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INVESTIGATIONS INTO GROWING AND HARVESTING INDUSTRIAL HEMP

Summary

Interest for possibilities of the industrial hemp (Cannabis sativa L.) growing in Latvia is increasing year by year and they are considered as one of the most promising renewable biomass sources to replace non-renewable natural resources for manufacturing of wide range industrial products. The aim of this research was to evaluate of biomass potential of some industrial hemp varieties to be recommended to grow in Latvia and clarify carbon content. The biometric parameters of ten industrial hemp cultivars have been investigated in 2011-2012. Depending on the variety the green over-ground biomass varies from 36 - 54 t ha^{-1} in 2011 and from 48 - 75 t ha^{-1} in 2012. The highest green over-ground biomass was obtained cultivar 'Futura 75' up to 75 t ha^{-1}. The carbon content in hemp stems was found from 41.62 – 45.38% . The article defines the key specific requirements for the hemp harvesting machines.

Key words: *hemp, cannabis sativa, growing, harvesting*

1. Introduction

The industrial hemp (*Cannabis sativa* L.) is one of the earliest domesticated and widespread crop all over the world. For many centuries hemp has been cultivated as a source of strong stem fibre and seed oil in Latvia [4]. In the 19th century the cultivation of industrial hemp in Europe declined but recently interest has been renewed, for example in Germany, France, the Netherland, the United Kingdom, Spain and Italy, but also elsewhere in the world [6]. And nowadays industrial hemp has become very important as a crop for biomass production. Environmental concern and recent shortages of wood fibre have renewed interesting hemp as a raw material for a wide range of industrial products including textiles, paper, and composite wood products [4].

It is fast-growing and suitable for Latvia's agro-climate conditions. Latvian hemp sowing areas are registered only in year 2008 and in year 2009 was grown 250 ha. In recent years, the amount of industrial hemp growers and cultivated areas has increased in Latvia and, according to data provided by Association of Industrial Hemp of Latvia, plantations area of hemps is approximately 600 ha in Latvia in 2012. And it means that, interest for possibilities of the hemp growing in Latvia is increasing year by year. And they are considered as one of the most promising renewable biomass sources because it contains the energy which comes from the sun [1]. Through the process of photosynthesis, chlorophyll present in plants absorbs the energy from the sun by converting the carbon-dioxide present in air and water from the ground in carbohydrates.

In Latvia industrial hemp is legally allowed to be grown but the main requirement is that hemp plants should have a low THC (*Tetrahydrocannabiol*) content (less than 0.2%). The EU common catalogue of varieties of agricultural plant species contains the list with more than 47 industrial hemp varieties [2]. And it is difficult to decide which variety from this list could be possible to grow in Latvia with good results and with high biomass yield. The aim of this research was to evaluate of biomass potential of some industrial hemp varieties to be recommended to grow in Latvia and clarify carbon content.

The most complicated technological operation in the growing of industrial hemp is its harvesting. The weather conditions in Latvia during the hemp vegetation and harvesting period sharply differ from the weather conditions in Western Europe.

2. Materials and methods

The field trial was carried out in 2011-2012 in Research and Study farm "Peterlauki" (56°53'N, 23°71'E) of the Latvia University of Agriculture, in the sod calcareous soils pHKCl 6.7, containing available for plants P 52 mg kg^{-1}, K 128 mg kg^{-1}, organic matter content 21 to 25 g kg^{-1} in the soil. There were ten industrial hemp cultivars tested – 'Bialobrzeskie', 'Futura 75', 'Fedora 17', 'Santhica 27', 'Beniko', 'Ferimon', 'Epsilon 68', 'Tygra', 'Wojko' and 'Uso 31'.

Hemp sowing was made by *Wintersteiger* plot sowing machine in the middle of May. The trial was randomly spaced, triplicate. The plot size 7 m^2. Fertilizer application rate – N120P80K112 kg ha^{-1}. Seed rate 50 kg ha^{-1} or average 250 germinate able seeds per 1 m^2. In the field rotation, industrial hemp followed previous crop – spring barley. Hemp was harvested by a small mower *MF-70* (leaving the stubble of 5-8 cm) when the first matured seed appeared.

During both growing seasons the industrial hemp stalk was estimated. Total height of hemp stalk was measured from the soil surface to the tip of plant. No pesticides like insecticides, herbicides, desiccants were used.

