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Hemp (*Cannabis sativa* L.) as an Environmentally Friendly Energyplant

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***Abstract* - Hemp is suitable as a renewable energy resource. The aim of this study was to clarify local hemp's (*Cannabis sativa* L.) possibilities for energy use. Arsenic (As), cadmium (Cd), lead (Pb) and titanium (Ti) presence in hemp was determined using an inductively coupled plasma optical emission spectrometer Optima 2100 DV. If there were increased N fertilizer rates, there were increased hemp 'Pūriņi' seeds and shive yield increases, but the oil content was reduced. Arsenic content was higher in the shives than in the stems with fibre. The ash content depends on non-organic substances which the plants absorb during the vegetation season. The lignin content depends on several factors: plant parts, and the N fertilizer rate. The unexplored factors have a great effect on the ash and lignin content. Hemp is suitable for cultivation and for bio-energy production in the agro-climatic conditions in Latvia.**

Keywords - Cannabis sativa* L., *oil, heavy metals, shive.

I. INTRODUCTION

Hemp has widespread use: food, animal feed and alternative energy (biogass, biodiesel and solid fuel). Hemp is a suitable plant in heavy metal contaminated soils, for production of good quality non-food products in changing climatic conditions (Citterio et al., 2003).

This plant is an irreplaceable rotation crop in organic farming (Energy..., 2009). Hemp is also quick-growing, it grows by an average of 50 cm a month. Hemp with its rich leafage suppresses weeds, and leaves left on the soil after harvesting, improve the soil structure (Adamovičs et al., 2007).

The aim of this study was to clarify local hemp's (*Cannabis sativa* L.) possibilities of use as an energy resource.

II. MATERIALS AND METHODS

Hemp (*Cannabis sativa* L.) – hemp family (*Cannbinaceae*) annual crop was tested in the following locations and under the conditions described in Table 1.

TABLE I
TRIALS' METHODS

Place		Agricultural science centre of Latgale
Soil type		Humi-podzolic gley soil
Soil composition	pH_{KCl}	7.3
	OM, %	3.8 (Turin's method)
	P_2O_5, mg kg^{-1}	83 (DL method)
	K_2O, mg kg^{-1}	65 (DL method)
Pre-crops	In 2008,	Summer rape
	In 2009	
	In 2010	Winter rape
Complex fertilizers	N:P:K, (kg ha^{-1})	6:26:30, 300
Sowing time	In 2008	9^{th} May
	In 2009	4^{th} May
	In 2010	13^{rd} May
Sowing rate	kg ha^{-1}	70
Hemp varieties	In 2008	'Pūriņi' (Latvian local hemp)
	In 2009	'Pūriņi', 'Bialobrzeskie'
	In 2010	
N fertilizer rate	kg ha^{-1}	N0, N60, N100
Harvesting time	In 2008	23^{rd} September
	In 2009	21^{st} September
	In 2010	28^{th} August
Trial plots		20 m^2
Replication		4 and 3 (in 2010)
Agro-chemicals		None

Arsenic (As), cadmium (Cd), lead (Pb) and titanium (Ti) presence was determined by the plasma optical emission spectrometer *Optima 2100 DV*, but oil content in hemp seed samples - by the corn analyzer *Infratec 1241*^{tm}.

Five consecutive growing hemp plants were taken for shive content determination, and they were cut 10 cm above the soil and were dried until moisture content was 8-10%. The sample was weighed (accuracy ± 0001 g), then scutched with the tool *ЛМ-3*, broken and shaken until the shives were withdrawn and weighed again and the result was calculated by the formulas (Freimanis et al., 1980). 5% may be dust, etc. these substances were eliminated from shive content

The analysis of ash content and lignin content was carried out three times for each average hemp sample which was divided into two, with and without the fibre from the hemp stem. The hemp's ash content was determined by a standard method: crushed samples with a mass of 1.0 g were placed in a muffle furnace at 750 ± 15 °C, and kept there for 40 minutes.

