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INDUSTRIAL HEMP (C*ANNABIS SATIVA* L.) AS A BIOMASS CROP

Poiša L.[1], Adamovičs A. [1], Jankauskiene Z.[2], Gruzdeviene E.[2]

1 Institute of Agrobiotechnology, Latvia University of Agriculture, Liela iela 2, Jelgava, LV-3001, Latvia, e-mail: lienapoisa@inbox.lv
2 Upytė Experimental Station of the Lithuanian Research Centre for Agriculture and Forest, Lininiku 3, Upyte, Panevezys district, LT-38 294, Lithuania, e-mail: soja@ltz.lt

1 INTRODUCTION

Nowadays hemp (*Cannabis sativa* L.) has become very important as a crop for biomass production. Hemp with its rich leafage suppresses weeds, and leaves left on the soil after harvesting, improve the soil structure (Adamovičs et al., 2007). This plant is an irreplaceable rotation crop in organic farming (MTT, 2009). Most of the hemp grown in Europe is used in the pulp and paper industry and the residual shives are used in animal bedding. Hemp is used to increase the density of fuel material and improve its energetic properties (MTT, 2009).
The aim of this study was to clarify the potential of growing hemp for biomass production in Latvia and Lithuania.

2 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 1 **Trials' methods**

Country		**Latvia**	**Lithuania**
Soil type		Humi-podzolic gley soil	Eutri-Endohypogleyic Cambisol
Soil composition	pH_{KCl}	7.3	7.5 (potentiometrically)
	OM, %	3.8 (Turin's method)	2.75-3.65 (Turin's method)
	P_2O_5, mg kg^{-1}	83 (DL method)	225-228 (A-L extraction)
	K_2O, mg kg^{-1}	65 (DL method)	122-171 (A-L extraction)
Pre-crops		Summer rape	Winter wheat
Complex fertilizers	N:P:K, (kg ha^{-1})	6:26:30, 300	5:15:30, 250 (2008), 300 (2009)
Sowing time	In 2008	9th May	13th May
	In 2009	4th May	5th May
Seeding rate	kg ha^{-1}	70	70
Hemp varieties	In 2008	'Pūriņi' (Latvian local hemp)	'Benico', 'Bialobrzeskie', 'Epsilon 68', 'Felina 32', 'USO 31'
	In 2009	'Pūriņi', 'Bialobrzeskie'	
N fertilize rate	kg ha^{-1}	N0, N60, N100	None
Harvesting time	In 2008	23rd September	5th September (for 'USO 31') and the 30th of September
	In 2009	21st September	15th September (for 'USO 31') and 6th November
Trial plots		20 m^2	20 m^2
Replication		4	3
agro-chemicals		None	None

Carbon content in hemp stem and shive samples was determined by carbon analyzer *Eltra CS-2000*, which operates on the principles of chromatography. Hemp's ash content was determined by a standard method for the rapid ash production method: crushed samples with a mass of 0.5 g were placed in a muffle furnace at 850 ± 15 °C, and kept there for 40 minutes. The carbon and ash content was determined by the methodology described by Čubars et al, (2009). Analysis of carbon content in ash was carried out three times for each average hemp samples which were divided into two, with and without the fibre from the hemp stem. Statistical analysis was performed by ANOVA (Доспехов, 1985; Arhipova and Bāliņa, 2003).

The weather conditions during trial years were different. In 2008, in Latvia the air temperature in the 3rd ten-day period of May was close to the long-term average, but there was no rain. In June and July a lack of precipitation occurred. In July the average daily temperature corresponded to the long-term average, the amount of precipitation was abundant. In May 2009 the temperature was the same as long-term average but amount of precipitation was only 32 % of the long-term average. The June and July were rainy. The amount of precipitation in August was only 22 % and in September – 52 % of long-term average. In 2008, in Lithuania the period for hemp seed emergence was favourable, but later on a lack of precipitation occurred (3rd ten-day period of May and 1st ten-day period of June). Then conditions for hemp growing and developing were favourable (2nd and 3rd ten-day periods of June). The weather in July was slightly cooler than that of the long-term period, but the rainfall was sufficient for hemp growing. The weather in August was warm and rainy, September was cooler and dryer. In 2009 the period for hemp seed emergence was semi-favourable – the shortage of precipitation occurred in the 2nd ten-day period of May, but the weather was warm. Later on the weather was warm, and the rainfall was sufficient for hemp growing and development. Warm weather and especially abundant precipitation in July and August delayed and prolonged hemp flowering period, delayed seed ripening period. In September it was still warm and rainy, seed maturity came late.

3 RESULTS AND DISCUSION

Energy production in the form of solid fuel from the whole hemp stem is a relatively new use for the crop (MTT, 2009). The cultivation year and the selected variety had significant effect on the hemp yield (Table 2). Hemp variety 'Epsilon 68' was the most productive. The yield is an important result of genetic and environmental interaction, and it is used as one of criteria for determination of the genotype response on specific agro-ecological conditions (Murphy et al., 2007).

