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Investigations about the impact of norms of the fertilisers and cultivars upon the crop capacity biomass of industrial hemp

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Abstract. Field trials were carried out in 2012–2014, on the Research and Study Farm 'Pēterlauki' of the Latvia University of Agriculture. Eleven sorts of industrial hemp (*Cannabis sativa* L.) – 'Bialobrzeskie', 'Futura 75', 'Fedora 17', 'Santhica 27', 'Beniko', 'Ferimon', 'Felina 32', 'Epsilon 68', 'Tygra', 'Wojko' and 'Uso 31' were sown in a sod calcareous soil (pH_{KCl} 6.7, P 52 mg kg^{-1}, K 128 mg kg^{-1}, the organic matter content 21–25 g kg^{-1}). The total seeding rate was 50 kg ha^{-1}. The plots were fertilised as follows: N-120, P_2O_5- 90, K_2O- 150 kg ha^{-1}. Hemp was sown in the middle of May, in 10 m^2 plots, triplicate. Hemp was harvested when the first matured seeds appeared. The biometrical indices, the height and stem diameter, the harvesting time, the amount of fresh and dry biomass and the fibre content were evaluated.

Yield of dry matter on average comprised 15.06 t ha^{-1}, depending on the cultivars. Cultivation year and cultivar notably affected hemp biomass yield. In 2012, the highest yield of dry biomass was produced from cultivars 'Futura 75' (21.33 t ha^{-1}) and 'Tygra' (20.87 t ha^{-1}), the lowest – from 'Bialobrzeskie' (11.95 t ha^{-1}). Significantly higher average yield of dry biomass was obtained from cultivars 'Futura 75' (17.76 t ha^{-1}), 'Tygra' (16.31 t ha^{-1}), 'Wojko' (15.51 t ha^{-1}) and 'Epsilon 68' (15.28 t ha^{-1}), the lowest – 'Bialobrzeskie' and 'Uso 31' (13.53 t ha^{-1}). Meteorological conditions influenced the dry biomass yield.

The aim of this study was find productive cultivar of industrial hemp (*Cannabis sativa* L.) and clarify nitrogen fertiliser rates impact for biomass production in Latvia.

Key words: *Cannabis sativa*, cultivars, biomass, fertilizers.

INTRODUCTION

Industrial hemp (*Cannabis sativa* L.) is a traditional industrial crop in many regions of Europe and of the World. For many centuries hemp has been cultivated as a source of strong stem fibre and seed oil (Ehrensing, 1998). The cultivation of industrial hemp in Europe declined in the 19th century, but recently an interest has been renewed in Germany, France, the Netherland, the United Kingdom, Spain, Italy, and also elsewhere in the world (Struik et al., 2000). Nowadays, industrial hemp has become very important as a crop for biomass production. Environmental concern and recent shortages of wood fibre have renewed an interest about hemp as a raw material for a wide range of industrial products including textiles, paper, and composite wood products (Ehrensing, 1998). Hemp is fast-growing and suitable for Latvia`s agro-climate conditions. Interest for possibilities of hemp growing in Latvia is increasing year by year (Ivanovs et al., 2015).

The hemp is considered to be one of the most promising renewable biomass sources to replace non-renewable natural resources for manufacturing of wide range of industrial products also in Latvia (Adamovics et al., 2012; Ivanovs et al., 2014; Lekavicius et al., 2015).

Nitrogen is the element that is most widely used in agriculture and it is the most important element for limiting the plant growth and development (Masclaux-Daubresse, 2010). Nitrogen fertilisation is an important environmental concern. Application of nitrogen-based fertilisers has proven very effective for increasing yields, but at the same time these fertilisers may be detrimental to the goal of sustainable agriculture and may raise the amount of nitrogen in ground water and surface water downstream of the farmland, contributing to the degradation of aquatic ecosystems (Erisman, 2011). Therefore, today the definition of fertiliser application rates is one of the major challenges that the environmentally conscious hemp growers are facing.

Industrial hemp`s need for nitrogen is high, especially during the vegetative growth period, and it should be available in the soil in sufficient quantity for a good growth and development (Ehrensing, 1998). Additional fertilisation of nitrogen stimulates hemp plant growth in field conditions (Amaducci et al., 2002; Amaducci et al., 2012). A lack of nitrogen will result in a lower yield because steps of growth will be missed and therefore will reduce the efficiency of radiation use (Struik et al., 2000). In the literature, it was found that hemp fertilisation methodology varies in different countries according to the existing soil and climatic conditions. For example, in the United States quoted nitrogen fertilisation rate is about 60 kg ha^{-1}, while in EU countries nitrogen fertilisation rates vary between 40–200 kg ha^{-1} depending on soil composition (Ehrensing, 1998). Recommendations for hemp breeding developed in EU are not considered to be suitable for Latvian climate and soil conditions. In Latvia, the recommendations for suitable nitrogen fertiliser rates for hemp breeding are not developed. Hemp is a contamination-free crop. At proper equipment support rural entrepreneurs can profitably use all the parts of the plants – fibre, sheave, leaves, seeds. Hemp is Gods' donation to mankind!