The moisture of the sample was determined before the lignin content determination. The lignin content in the samples was determined by Clason's method where polysaccharides were hydrolysed with a 72% sulphuric acid (H_2SO_4) solution (Zaķis, 2008).

The weather conditions during trial years were different. In 2008, in Latvia the air temperature in the 3^{rd} ten-day period of May was close to the long-term average, but there was no rain. In June and July there was no precipitation also. In July the average daily temperature corresponded to the long-term average and the amount of precipitation was abundant. In May

2009, the temperature was the same as the long-term average, but the amount of precipitation was only 32 % of the long-term average. There was rain in June and July. The amount of precipitation in August was only 22 % and in September – 52 % of the long-term average.

A statistical evaluation of the data has been made by variance analysis, the LSD test. Calculations were made using the program ANOVA.

III. Results And Discussion

Hemp with different uses was compared in the trial: fibre - variety 'Bialobrezskie', for seed production - local hemp 'Pūriņi' which has been grown in Latvia for more than 200 years.

N-fertilizer rates had the positive significant effect on the shive content of hemp ‘Pūriņi’, but had the negative effect on the oil content (Fig. 1, Fig 2).

The seed yield for hemp 'Pūriņi' was 2205 kg per ha in 2009, and 1699 kg per ha in 2008, but for 'Bialobrzeskie' - 468 kg per ha in 2009 (Fig. 1, Fig. 2, and Fig. 3).

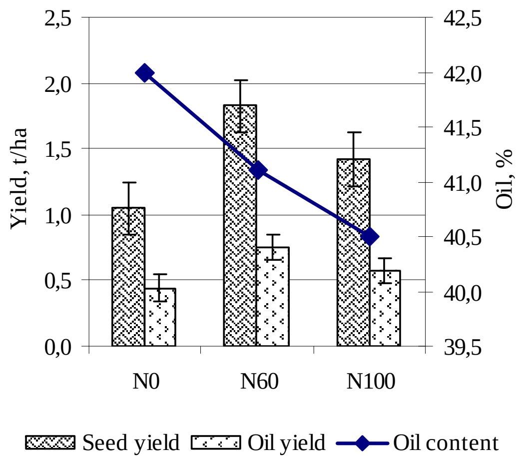

Fig. 1. The seed and oil yield and oil content for the hemp ‘Pūriņi’ in 2008.

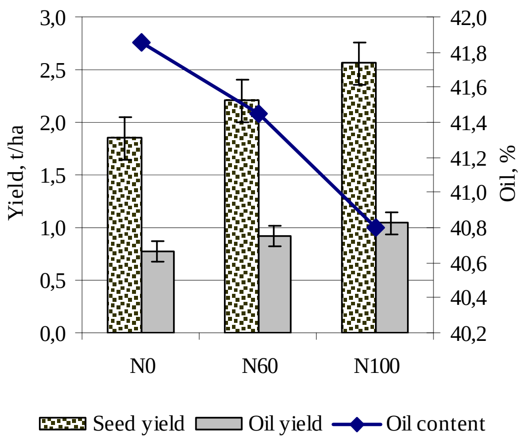

Fig. 2. The seed and oil yield and oil content for the hemp ‘Pūriņi’ in 2009.

It is possible to get 370-420 litres of hemp oil and about 600 kg of hemp cake from one tonne of hemp seed (Adamovičs et al., 2007). One litre of biodiesel substitutes 0.9 litre of fossil diesel fuel, because biodiesel has a lower calorific value than fossil diesel fuel (Kalniņš, 2009).

From one hectare of hemp 'Pūriņi' it was possible to get 500 - 1000 kg of biodiesel, which is two times greater than indicated in the literature (Adamovičs et al., 2007; Kalniņš, 2009).

