SCREENING HEMP (CANNABIS SATIVA L.) BIOMASS AND CHEMICAL COMPOSITION AS INFLUENCED BY SEED RATE AND GENOTYPE

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Abstract. Nowadays the industrial hemp (Cannabis sativa L.) becomes an attractive plant due to its multiple uses. In 2016 the cultivated area of this plant in Lithuania was close to 2.5 thousand hectares. The main interest areas in this plant are valuable seeds, fibre and hurs, cannabinoids and essential oils, and, of course, energy potential. The investigation of hemp biomass and chemical composition was carried out at the Upytė Experimental Station of LRCAF in 2014. The data showed that both factors had significant influence on hemp fresh and totally dry above-ground biomass. Notwithstanding that the amount of C, N, C/N, S, K, Na, crude ash and the calorific value were evaluated, the tested factors did not show any significant influence on the tested parameters (chemical composition).

Keywords: hemp biomass, chemical composition, calorific value.

Introduction
Nowadays we know the industrial hemp (Cannabis sativa L.) as a plant of multiple uses. Nevertheless, over many centuries hemp was used mainly as a textile plant [1-4]. Also hemp fiber could be widely used in paper, composites, agriculture, automotive, construction, isolation, medicine, etc. [5-8].

The interest in this plant is growing not only in the Baltic countries [9], but overall the world also [2; 10].

Hemp plants are growing relatively rapidly, thus enough huge amount of biomass could be produced under certain growing conditions. In the previous our trials, in 2010, plants of the tested hemp genotypes gave around 10.5 t·ha⁻¹ of dry biomass (DM), and 11.5 t·ha⁻¹ in 2011. Cultivars “Futura 75” (11.8 t·ha⁻¹), “Bialobrzeskie” (11.6 t·ha⁻¹) and “Epsilon 68” (11.3 t·ha⁻¹) showed the best results of the dry mass yield in 2010, while in 2011, the most productive were the cultivars “Beniko” (13.1 t·ha⁻¹), and “Futura 75” (12.3 t·ha⁻¹) [10].

The biomass is described as "plant material derived from the reaction between CO₂ in the air, water and sunlight, via photosynthesis, to produce carbohydrates that form the building blocks of biomass [11]. Biomass consists of different amounts of cellulose, hemicellulose, lignin and a small amount of other compounds, thus in many references the hemp chemical composition is describe generally as the amount of cellulose, holocellulose, and lignin, and very rarely the chemical composition in the elements is presented.

The aim of the paper is the presentation of some elements of chemical compositions of hemp biomass as influenced by the genotype and seed rate, as well as the evaluation of possible calorific value of hemp biomass.

Materials and methods
The investigation of the hemp plant morphological parameters was carried out at the Upytė Experimental Station of the Lithuanian Research Centre for Agriculture and Forestry in 2014. The soil – Eutri-Endohypogleyic Cambisol, CMg-n-w-eu [12].

The scheme of bi-factorial trial, plot size, etc. were described in previous paper [7].

For chemical analyses the samples were dried at 65±5 °C. Prior analyses the samples were ground by an ultracentrifugal mill ZM 200 (Retch) using sieves of 2 mm mesh size.

The C, N and S contents in the plant samples were determined simultaneously by a dry combustion method (Dumas) using a fully automatic analyser Vario EL III (Elementar, Germany). This method is based on combustion at ~ 900 °C.

Na, K were determined by atomic absorptiometry using AAnalyst 200 (Perkin Elmer).
The ash content was determined by the standard procedure (LST EN 14775). This method covers the determination of ash, expressed as the percentage of residue remaining after dry oxidation at 550.

The calorific value was measured using an IKA bomb calorimeter (C 200, Germany).

For statistical data evaluation the statistical software developed in the Lithuanian Institute of Agriculture was used, the ANOVA method was applied [13].

Meteorological conditions (Fig. 1) were described in the previous paper [7].

![Fig. 1. Mean weather temperature and precipitation during hemp growing period](image)

**Results and discussion**

In 2014, the fresh hemp biomass yield (stems, leaves, inflorescences and seeds) was enough high (30.2-48.2 t·ha⁻¹) (Table 1). The tested parameters showed a significant influence on this parameter. The yield of variety Bialobrzeskie was significantly higher (43.7 t·ha⁻¹) than that of variety USO 31 (33.3 t·ha⁻¹). Hemp sown at a higher seed rate (70 calorific⁻¹) produced higher fresh biomass yield (42.4 t·ha⁻¹) than that (3.45 calorific⁻¹) when sowing at the rate of 45 calorific⁻¹.

