a procedure enabling the calculation of the values of the calorific value and combustion heat which was expressed in kJ kg^{-1}. For the measurements TruSpeed method was applied.

The calorific value (CV) is numerically equal to the difference between combustion heat (CH) and the amount of heat needed to evaporate the water content in the fuel and resulting from the combustion of hydrogen from the fuel. The value of the heat of vaporization of water at 0°C was assumed as 2500 kJ·kg^{-1}, therefore

$$CV = CH - 2500 \times M_{H2O},$$

where:
M_{H2O} is the total weight (in kg) of water produced by burning 1 kg of material (fuel). For data analysis, the statistical program R Commander R i386, version 3.2 was used. The data were analyzed using one-way ANOVA analysis with the significance level of $p \geq 0.05$

RESULTS AND DISCUSSION

The obtained calorific values and combustion heat for the plants in the second year of vegetation are presented in Table 1. The highest average calorific value and the combustion heat was found for the L30 combination and they amounted to 17106.65 kJ·kg^{-1} and 15581.65 kJ·kg^{-1}, respectively.

L30 sample differed significantly from the L1 and L5 combinations. The lowest values of combustion heat and calorific value were recorded for the samples characterized by 1 minute exposition time to laser radiation and these parameters amounted subsequently to 16129.23 kJ·kg^{-1} and 14604.23 kJ·kg^{-1}.

Based on the obtained results it can be concluded that the application of the longest in this study pre-sowing seed stimulation time (30 minutes) resulted in the increase in the values of combustion heat and calorific value, and that the seed exposure time lasting 1 minute produced the decrease in these parameters relative to the control sample.

Table 2 shows the results of measurements of calorific value and combustion heat for the plants after the first year of vegetation. The highest values of these parameters were recorded for the seeds exposition time to laser radiation of 15 minutes. The above parameters amounted to 17166.22 kJ·kg^{-1} and 15641.22 kJ·kg^{-1} for the combustion heat and calorific value, respectively. The combination L15 differed significantly from L5, L30 and the control sample. The lowest combustion heat (16818.58 kJ·kg^{-1}) and calorific value (15293.58 kJ·kg^{-1}) were observed for the control sample. For all the samples from the second vegetation year the increase in combustion heat and calorific values were detected as compared to control.

Table 1. The mean calorific value and combustion heat for each experimental combination of Thuringian Mallow plants in the second year of vegetation. Results were subjected to pair-wise comparison using the Tukey's test

Experimental combination	Calorific value [kJ·kg^{-1}]	Combustion heat [kJ·kg^{-1}]
L1	14604.23 a	16129.23 a
L5	14953.95 a b	16478.95 a b
L10	15062.28 a c	16587.29 a c
L15	15377.88 b c	16902.88 b c
L30	15581.65 c	17106.65 c
Control	15097.12 a c	16622.12 a c

Explanations: L1, L5, L10, L15, L30 – exposition time to pre-sowing He-Ne of 1, 5, 10, 15 and 30 minutes, Control – untreated sample; means with the same letter are not significantly different at 0.05 level of significance.

Table 2. The mean calorific value and combustion heat for each experimental combination of Thuringian Mallow plants in the first year of vegetation. Results were subjected to pair-wise comparison using the Tukey's test

Experimental combination	Calorific value [kJ·kg^{-1}]	Combustion heat [kJ·kg^{-1}]
L1	15485.16 a b	17010.16 a b
L5	15392.85 a	16917.85 a
L10	15478.54 a b	17003.54 a b
L15	15641.22 b	17166.22 b
L30	15338.51 a	16863.51 a
Control	15293.58 a	16818.58 a

Explanations: as above.

As shown in Table 3, the highest fresh and dry weight of the 10 plants in the second year of vegetation was determined for the combination of L30 (1.62 kg fresh weight, 0.86 kg dry weight). This combination was also characterized by the highest calorific value and combustion heat results – compared to Table 1. Fresh and dry weights of the L30 sample were higher by approx. 40 % as compared to control. Similarly, high mass was found for the sample after laser stimulation for 15 minutes (1.48 kg fresh weight, 0.76 kg dry weight).

The lowest mass as well as energetic parameters were found for experimental combination L1 (0.72 kg fresh weight, 0.39 kg dry weight). Fresh weights differed statistically between the combinations of L1 and L30 as well as between L15 and L1, while dry weights were significantly different for samples L1 and L30.