The yield of green and dry biomass was evaluated at hemp harvesting time. The main task of research presented here was to evaluate biomass potential of ten industrial hemp cultivars under Latvian climatic conditions. The yield of absolutely dry hemp biomass was calculated according to the data of green biomass and its moisture content at harvesting in study years. The carbon content in hemp stem was determined by carbon analyzer *Eltra CS-500*, which operates on the principles of chromatography. The ash content in hemp stem was determined by a standard method for the rapid ash production method ISO 5984:2002.

Meteorological data as temperature was obtained from Dobele Hydro-meteorological Station (HMS). Precipitations were taken during growing season near to the trials fields in farm Peterlauki. Meteorological conditions during both growing season can be described as good with temperature (Fig. 1) and wet with periodic substantial rainfall (Fig. 2) what was good for hemp growth and development.

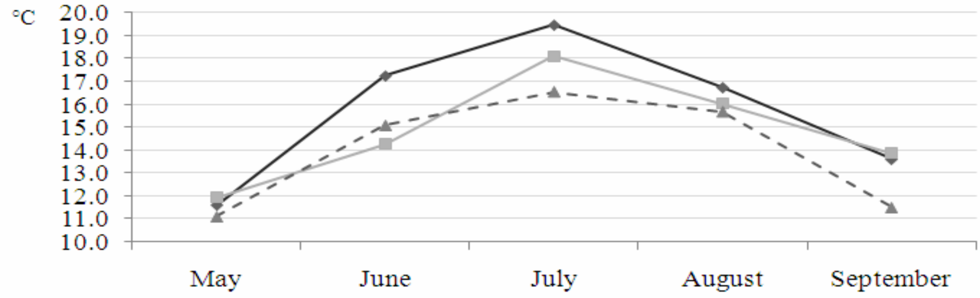

Figure 1. Average temperature during the growing season, 2011 – 2012 and long-term average (°C):

2011 2012 Longterm

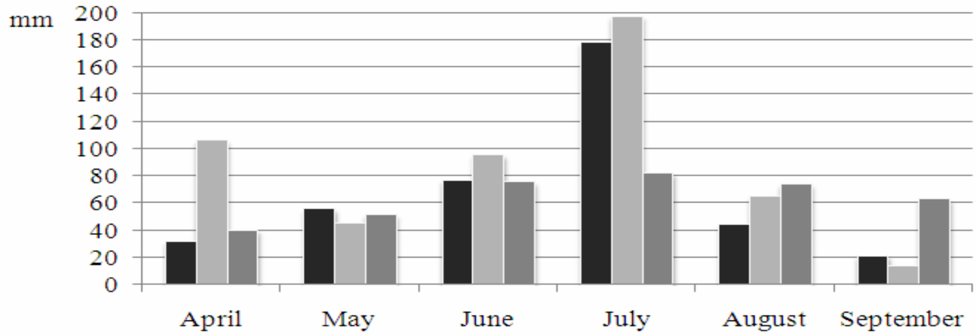

Figure 2. Precipitations during growing season in 2011 – 2012 and long-term (mm):

2011 2012 longterm, mm

A statistical evaluation of the data has been made by ANOVA, variance analysis, the LSD test. Correlation and regression analysis methods were used for data processing.

In order to facilitate the choice of a more efficient harvesting technology of industrial hemp, investigations have been started into the technical-economic and performance indicators of the machines.

3. Results and discussion

Industrial hemp cultivars growth and development is dependent of meteorological conditions during growing period [6]. Hemp grows best when mean daily temperatures are between 14°C and 27°C and it requires abundant moisture throughout the growing season, particularly while young plants are becoming established during the first six weeks of growth [4]. According to the data presented in Figure 1 and Figure 2, we can see that meteorological conditions during both trial years were diverse, but both growing seasons were abundant in rainfall which differed only at hemp growing stages and there was good temperature for hemp growth.

According to results, in the years of investigation, the highest stalk length was observed of cultivar ‘Bialobrzeskie’ (2.63 m) in 2011 and cultivar ‘Tygra’ (3.06 m) in 2012 (Tab. 1). There were significant difference between different cultivars and growing season. The lowest stalk length was observed of cultivar ‘Wojko’ (1.95 m) in 2011 and cultivar ‘Bialobrzeskie’ (2.26 m) in 2012.

Statistical evaluation showed that the meteorological conditions during growing season as a factor had an influence on the results of total hemp stalk length.