The aim of this study was find productive variety of industrial hemp (*Cannabis sativa* L.) and clarify nitrogen fertiliser rates impact for better biomass production in Latvia.

MATERIALS AND METHODS

Field trials were carried out in 2012–2014, on the Research and Study Farm 'Pēterlauki' (56°53‶N, 23°71‶E) that is supervised by the Latvia University of Agriculture (Fig. 1). Eleven cultivars of industrial hemp (*Cannabis sativa* L.) cultivars – 'Bialobrzeskie', 'Futura 75', 'Fedora 17', 'Santhica 27', 'Beniko', 'Ferimon', 'Felina32', 'Epsilon 68', 'Tygra', 'Wojko' and 'Uso 31' were sown in a sod calcareous soil (pH_{KCl} 6.7, containing available P 52 mg kg^{-1}, K 128 mg kg^{-1}, the organic matter content in the soil from 21 to 25 g kg^{-1}). The total seeding norm was 50 kg ha^{-1}or average 250 germinated seeds per 1 m^2. In the field rotation, industrial hemp followed the previous crop – spring barley.

The plots with hemp cultivars were fertilised as follows: N-120, P_2O_5-90, K_2O-150 kg ha^{-1}. Industrial hemp cultivars 'Futura 75', 'Tygra' and 'Santhica 27' were tested under seven different nitrogen fertiliser application rates: control – N0P0K0; background fertiliser (next in text marked as F) – P80K112; F+N30; F+N60; F+N90; F+N120;

F+N150; F+N180 kg ha^{-1}. Hemp was sown by using *Wintersteiger* plot sowing machine in the middle of May, in 10 m^2 plots, triplicate. Hemp was harvested by a small mower 'MF-70' when first matured seeds appeared.

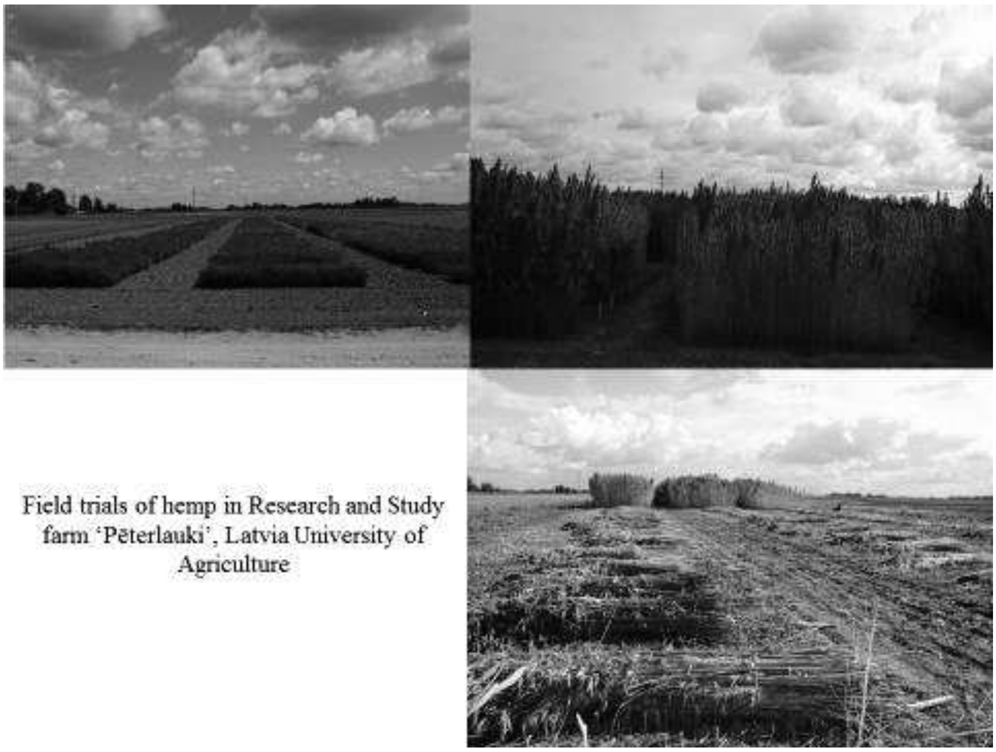

Figure 1. Hemp field tests in spring and in autumn.

Biometrical indices of the hemp seedlings, height and stem diameter in the middle thereof at harvesting time, amount of fresh and dry biomass, and fibre content were evaluated.

The parameters of meteorological conditions (the mean air temperature, °C and rainfall, mm) were recorded by the weather station located on the trial field. In the years 2012–2014, the period for hemp seed emergence was favourable, but in 2013 there was a lack of precipitation (the 1st ten-day period of June) (Fig. 2). In 2006, the drought and the warm weather were recorded in June, July, while in 2014 this period was much more abundant in rainfall. The rainfall in June and July is important as it strongly influences the yield. The mean air temperature in August was very similar in all the years, but the amount of rainfall differed markedly – in 2014 it was twice as high as the long-term average, and in 2013 it was approximately twice as low as the long-term average. In September and the 1st ten-day period of October the weather was still warm, later on it became cooler. In the hemp dew retting period the weather was quite dry (not favourable) in all the years.