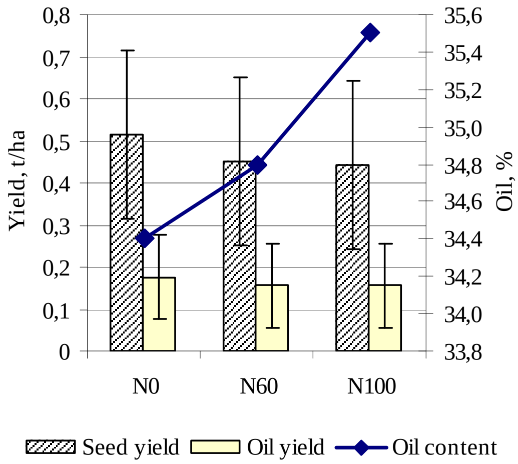

Fig. 3. The seed and oil yield and oil content for the hemp ‘Bialobrzeskie’ in 2009.

Hemp is used to increase the fuel material density and improve the energy traits (Energy..., 2009). The acquisition of hemp solid fuel is made in two ways: from the stem or just the shive.

The nitrogen fertilizer rate increase from N0 to N100 kg/ha provided a significant ($p<0.05$) increase in dry matter (DM) for both varieties of hemp, as confirmed by other studies (Grabowska et al., 2005; Energy..., 2009).

The agro-meteorological conditions of the year had significantly influenced the hemp yield (Fig. 4., Fig. 5).

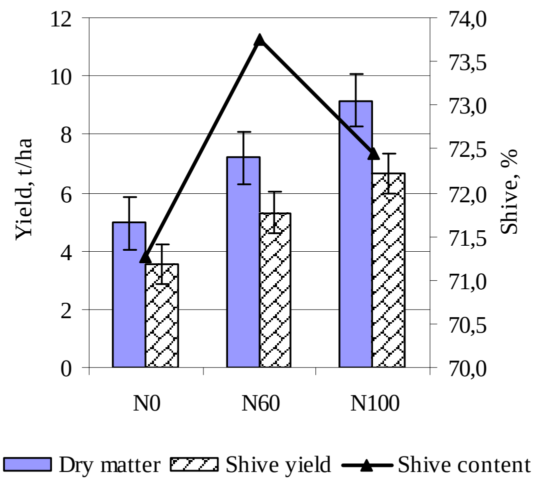

Fig. 4. The dry matter and shive yield and shive content for the hemp ‘Pūriņi’ in 2008.

The hemp shive yield of 'Pūriņi' and ‘Bialobrzeskie’ were not significantly different in 2009 (Fig. 5, Fig. 6). The largest shive content was after using N fertilizer rate N60.

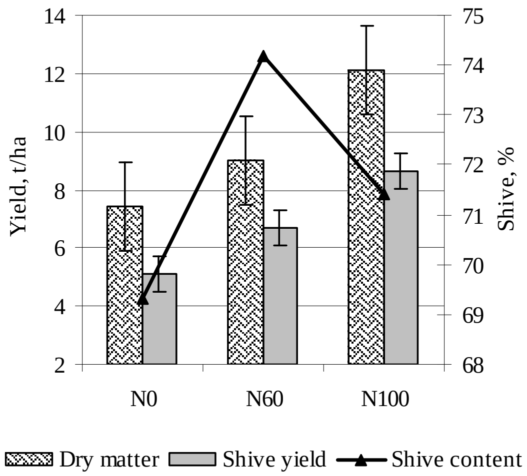

Fig. 5. The dry matter and shive yield and shive content for the hemp 'Pūriņi' in 2009.

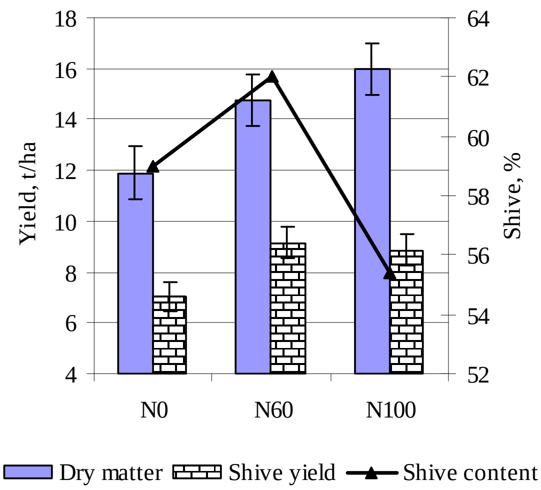

Fig. 6. The dry matter and shive yield and shive content for the hemp 'Bialobrzeskie' in 2009.