TABLE 2 **The hemp harvest indicators in Lithuania**

Hemp varieties	**Green biomass, t ha^{-1}**		**Dry biomass, t ha^{-1}**		**Plant height, m**	
	2008	**2009**	**2008**	**2009**	**2008**	**2009**
‘Benico’	24.9	30.6	11.5	14.3	1.84	2.09
‘Bialobrzeskie’	23.6	28.3	10.9	13.6	1.76	1.98
‘Epsilon 68’	27.6	35.8	12.1	17.0	1.82	2.01
‘Felina 32’	22.9	24.8	10.9	12.3	1.64	1.87
‘USO 31’	27.1	34.5	14.2	17.0	1.63	1.85
Average	25.2	30.8	11.9	14.8	1.74	1.96
LSD_{05year}	3.20		1.54		0.13	
$LSD_{05variety}$	5.22		2.43		0.21	
$LSD_{05\text{interactions between year and variety}}$	7.34		4.44		0.29	
η_{year}, % (impact rate)	31.5 ($p<0.01$)		34.3 ($p<0.01$)		39.9 ($p<0.01$)	
$\eta_{variety}$, %	35.0 ($p<0.05$)		35.8 ($p<0.001$)		24.3 ($p<0.05$)	
$\eta_{\text{interactions between year and variety}}$, %	5.0 ($p>0.05$)		5.2 ($p>0.05$)		0.2 ($p>0.05$)	

The hemp with different options for use was compared in the trial (Table 3): variety ‘Bialobrezskie’ for fibre production and local hemp 'Pūriņi' for seed, which has been grown in Latvia for 200 years. The increase of nitrogen fertilizer rates from N0 to N100 kg ha^{-1} provided a significant ($p<0.05$) increase of green and dry biomass in both varieties, which is confirmed by other studies (Grabowska et al., 2005; MTT, 2009). The proportion of nitrogen fertilizer effect on hemp harvest was 29% in 2009. In 2009 N-fertiliser rates between N0 and N100 had different significant ($p<0.05$) effects on hemp ‘Pūriņi’ and ‘Bialobrzeskie’, but there were no significant differences between N0 and N60, and between N60 and N100. Variety or genotype effects were also significant ($p<0.05$) and accounted for about 50%.

TABLE 3 **The hemp harvest indicators in Latvia**

Hemp varieties	**Fertilizer rates, kg ha^{-1}**	**Green biomass, t ha^{-1}**		**Dry matter, t ha^{-1}**		**Plant height, m**	
		2008	**2009**	**2008**	**2009**	**2008**	**2009**
‘Pūriņi’	N0	19.93	30.0	4.96	7.4	1.41	1.58
	N60	28.50	36.0	7.20	9.0	1.55	1.81
	N100	35.82	46.0	9.17	12.1	1.50	1.77
Average		28.08	37.3	7.11	9.5	1.49	1.72

$LSD_{0,05}$		7.2		1.53		0.23	
'Bialobrzeskie'	N0	-	45.0	-	11.9	-	2.73
	N60	-	52.8	-	14.8	-	2.90
	N100	-	59.5	-	16.0	-	2.74
Average		-	52.4	-	14.2	-	2.79
$LSD_{0,05}$			5.9		1.4		0.04

The tallest hemp in both experimental years (Table 3) was obtained applying N fertilizer at rate N60 kg ha^{-1}, in other studies it is also indicated that the high fertilizer rates could not give positive effect for hemp (Grabowska et al., 2005). Intensity of hemp growing coincided with studies of other authors (Adamovičs et al., 2007; Jankauskiene et al., 2009). Hemp 'Pūriņi' begins to bloom by 1-1.5 month earlier than the variety 'Bialobrzeskie', but plants of 'Pūriņi' are shorter (Poiša et al., 2009).

Non-flammable part of fuel material consists of ash. The ash content in pellets and briquettes production must not exceed 1.5% (Tardenaka et al., 2006). The resulting ash quantity in the trials is larger than permitted, so hemp can only be used as an addition for briquettes and pellets production. Ash content (Fig.1) was significantly ($p<0.05$) affected by location and meteorological conditions, but not affected ($p>0.05$) by the plant (stem or shive), so it can be used as a whole plant for the solid fuel production.