Interestingly, for the crops from the first vegetation year, the mass of L1 sample (0.48 kg fresh and 0.26 kg dry weight) was the highest, although the results between the different combinations differed only slightly and there was no difference at the statistical level. Almost identical result for fresh weight was found for the L30 combination (0.47 kg). Comparable dry masses were found for the L30 (0.23 kg) and L15 (0.23 kg) samples. The lowest mass as well as energetic parameters were found for the control sample (fresh weight of 0.35 kg and dry weight of 0.18 kg). Relatively low weight was obtained for L10 sample (fresh weight of 0.36 kg and dry weight of 0.18 kg).

Almost the same amount of fresh weight was observed for L30 combination (0.47 kg), and similarly high values of dry matter content, like for L1 sample, were registered for L30 (0.23 kg) and L15 (0.23 kg) samples. The lowest mass as well as energy performance was observed for the control sample (0.35 kg fresh weight and 0.18 kg dry weight), low weight was also recorded for L10 sample (0.36 kg wet weight and 0.18 kg dry mass).

CONCLUSIONS

The above results allow for the conclusion that the pre-sowing laser stimulation of *Lavatera thuringiaca* seeds results in the increase of weight of harvested crop yield for the selected experimental combinations. The obtained mass of 10 plants was higher in the second year of vegetation. 40% increase in weight of the L30 sample was found relative to the control.

For that sample, the amount of energy generated in the combustion process was also the highest. In the first vegetation year the energetic parameters were similar. The highest combustion heat and calorific value were found for the sample characterised with exposition time of 15 minutes, and the lowest for the control sample. The highest masses were found for the L1, L15 and L30 samples, while the lowest for the control and L10 samples. Despite the lack of statistical differences we can see that in most of the cases the pre-sowing impact of laser light on seeds is beneficial to the final crop yield of Thuringian Mallow. Thus, after the application of certain parameters of laser radiation to

Table 3. Mean values of fresh and dry weight of the 10 plants of various combinations for Thuringian Mallow in the first and the second year of vegetation. Results were subjected to pair-wise comparison using the Tukey's test concerning the vegetation year

Experimental combination	Fresh weight of 10 plants (second year of vegetation) [kg]	Dry mass of 10 plants (second year of vegetation) [kg]	Fresh weight of 10 plants (first year of vegetation) [kg]	Dry mass of 10 plants (first year of vegetation) [kg]
L1	0.72 a	0.39 a	0.48 a	0.26 a
L5	1.03 a b	0.57 a b	0.44 a	0.21 a
L10	1.21 a c	0.66 a b	0.36 a	0.18 a
L15	1.48 b c	0.76 a b	0.43 a	0.23 a
L30	1.62 c	0.86 b	0.47 a	0.23 a
Control	0.97 a b	0.54 a b	0.35 a	0.18 a

the processing of seeds, this plant can be more useful for energetic purposes through more efficient crops.

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WPŁYW PRZEDSIEWNEGO NAŚWIETLANIA LASEREM NASION *LAVATERA THURINGIACA* L. NA PLON BIOMASY I JEJ WARTOŚĆ ENERGETYCZNĄ

Streszczenie. Celem badań była ocena wpływu przedsiewnej stymulacji nasion ślazówki turyngskiej (*Lavatera thuringiaca* L.) światłem lasera He-Ne o różnych czasach ekspozycji na uzyskany plon oraz parametry energetyczne tj. wartość opałową i ciepło spalania. Nasiona poddano oddziaływaniu lasera przez okres 0, 1, 5, 10, 15 i 30 minut. Pomiary przeprowadzono niezależnie dla roślin w drugim roku użytkowania oraz dla roślin jednorocznych. Wyniki były zróżnicowane i świadczą o wpływie promieniowania laserowego na uzyskaną masę i wartość opałową poszczególnych kombinacji ślazówki turyngskiej. Odnotowano różnice istotne statystycznie dla parametrów energetycznych tj. dla ciepła spalania, wartości opałowej oraz masy między próbkami o czasie stymulacji 30 minut (L30) a próbkami stymulowanymi przez 1 minutę (L1) oraz różnice dla próbek stymulowanych przez 30 minut (L30) i próbek stymulowanych przez 5 minut (L5) dla roślin w drugim roku wegetacji. Dla roślin po pierwszym roku wegetacji zarejestrowano różnice dla wartości opałowej i ciepła spalania między próbkami stymulowanymi przez 15 minut (L15) a próbą kontrolną, między próbkami L15 i L5 oraz między próbkami L15 a L30. Dla wszystkich próbek z drugiego roku wegetacji odnotowano zwiększenie wartości opałowej oraz ciepła spalania, w porównaniu z kontrolą. Dzięki zastosowaniu określonych parametrów promieniowania laserowego do obróbki nasion, te rośliny mogą być bardziej przydatne do celów energetycznych poprzez efektywniejszy plon.