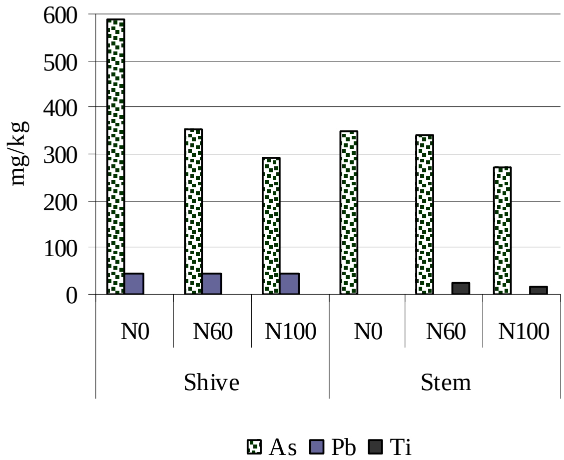

Fig. 7. Metals in hemp 'Pūriņi' at different N fertilizer rates and plant content in 2009, mg/kg DM.

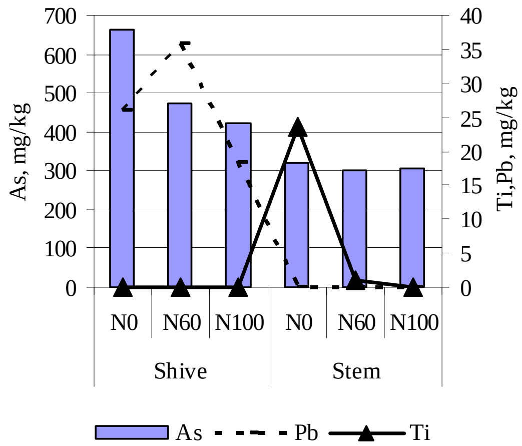

Fig. 8. Metals in hemp variety 'Bialobrzeskie' at different N fertilizer rates and plant content in 2009, mg/kg DM.

V. Scholz and H.J. Hellebrand (2003) studied 10 different energy crops in Germany. They found, that the 8-year-average of the dry matter yield was 11.2 t/ha from hemp.

Since hemp cultivation has little need for pesticide use, the hemp cultivation is environmentally friendly.

Cadmium was not noted in stems of hemp (Fig 7, Fig. 8). The lower the N fertilizer rate in hemp, the lower was the content of As. Arsenic which appears in the air with the burning of fossil fuels. Hemp has absorbed As from the atmosphere and water. The more the plants are provided with nutrients, the less they absorb arsenic.

Heavy metal (HM) concentrations in all plant parts are different: it is the highest in the root, it is practically absent in the hemp seed, and less in the stem. There is more HM in the hemp shive than in the stem (Citterio et al., 2003; Piotrowska-Cyplik et al., 2003; Eboh et al., 2005; Пастухова, 2008). Plants absorb HM not only through the roots, but also through the leaves (Пастухова, 2008).

The non-combustible material of fuel consists of ash and moisture. Ash is the mineral that is left over after fuel burning (Белосельский et al., 1980; Cars, 2008).

Ashes in organic fuel derive from the formation process and from transportation, storage and the handling process. If the last three are ignored, then the least ash content is in the wood (in absolutely dry wood) - about 1% (Cars, 2008). The non-flammable part of fuel material consists of ash. The ash content in pellet and briquette production must not exceed 1.5% (Tardenaka et al., 2006). The resulting ash quantity in the trials was larger than permitted, so hemp can only be used as an addition for briquette and pellet production.

Wood grows for an average of 20-40 years and is more expensive. Pellet and briquette manufacturers have a need for biomass plants, which could be added to the wood if the total ash content does not exceed 1.5% (standard *DIN 51731*). The ash content of hemp was different (1.0 – 7.3%), but it is greater than the permitted 1.5% (Fig. 9, Fig. 10).