<table>
<thead>
<tr>
<th>Variety (Factor A)</th>
<th>Seed rate (Factor B)</th>
<th>Mean for Factor A</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>45 kg·ha⁻¹</td>
<td>70 kg·ha⁻¹</td>
</tr>
<tr>
<td>USO 31</td>
<td>30 167</td>
<td>36 476</td>
</tr>
<tr>
<td>Bialobrzeskie</td>
<td>38 905</td>
<td>48 429</td>
</tr>
<tr>
<td>Mean for Factor B</td>
<td>34 536*</td>
<td>42 452*</td>
</tr>
</tbody>
</table>

\[ \text{LCD}_{0.05} \text{ (variety)} = 3 059 \text{ LCD}_{0.05} \text{ (seed rate)} = 3 059 \text{ LCD}_{0.05} \text{ (variety x seed rate)} = 5 298 \]

* – significant at 0.05 probability level

The moisture content in the fresh biomass was between 63-66 % (Table 2). Statistical analysis did not show any significant differences in it.

Totally the dry hemp biomass yield was between 10.0 and 16.9 t·ha⁻¹ (Table 3). Both tested factors showed a significant influence on this parameter. The dry biomass yield of variety Bialobrzeskie was significantly higher (15.5 t·ha⁻¹) than that of variety USO 31 (11.8 t·ha⁻¹).

Hemp sown at a higher seed rate (70 calorific⁻¹) produced higher dry biomass yield (15.2 t·ha⁻¹) than that (12.1 calorific⁻¹) when sowing at the rate of 45 calorific⁻¹.

The carbon content found in our trials (Table 4) was slightly higher (44 %) than that found in the trials conducted in 2008-2009 where the carbon content in hemp plants was between 38 % and 41 %) [14]. Neither genotype nor seed rate showed the influence on the carbon content in hemp biomass.
Table 2

Moisture content (%) in hemp fresh biomass yield as influenced by genotype and seed rate

<table>
<thead>
<tr>
<th>Variety (Factor A)</th>
<th>Seed rate (Factor B)</th>
<th>Mean for Factor A</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>45 kg·ha⁻¹</td>
<td>70 kg·ha⁻¹</td>
</tr>
<tr>
<td>USO 31</td>
<td>66.4</td>
<td>62.7</td>
</tr>
<tr>
<td>Bialobrzeskie</td>
<td>63.8</td>
<td>65.1</td>
</tr>
<tr>
<td>Mean for Factor B</td>
<td>65.1</td>
<td>63.9</td>
</tr>
</tbody>
</table>

\(\text{LCD}_{05} (\text{variety}) = 2.22 \ \text{LCD}_{05} (\text{seed rate}) = 2.22 \ \text{LCD}_{05} (\text{variety x seed rate}) = 3.85\)

Hemp dry biomass yield (calorific) as influenced by genotype and seed rate

<table>
<thead>
<tr>
<th>Variety (Factor A)</th>
<th>Seed rate (Factor B)</th>
<th>Mean for Factor A</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>45 kg·ha⁻¹</td>
<td>70 kg·ha⁻¹</td>
</tr>
<tr>
<td>USO 31</td>
<td>10 021</td>
<td>13 624</td>
</tr>
<tr>
<td>Bialobrzeskie</td>
<td>14 205</td>
<td>16 879</td>
</tr>
<tr>
<td>Mean for Factor B</td>
<td>12 113*</td>
<td>15 252*</td>
</tr>
</tbody>
</table>

\(\text{LCD}_{05} (\text{variety}) = 1 177 \ \text{LCD}_{05} (\text{seed rate}) = 1 177 \ \text{LCD}_{05} (\text{variety x seed rate}) = 2 038\)

* – significant at 0.05 probability level;

Table 3

Carbon content (%) DM in hemp biomass as influenced by genotype and seed rate

<table>
<thead>
<tr>
<th>Variety (Factor A)</th>
<th>Seed rate (Factor B)</th>
<th>Mean for Factor A</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>45 kg·ha⁻¹</td>
<td>70 kg·ha⁻¹</td>
</tr>
<tr>
<td>USO 31</td>
<td>44.6</td>
<td>44.9</td>
</tr>
<tr>
<td>Bialobrzeskie</td>
<td>44.7</td>
<td>44.13</td>
</tr>
<tr>
<td>Mean for Factor B</td>
<td>44.65</td>
<td>44.52</td>
</tr>
</tbody>
</table>

\(\text{LCD}_{05} (\text{variety}) = 0.231 \ \text{LCD}_{05} (\text{seed rate}) = 0.231 \ \text{LCD}_{05} (\text{variety x seed rate}) = 0.400\)

The nitrogen content in hemp biomass was between 0.96-1.20 % (Table 5). Statistical analysis did not show any significant differences in it.