Table 1. Stalk length of industrial hemp varieties

Varieties	Plant stalk length, m		
	2011	2012	Average
Bialobrzeskie	2.63	2.26	2.44
Futura 75	2.54	2.48	2.51
Fedora 17	2.47	2.59	2.53
Santhica 27	2.52	2.66	2.59
Beniko	2.52	2.84	2.68
Ferimon	2.41	2.84	2.63
Epsilon 68	2.50	2.88	2.69
Tygra	2.49	3.06	2.78
Wojko	1.95	2.83	2.39
Uso 31	2.32	2.58	2.45
Average	2.44	2.70	2.57
$LDS_{0.05\ variety} = 0.21$; $LDS_{0.05\ year} = 0.09$; $LDS_{0.05 interaction\ between\ variety\ and\ year} = 0.29$			

Table 2. Biomass yield of industrial hemp varieties, 2011-2012

Varieties	Green biomass, t ha^{-1}			Dry biomass, t ha^{-1}		
	2011	2012	Average	2011	2012	Average
Bialobrzeskie	45.80	51.25	48.53	17.15	11.95	14.55
Futura 75	54.56	75.00	64.78	21.22	21.33	21.27
Fedora 17	45.69	57.54	51.61	16.60	18.23	17.42
Santhica 27	47.16	66.43	56.79	19.84	17.39	18.61
Beniko	50.21	48.97	49.59	20.51	19.27	19.89
Ferimon	46.69	52.40	49.55	16.90	18.59	17.75
Epsilon 68	54.13	68.45	61.29	20.26	12.89	16.57
Tygra	44.80	58.83	51.82	18.61	20.87	19.74
Wojko	47.15	59.48	53.32	20.33	19.91	20.12
Uso 31	36.57	51.49	44.03	12.65	17.38	15.01
Average	47.28	58.98	53.13	18.41	17.78	18.09
$LDS_{0.05\ variety}$	10.24			3.45		
$LDS_{0.05\ year}$	4.58			1.54		
$LDS_{0.05\ interaction\ between\ variety\ and\ year}$	14.49			4.88		
$\eta^2\%_{variety}$ (impact rate)	26.7 ($p<0.05$)			36.3 ($p<0.05$)		
$\eta^2\%_{year}$ (impact rate)	26.2 ($p<0.05$)			5.9 ($p<0.05$)		
$\eta^2\%_{interaction\ between\ year\ and\ variety}$ (impact rate)	7.6 ($p>0.05$)			16.8 ($p>0.05$)		