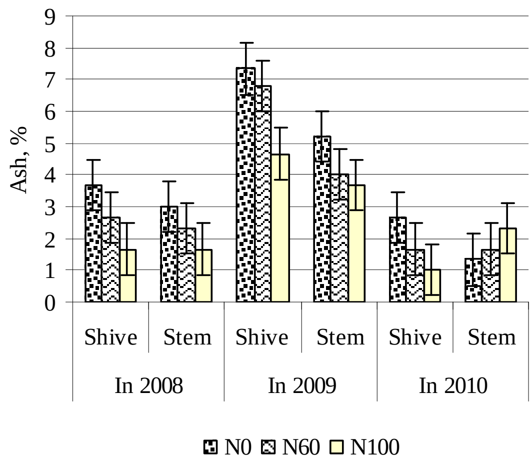

Fig. 9. Ash content in hemp 'Pūriņi' at different N fertilizer rates and plant content in 2008-2010, %.

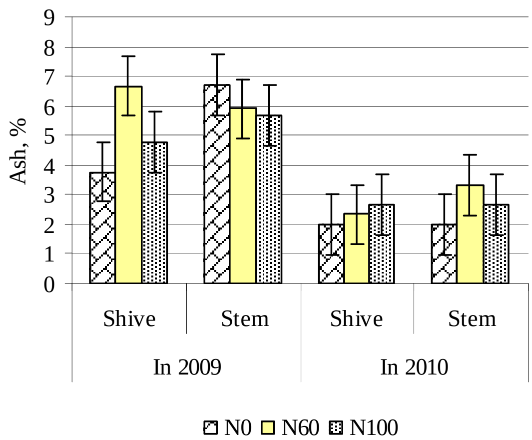

Fig. 10. Ash content in hemp variety 'Bialobrzeskie' at different N fertilizer rates and plant content in 2009-2010, %.

Ash content may change substantially by cultivation years (Fig. 9, Fig. 10, Tab. 2). It is also affected by the N fertilizer rate and plant parts. The ash content of the stem in 2009 was higher than in the shive. It was influenced by possible soil contamination (Kymäläinen et al., 2004).

TABLE 2

THE PROPORTION OF INFLUENCING FACTORS ON ASH CONTENT FOR HEMP (*P<0.05), H^2, %

Factor	**Hemp varieties**	
	Pūriņi	**Bialobrzeskie**
Cultivation year (Factor A)	62,6*	70,7*
Plant content – stem or shive (Factor B)	4,0*	3,4*
N fertilizer rate (Factor C)	8,6*	4,5*
Interaction between factors AB	5,0*	0,9
Interaction between factors AC	2,7	1,1
Interaction between factors BC	2,8*	2,5
Interaction between factors ABC	1,3	7,0*
Effect of unexplored factors	12,2	8,1
S_x	**0,50**	**0,38**
$LSD_{0.05}$	**1,44**	**1,12**

Chemical contamination (glue, varnish, etc.) is not acceptable in pellet production, therefore the cohesive substance lignin is important for holding the pellets together. The lignin content for hemp was from 27% to 42% (Fig. 11, Fig. 12). The lignin content is affected more by the interaction of various factors (Table 3).

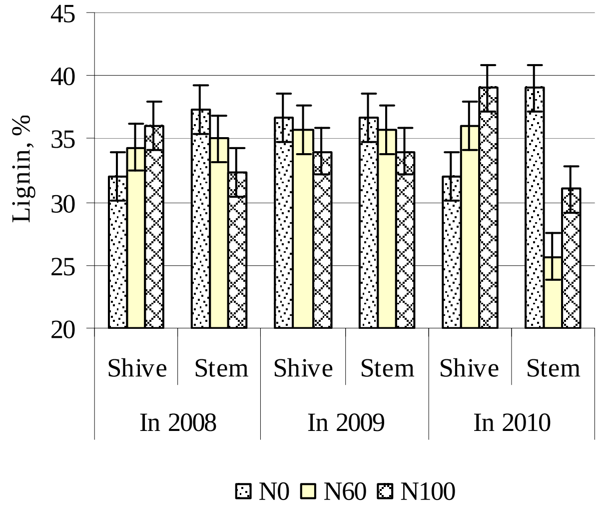

Fig. 11. Lignin content in hemp 'Pūriņi' at different N fertilizer rates and plant content in 2008-2010, %.