Słowa kluczowe: energia odnawialna, biomasa, Thuringian Mallow, ciepło spalania, wartość kaloryczna, naświetlanie laserem

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Assessment of Mechanical Properties of Fresh Fruit and Brine Pickles Obtained from Selected Varieties of Field Cucumber, Depending on the Chemical Composition of Brine, Duration of Pickling and Additional Starting Cultures

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Summary. Monitoring of the mechanical properties of fruit obtained from cucumber plants is extremely important because of their use in processing, since these properties are reflected by the finished products of processing. Mechanical defects produced at the time of harvesting, during transport and at the specific stages of processing may adversely affect the course of technological processing (brine and vinegar pickling), resulting in spoilt preserves no longer useful for commercial purposes. The study was designed to identify selected mechanical properties in fresh and pickled fruit obtained from field cucumbers during spontaneous fermentation and fermentation promoted by selected lactic bacteria cultures. Additionally, water contents were measured in fresh cucumbers. The findings show significant differences between the analysed parameters.

Key words: field cucumber, pickling, peel and flesh puncture strength, water contents.

INTRODUCTION

Cucumber (Cucumis sativus L.) is an annual, allogamous plant representing gourd family. It has high requirements related to temperatures and soil. The plant originated in India and as a result cucumber is highly sensitive to ground frost, winds and cold weather, it requires fertile and highly permeable soil, which warms up rapidly and is free of frost pockets [1, 2]. The optimum temperature for germination is approx. 30 °C, yet growing in the field, the plant can develop at slightly lower temperatures, exceeding 18°C [5, 19].

The processing of vegetables based on fermentation and preservation with vinegar and sugar, designed to improve their stability has been commonly used for centuries. Food processing industry includes a wide range of plants specializing in such produce as cucumbers and cabbage as well as dried vegetables. The highly processed products account for 25% of fruit and vegetable preserves production [13, 18].

Fermentation is a long-lasting process depending to a large degree on temperature, the quantity of multiplied lactic bacteria, the contents of sodium chloride in the brine, as well as the choice of suitable starting cultures. This is a method of preserving raw materials with high water contents and chemical composition enabling accumulation of the desirable microorganisms promoting fermentation and playing the role of natural preservatives [4, 14].

Lactic acid fermentation is an anaerobic process of transformation of sugars (glycolysis) present in the raw material into lactic acid, accompanied with enzymatic changes of proteins and lipids promoted by proteases and lipases, which produce non-toxic aromas, flavours and substances modifying the texture of the produce and result in properties which are attractive for consumers. Such vegetable products have also been found with reduced contents of anti-nutrients, such as protease and phytate inhibitors responsible for malabsorption of proteins and trace elements [6, 24].

When fermentation process is carried out by homofermentative bacteria, lactic acid is the only product of metabolism of microorganisms. If heterofermentative bacteria are involved in the process, other compounds are generated in addition to the main product; these include acetic acid, ethyl alcohol, glycerine, acetic aldehyde, butanediol [3, 8, 23]. The environment hosting the fermentation reaction is found with a decrease in pH, from 5.5 to 3.5 leading to slower pace of enzymatic changes and breathing processes in the tissues, which results in oxidation of ascorbic acid and browning of the surface [3, 8, 17, 23]. Such low pH is mainly responsible for microbiological conservation of the fermented products as very few pathogens can survive in environmental conditions of this kind [22].

Mechanical properties of cucumbers are examined in order to optimize the cultivars selection, harvesting, storage, transport and processing. Cucumbers are characterized by significant anisotropy, therefore it is necessary to conduct studies on a cyclical basis and to adopt comprehensive approach. As a result it is possible to easily identify the quality of the raw material, i.e. its firmness and hardness which are