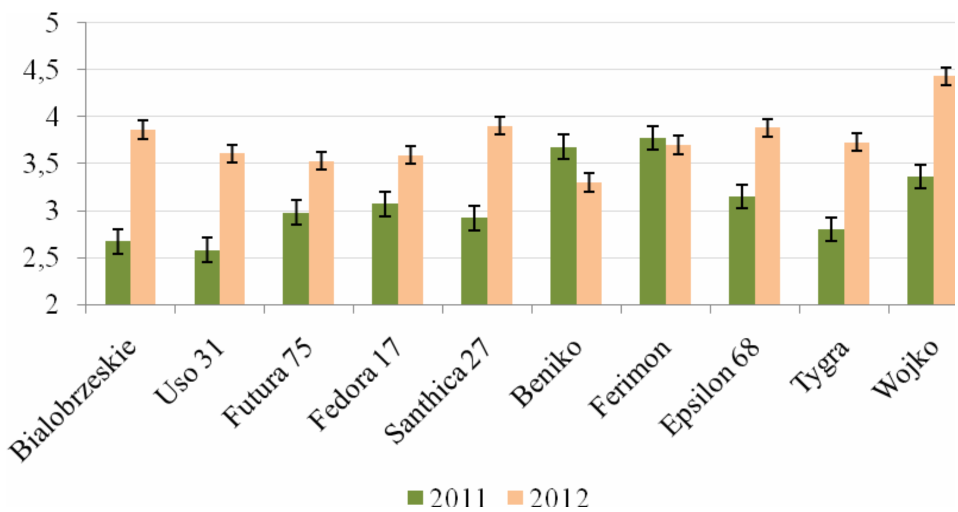

Figure 3. Ash content in hemp of different varieties, %

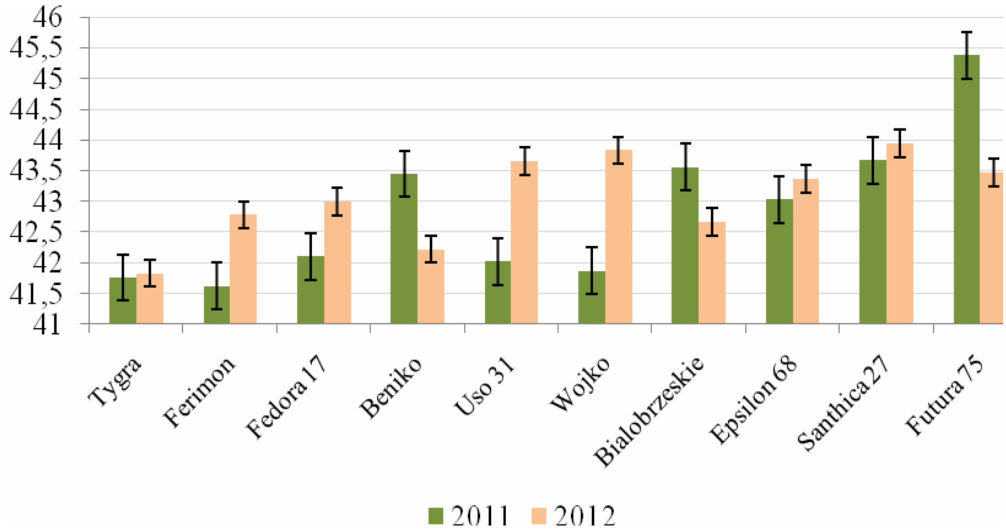

Figure 4. Carbon content in hemp of different varieties, %

In 2011, industrial hemp cultivars produced sufficiently high amount of green biomass (Tab. 2). Cultivars 'Epsilon 68' and 'Beniko' produced significantly ($p<0.05$) higher amount of green biomass (up to 50 t ha^{-1}) than the other cultivars tested. But in 2012, the green biomass was obtained higher. In this growing season the significantly higher amount of green biomass was obtained cultivar 'Futura 75' (75 t ha^{-1}). The lowest green biomass yield was obtained cultivar 'Uso 31' in 2011.

According to the data of industrial hemp green biomass and amount of plant moisture content at harvesting (it was about 19-45 % in both trial years), the hemp dry biomass yield was calculated. There was significant difference of dry biomass yield between different cultivars in both years. The significantly highest amount of dry biomass yield up to 20 t ha^{-1} was observed from cultivars 'Futura 75' (21.22 t ha^{-1}), 'Beniko' (20.51 t ha^{-1}), 'Wojko' (20.33 t ha^{-1}) and 'Epsilon 68' (20.26 t ha^{-1}) but the lowest – cultivar 'Uso 31' (12.65 t ha^{-1}). In 2012, the significantly highest amount of dry biomass yield was observed from cultivars 'Futura 75' (21.33 t ha^{-1}) and 'Tygra' (20.87 t ha^{-1}) but the lowest from cultivar 'Bialobrzeskie' (11.95 t ha^{-1}). Statistical evaluation showed that the meteorological conditions during growing season as a factor had an influence on the results of total green and dry biomass yield.

The ash content is one of the major qualitative characteristics of biomass. The ash content of all plant sheave must be up to 3%. The ash content should not surpass 5-7% under the conditions of correct stockpile. Nevertheless, the experience shows that the ash content can reach even 20% [5]. The ash content of hemp cultivars was different and ranged from 2.58 to 3.77 % (Fig. 3).

Carbon is one of the most important products of photosynthesis for biomass production and it is the primary fuel burning element. It has a high caloric value and this accounts for most of the burnt mass [3]. According to the research results, there were seen that the carbon content in hemp stems varies from 41.62-45.38% in 2011 and from 41.332-43.94% in 2012 and it depend on cultivars.

Proper hemp harvesting in optimum terms raises by 60-80% the cost-efficiency of the production of this crop, as well as the quality of the end product. The ripeness stage of hemp in Latvia starts in September but the seed maturity even at the beginning of October. That is why it is important to choose for growing the sorts with a maximum short vegetation period. In order to ensure normal and sufficiently quick process of the stalk retting, hemp should be harvested in August. Complete seed ripening takes place later than the stalk maturity for harvesting. Depending on the main production purpose of hemp – for fibre, seeds, or both types of production, the harvesting times may shift a little.