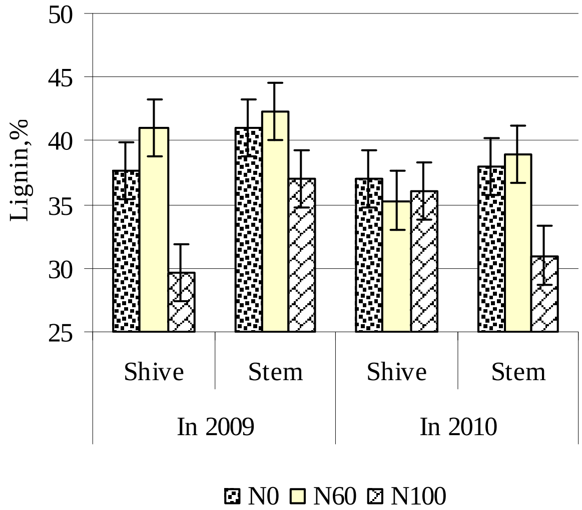

Fig.12. Lignin content in hemp variety 'Bialobrzeskie' at different N fertilizer rates and plant content in 2009-2010, %.

The high effect of unexplored factors (20%) was found after the trials of lignin content. It is possible that these differences contributed to the wide variation within the variety, making it difficult to ascertain the relevance of the investigated factors of the lignin content in different parts of the hemp plant (Table 3).

TABLE 3

THE PROPORTION OF INFLUENCING FACTORS ON LIGNIN CONTENT FOR HEMP (*P<0.05), H^2, %

Factor	**Hemp varieties**	
	Pūriņi	**Bialobrzeskie**
Cultivation year (Factor A)	3,8	6,4*
Plant content – stem or shive (Factor B)	2,0	5,7*
N fertilizer rate (Factor C)	5,0*	41,4*
Interaction between factors AB	8,0*	6,4*
Interaction between factors AC	10,3*	5,5
Interaction between factors BC	26,7*	0,5
Interaction between factors ABC	22,4*	14,1*
Effect of unexplored factors	20,2	19,6
S_x	**1,15**	**1,33**
$LSD_{0.05}$	**3,29**	**3,90**

It was found in the other research that soil contamination with HM affected the lignin content and pulp quality in plants (Mater, 2009). Heavy metals also affect the corrosion of the heat exchanger pipes in boilers.

Biogas yield was average 532±6 $l \cdot kg_{vos}$, methane yield was 294±2 $Nl \cdot kg_{vos}$, average methane content in biogas was 55.2%, and potential biomethane yield from unit of area was 3113 Nm^3/ha from hemp varieties 'Bialobrzeskie' and local hemp 'Pūriņi' in agroecological conditions in 2009 (Adamovics et al., 2010).

The hemp logs have an excellent calorific value of over 15 MJ/kg. For hemp, key characteristics such as net calorific value, ash content, and melting behavior, and the risk of corrosion or polluting emissions, are all favorable. Low bulk density and size reduction difficulties might limit its use for pellet production and in small boilers; its use in electricity generating plants and medium-to-large boilers would have better prospects (Rice, 2008).

Hemp is an environmentally friendly plant. Hemp is suitable for cultivation and for bio-energy production in the agro-climatic conditions in Latvia.

IV. CONCLUSIONS

An increased nitrogen fertilizer rate reduces the oil content of hemp seeds. Since plants absorb arsenic from the air and water, it is important to provide plants with the necessary nutrient components.

The largest shive content was applying N fertilizer rate N60, but the largest dry matter content - applying N100 kg/ha. The ash content depends on non-organic substances which plants absorb during the vegetation season. The lignin content depends on several factors: plant parts, and the N fertilizer rate. The unexplored factors have a great effect on the the ash and lignin content.