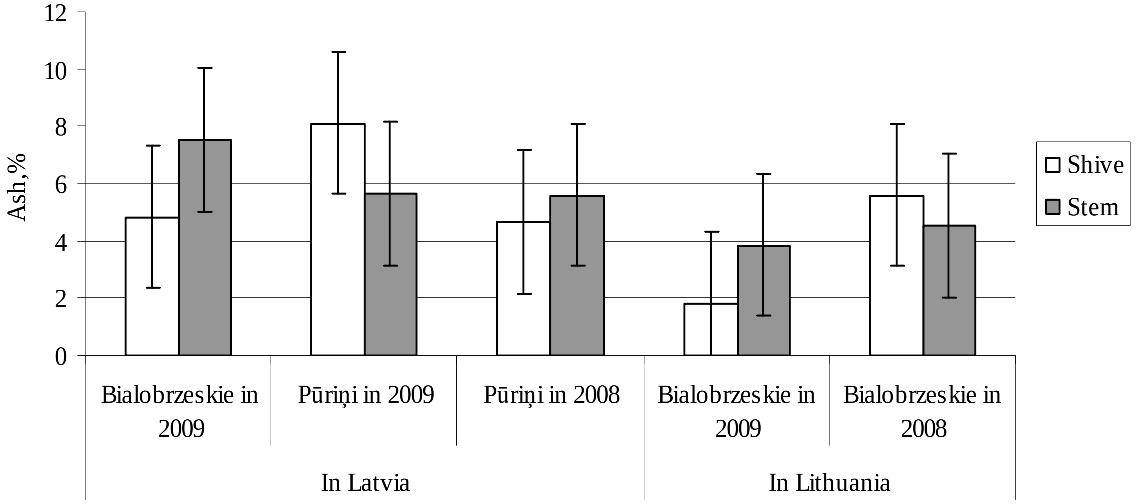

FIGURE 1 **Ash content in hemp of different varieties, %**

Carbon is one of the most important products of photosynthesis, which is the primary fuel burning element. Carbon has a high calorific value, and this accounts for most of the burnt mass (Белосельский et al., 1980; Cars, 2008). Data from our investigation show, that carbon content in hemp (Tab. 2) was between 38% and 41%.

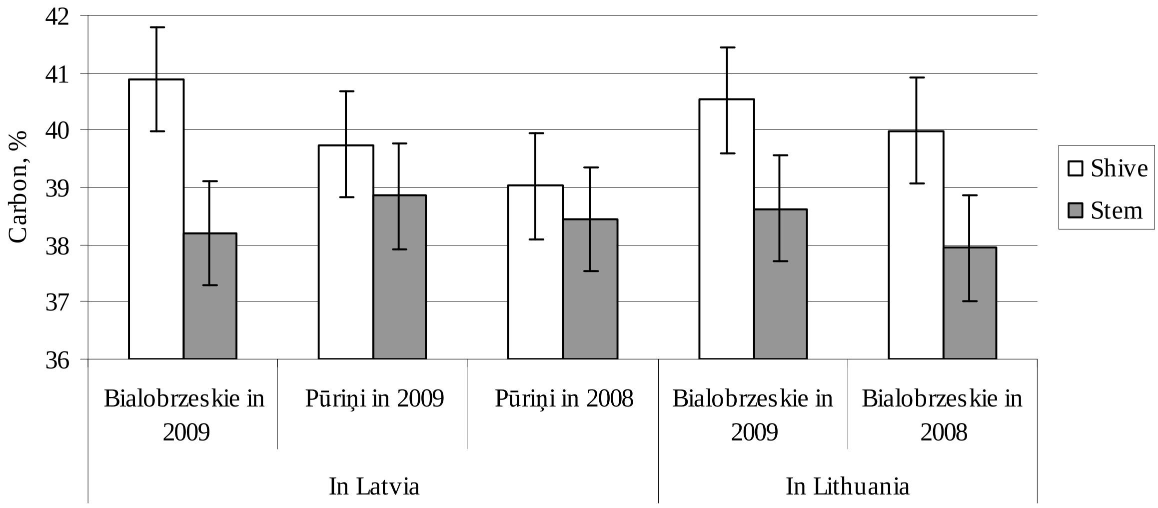

FIGURE 2 **Carbon content in hemp of different varieties, %**

Regression analysis showed (n=12) that the changes of ash content (19.5%) for the hemp variety 'Bialobrzeskie' (2009) can be explained by a linear regression model. In the study the significant relationship between ash (y) and carbon content (x) for hemp variety 'Bialobrzeskie' was not determined.

The result of our investigation confirms that hemp is acceptable as a biomass plant for Baltic region.

4 CONCLUSIONS

The growing year and the variety had a significant effect on hemp yield. Variety or genotype effect was significant ($p<0.05$) and accounted for around 50%.

The increase of nitrogen fertilizer rate from N0 to N100 kg ha^{-1} provided a significant ($p<0.05$) increase in green biomass, dry matter, and plant height.

The resulting ash quantity for trials is larger than permitted, so hemp can be used only as an addition for briquettes and pellets production. Ash content was significantly ($p<0.05$) affected by location and meteorological conditions, but not affected ($p>0.05$) by the part of plant (stem or shive), so it can be used as the whole plant for the solid fuel production.

The carbon content found in hemp plants was between 38% and 41%. In both countries the figures are similar, which confirms the Baltic region as suitable for hemp cultivation as a biomass plant.

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