The most complicated specific harvesting machine for industrial hemp is a specialised combine harvester. In Latvia a combine harvester was used in 2012 with a working width of 4.5 m (the Kemper Champion harvester and the Claas cylinder disintegrater). Such a combine harvester ensures reaping, threshing of the seedy part, stalk cutting at the height of 60 cm, and their laying in a ribbon. 6 such combine harvesters were used in Europe in 2012. Unfortunately, the use of expensive machinery for harvesting industrial hemp, as well as specialised hemp harvesters (Fig. 5) (worth €300000) require high concentration of the hemp plantations, and, as experience shows, due to the great amortisation costs, at present it has little effect (the costs of the services of such combine harvesters constitute 200 € /ha).

Generally the seedy part of hemp is harvested by properly adjusted grain combine harvesters. The most complicated process of such harvesting is cutting the stalks with high fibre content. The finger-segment cutting mechanism of the combine harvesters performs this technological process satisfactorily by cutting the stalks 80-100 cm high. An important technological aim of the following work is to increase the cutting height to 130-150 cm. This would allow increasing the mass of the fibre part remaining on the field by 1.5 times which, after the stalk retting, is intended for the production of fibre.

Hemp harvesting for fibre production is usually set in August, leaving the following processing – the stalk retting and gathering (pressing into round or square bales) – till the end of September.

The harvesters of the fibrous stalks have specific requirements. On vast areas the rotary harvesters are not quite suitable for efficient gathering of the stalks intended for fibre production because the fibre winds round the rotary parts: power shafts and rotating disks. There is a risk that the bearing units may be damaged. Investigations show that the most suitable ones are the finger-segment harvesters. The best of this group of harvesters are the duplex harvesters with a greater cutting speed. In any variant one should pay attention to the wear degree of the segment knives. Harvesting of the biomass for energetic purposes can be carried out by forage harvesters with shredders.

If the stalks are 3-4 m tall, in order to simplify harvesting and further processing, it is advisable to cut them in two levels (reducing the length of the stalks two times). To carry out such cutting, there are special harvesters (Fig. 5); however they have a high price – more than €12000, and such a harvester may pay back only on large specialised hemp growing farms (40-60 ha).

The hemp stalk retting process at the mean air temperatures 8-12^{o} lasts 3-5 weeks. As after cutting the hemp stalks have no strict orientation, the flax ribbon spreaders, overturners or fluffers cannot be used for further improvement of their retting conditions. The only practical and realisable way how to improve the conditions of the retting process (production of uniformly retted mass of the hemp stalks in a vertical section) is tedding. The most suitable machines for tedding and swathing the hemp fibre are rotary carousel rakes with the tines not less than 45 cm long.

The hemp fibre is picked up from the field by means of round and square bale presses at the 16% moisture. The design of the baling machine must not include rotary elements which transfer the mass from the pick up mechanism to the baling chamber. Therefore the forage balers with shredders are not suitable for this work. An optimal design is a machine with the harvesting fingers (for instance, Z-562). As the stalks are exposed to bending during the baling process by means of the round bale presses, giving a cylindrical form to the bale, certain losses of shove (5-10%) arise under the impact of the baling mechanism [7].

After baling, the round or square bales are loaded by means of frontal loaders into trucks or tractor trailers (in 2 or 3 layers), the load is fixed and transported to the flax processing factories.

Figure 5. Specialised hemp harvester

4. Conclusions

The trial carried out in 2011-2012 enables that industrial hemp cultivars tested ‘Bialobrzeskie’, ‘Futura 75’, ‘Fedora 17’, ‘Santhica 27’, ‘Beniko’, ‘Ferimon’, ‘Epsilon 68’, ‘Tygra’, ‘Wojko’ and ‘Uso 31’ could be successfully grown in Latvia for biomass production. But the highest biomass yield, during both trial years, was obtained from cultivar ‘Futura 75’. According to the data we can conclude that the growing season and the selected industrial hemp variety had a significant ($p<0.05$) effect on hemp yield.

According to the results, the ash content was significantly ($p<0.05$) affected by different meteorological conditions during the growing season, but not affected ($p>0.05$) by the selected cultivar.

According to the research results, there were seen that the carbon content in hemp stems varies from 41.62-45.38% in 2011 and from 41.332-43.94% in 2012 and it depend on cultivars.

Proper hemp harvesting in optimum terms raises by 60-80% the cost-efficiency of the production of this crop, as well as the quality of the end product.

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