Table 4

Nitrogen content (%) DM in hemp biomass as influenced by genotype and seed rate

<table>
<thead>
<tr>
<th>Variety (Factor A)</th>
<th>Seed rate (Factor B)</th>
<th>Mean for Factor A</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>45 kg·ha⁻¹</td>
<td>70 kg·ha⁻¹</td>
</tr>
<tr>
<td>USO 31</td>
<td>1.06</td>
<td>0.99</td>
</tr>
<tr>
<td>Bialobrzeskie</td>
<td>0.85</td>
<td>1.20</td>
</tr>
<tr>
<td>Mean for Factor B</td>
<td>0.96</td>
<td>1.10</td>
</tr>
</tbody>
</table>

\(\text{LCD}_{05} (\text{variety}) = 0.164 \ \text{LCD}_{05} (\text{seed rate}) = 0.164 \ \text{LCD}_{05} (\text{variety x seed rate}) = 0.284\)

The ratio between the carbon and nitrogen content in hemp biomass was between 39.2 and 52.6 % (Table 6), but the influence of the tested factors was not established.

Table 5

Ratio between carbon and nitrogen content in hemp biomass as influenced by genotype and seed rate

<table>
<thead>
<tr>
<th>Variety (Factor A)</th>
<th>Seed rate (Factor B)</th>
<th>Mean for Factor A</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>45 kg ha⁻¹</td>
<td>70 kg·ha⁻¹</td>
</tr>
<tr>
<td>USO 31</td>
<td>42.58</td>
<td>46.76</td>
</tr>
<tr>
<td>Bialobrzeskie</td>
<td>52.6</td>
<td>39.21</td>
</tr>
<tr>
<td>Mean for Factor B</td>
<td>47.59</td>
<td>42.98</td>
</tr>
</tbody>
</table>

\(\text{LCD}_{05} (\text{variety}) = 7.132 \ \text{LCD}_{05} (\text{seed rate}) = 7.132 \ \text{LCD}_{05} (\text{variety x seed rate}) = 12.353\)

The sulphur content in hemp biomass did not differ between the treatments (Table 7).
Table 7

<table>
<thead>
<tr>
<th>Variety (Factor A)</th>
<th>Seed rate (Factor B)</th>
<th>Mean for Factor A</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>45 kg·ha⁻¹</td>
<td>70 kg·ha⁻¹</td>
</tr>
<tr>
<td>USO 31</td>
<td>0.14</td>
<td>0.13</td>
</tr>
<tr>
<td>Białobrzeskie</td>
<td>0.13</td>
<td>0.15</td>
</tr>
<tr>
<td>Mean for Factor B</td>
<td>0.14</td>
<td>0.14</td>
</tr>
</tbody>
</table>

$\text{LCD}_{05} (\text{variety}) = 0.015 \; \text{LCD}_{05} (\text{seed rate}) = 0.015 \; \text{LCD}_{05} (\text{variety x seed rate}) = 0.026$

The potassium content in hemp biomass was between 1.27 and 1.59 % (Table 8). Statistical analysis did not show any significant differences in it.

Table 8

<table>
<thead>
<tr>
<th>Variety (Factor A)</th>
<th>Seed rate (Factor B)</th>
<th>Mean for Factor A</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>45 kg·ha⁻¹</td>
<td>70 kg·ha⁻¹</td>
</tr>
<tr>
<td>USO 31</td>
<td>1.59</td>
<td>1.27</td>
</tr>
<tr>
<td>Białobrzeskie</td>
<td>1.45</td>
<td>1.52</td>
</tr>
<tr>
<td>Mean for Factor B</td>
<td>1.52</td>
<td>1.39</td>
</tr>
</tbody>
</table>

$\text{LCD}_{05} (\text{variety}) = 0.082 \; \text{LCD}_{05} (\text{seed rate}) = 0.082 \; \text{LCD}_{05} (\text{variety x seed rate}) = 0.142$

The content of sodium in hemp biomass was very low – 0.65-0.07 % (Table 9). Any significant differences in the sodium content in hemp biomass were not found also.

Table 9

<table>
<thead>
<tr>
<th>Variety (Factor A)</th>
<th>Seed rate (Factor B)</th>
<th>Mean for Factor A</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>45 kg·ha⁻¹</td>
<td>70 kg·ha⁻¹</td>
</tr>
<tr>
<td>USO 31</td>
<td>0.067</td>
<td>0.069</td>
</tr>
<tr>
<td>Białobrzeskie</td>
<td>0.065</td>
<td>0.070</td>
</tr>
<tr>
<td>Mean for Factor B</td>
<td>0.066</td>
<td>0.070</td>
</tr>
</tbody>
</table>

$\text{LCD}_{05} (\text{variety}) = 0.0041 \; \text{LCD}_{05} (\text{seed rate}) = 0.0041 \; \text{LCD}_{05} (\text{variety x seed rate}) = 0.0107$

The ash content is one of the major qualitative characteristics of biomass [15]. In our investigation it was really high – even 6.7-10.2 % (Table 10), while other references report about rather lower ash content. The ash content of the pellets made of hemp biomass varied from 3.6 to 3.8 % [16].