Hemp with net calorific value, ash content, and the risk of corrosion or polluting emissions, is an environmentally friendly plant for bio-energy production.

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Liena Poiša, Aleksandrs Adamovičs. Sējas kaņepes *(Cannabis sativa L.)* kā videi draudzīgs energoaugs
Kaņepes ir piemērotas audzēšanai Latvijas agroklimatiskajos apstākļos. Pētījuma mērķis: novērtēt kaņepju (*Cannabis sativa* L.) izmantošanas iespējas enerģijas iegūšanai. Pētījumā tika salīdzinātas kaņepes ar atšķirīgām izmantošanas iespējām: šķiedras ieguvei – Polijas šķirne 'Bialobrezskie' un sēklu ieguvei – vietējās kaņepes 'Pūriņi', kas Latvijā ir audzētas vairāk kā 200 gadus. Arsēna (As), kadmija (Cd), svina (Pb) un titāna (Ti) daudzums kaņepēs noteikts ar induktīvi saistītās plazmas optiskās emisijas spektrometru Optima 2100 DV. Spaļu ražība kaņepēm 'Pūriņi' un 'Bialobrzeskie' 2009. gadā būtiski neatšķiras. Vislielākais spaļu saturs bija, lietojot slāpekļa papildmēslojuma devu N60. Palielinot N papildmēslojuma devas, palielinājās kaņepju sēklu un spaļu ražība, bet samazinājās eļļas saturs. Spaļos bija lielāks As daudzums nekā stublājam ar lūksni. Kaņepju spaļos ir vairāk smago metālu, nekā stublājā. Pelnu saturs var būtiski mainīties pa audzēšanas gadiem. To ietekmē arī N papildmēslojuma devas un auga daļas. Kaņepēm lignīna saturs bija no 27% līdz 42%. Lignīna satura izmēģinājumos konstatēts augsts nepētīto faktoru īpatsvars – 20%. Iespējams, ka šādas atšķirības veicināja plašās atšķirības šķirnes ietvaros, kas apgrūtināja noskaidrot pētāmo faktoru būtiskumu uz lignīna saturu dažādās kaņepju augu daļās. Kaņepes ir videi draudzīgs energoaugs.

Лиена Пойша, Александр Адамович. Конопля посевная *(Cannabis sativa L.)* как экологически чистый источник энергии
Конопля является возобновляемым источником энергии, подходящим для агроклиматических условий Латвии. Цель исследования: оценить возможности использования конопли (Cannabis sativa L.) для получения энергии. В исследовании проводилось сравнение различных возможностей использования конопли: для производство волокна – польский сорт Bialobrezskie', и получения семян – местная конопля 'Pūriņi', выращиваемая в Латвии на протяжении более 200 лет. Содержание мышьяка (As), кадмия (Cd), свинца (Pb) и титана (Ti) в конопле определялось спектрометром с индуктивно-связанной плазмой Optima 2100 DV. Урожайность костры для обоих сортов конопли в 2009 году существенно не отличалась. Самое большое содержание костры было достигнуто при использовании дозы N60 дополнительного азотного удобрения. При повышении дозы азотного удобрения, достигается увеличение урожайности семян и костры конопли, но снижается содержание масла. В костре наблюдалось более высокое содержание As, чем в стеблях с лубом. В костре конопли больше тяжёлых металлов, чем в их стеблях. Содержание золы может существенно меняться в зависимости от года культивации, на этот фактор влияет также дозы дополнительного N удобрения и выбор части растения. Содержание лигнина в конопле варьировало от 27% до 42%. В экспериментах, связанных с содержанием лигнина, был констатирован высокий удельный объём неисследованных факторов – 20%. Возможно, что таким особенностям способствовали значительные различия в сортах конопли, что усложнило изучение важности влияния исследуемых факторов на содержание лигнина в разных частях растения. Конопля является благоприятным энергическим растением для окружающей среды.