Table 10

<table>
<thead>
<tr>
<th>Variety (Factor A)</th>
<th>Seed rate (Factor B)</th>
<th>Mean for Factor A</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>45 kg·ha⁻¹</td>
<td>70 kg·ha⁻¹</td>
</tr>
<tr>
<td>USO 31</td>
<td>13.5</td>
<td>6.74</td>
</tr>
<tr>
<td>Białobrzeskie</td>
<td>7.13</td>
<td>10.16</td>
</tr>
<tr>
<td>Mean for Factor B</td>
<td>10.31</td>
<td>8.45</td>
</tr>
</tbody>
</table>

$\text{LCD}_{05} (\text{variety}) = 1.706 \; \text{LCD}_{05} (\text{seed rate}) = 1.706 \; \text{LCD}_{05} (\text{variety x seed rate}) = 2.956$

In the investigation in Latvia, the hemp stem average calorific value was 16.98 MJ·kg⁻¹ ±0.5 % [15]. In the investigation in Lithuania, the average calorific value of the pellets made of hemp biomass varied from 17.2 to 17.5 MJ·kg⁻¹ DM, and was close to the calorific value of some wood species [16].

Polish researches confirm that hemp biomass has great calorific value (about 19 MJ·kg⁻¹) and is an excellent feedstock for energy production [17].

In our investigation the calorific value of hemp biomass was close 18 MJ·kg⁻¹, and did not depend on the genotype and seed rate (Table 11).
Table 11

<table>
<thead>
<tr>
<th>Variety (Factor A)</th>
<th>Seed rate (Factor B)</th>
<th>Mean for Factor A</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>45 kg·ha(^{-1})</td>
<td>70 kg·ha(^{-1})</td>
</tr>
<tr>
<td>USO 31</td>
<td>17.50</td>
<td>18.10</td>
</tr>
<tr>
<td>Bialobrzeskie</td>
<td>17.97</td>
<td>17.73</td>
</tr>
<tr>
<td>Mean for Factor B</td>
<td>17.73</td>
<td>17.92</td>
</tr>
</tbody>
</table>

\(\text{LCD}_{05} (\text{variety}) = 0.139\) \(\text{LCD}_{05} (\text{seed rate}) = 0.139\) \(\text{LCD}_{05} (\text{variety x seed rate}) = 0.241\)

Calculations of the possible hemp calorific value harvest per ha show huge resources of energy – 175 477-299 439 kJ·ha\(^{-1}\) (Table 12). The hemp biomass calorific value per ha depended on the genotype as well as on the seed rate – variety Bialobrzeskie had greater calorific potential (277 233 kJ·ha\(^{-1}\)), than USO 31 (211 127 kJ·ha\(^{-1}\)). Crops sown at higher seed rate (70 calorific\(^{-1}\)) produced higher calorific potential (273 108 kJ·ha\(^{-1}\)) than that (215 252 kJ·ha\(^{-1}\)) sown at the seed rate of 45 calorific\(^{-1}\).

Table 12

<table>
<thead>
<tr>
<th>Variety (Factor A)</th>
<th>Seed rate (Factor B)</th>
<th>Mean for Factor A</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>45 kg·ha(^{-1})</td>
<td>70 kg·ha(^{-1})</td>
</tr>
<tr>
<td>USO 31</td>
<td>175 477</td>
<td>246 777</td>
</tr>
<tr>
<td>Bialobrzeskie</td>
<td>255 027</td>
<td>299 439</td>
</tr>
<tr>
<td>Mean for Factor B</td>
<td>215 252*</td>
<td>273 108*</td>
</tr>
</tbody>
</table>

\(\text{LCD}_{05} (\text{variety}) = 19 954.7\) \(\text{LCD}_{05} (\text{seed rate}) = 19 954.7\) \(\text{LCD}_{05} (\text{variety x seed rate}) = 34 562.6\)

* – significant at 0.05 probability level;

Conclusions

Both factors (genotype and seed rate) had a significant influence on the hemp fresh and totally dry above-ground biomass yield as well as on the calorific value per ha. Notwithstanding that the amount of C, N, C/N, S, K, Na, crude ash and the calorific value were evaluated, the tested factors did not show any significant influence on the tested parameters (chemical composition).

References