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 fresh and dry biomass was evaluated at hemp harvesting time.

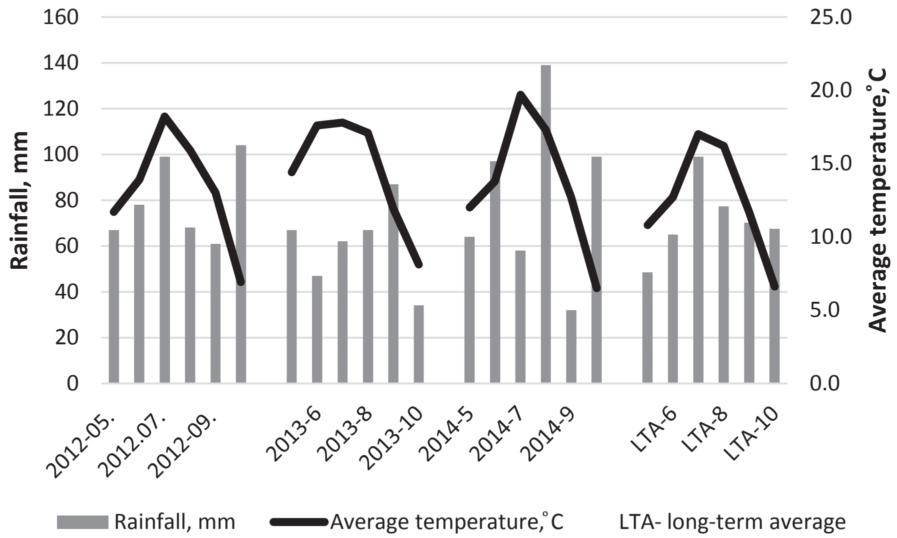

Figure 2. Meteorological conditions during vegetation periood.

Hemp stalk samples from each plot were taken and dried. Before starting dew retting, the technical stalk part from the hemp stalks was prepared (cutting away the top part of the plant containing panicle and leaves). The hemp stalk samples (average 2kg x 2 per cultivars) was dew retting the grassland for 2–3 weeks; then the dry straw was weighed and broken by a self-constructed tool (Fig. 3).

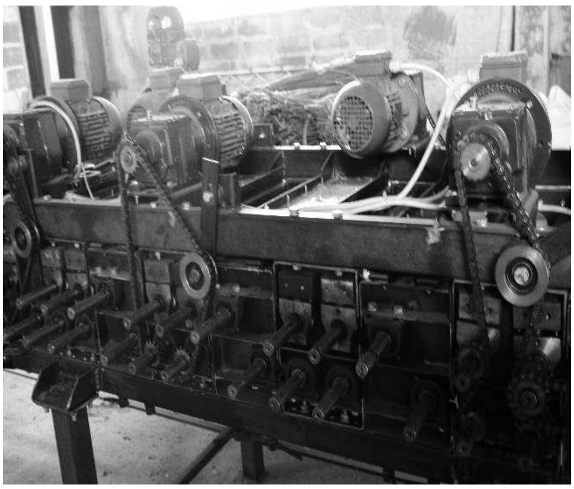

Figure 3. An aggregate of self-constructed tools for the production of fibre from the hemp stalks.

The obtained material was shaken manually until the sheaves were withdrawn. The obtained fibre was weighed and the fibre content in the straw was calculated by the formula:

$$F_{cs} = W_f \, 100 / W_s , \tag{1}$$

where: F_{cs} – the fibre content in the stalks, %; W_f – the weight of the obtained f_i bre, g; W_s – the weight of the technical stalk, g.

The main task of research was to evaluate the biomass potential of industrial hemp cultivar 'Futura 75' under different nitrogen fertiliser rates. The yield of absolutely dry hemp biomass was calculated according to the data of fresh biomass and its moisture content at harvesting in study years. The experimental data were subjected to ANOVA analysis.

RESULTS AND DISCUSSION

Industrial hemp biomass depends on the applied cultivar, fertiliser rates and meteorological conditions during the growing period (Ehrensing, 1998; Jankauskiene & Gruzdeviene, 2010; Ivanovs et al., 2014). Hemp grows better when an average daily temperature varies between 14 °C and 27 °C. It requires abundant moisture throughout the growing season, particularly during the first six weeks of growth (Ehrensing, 1998; Jankauskiene & Gruzdeviene, 2013).

Yield of hemp dry matter acquired within the field trials under agro-climatic conditions of Latvia on average comprised 15.06 (13.32–17.78 t ha^{-1}), depending on the cultivar. Cultivation year and selected cultivar notably affected hemp biomass yield (Table 1). The lowest fluctuations in the yields during the years of experiments were observed for the sort 'Futura75'.

Table 1. Biomass yield from different industrial hemp cultivars, 2012–2014

Hemp variety (F_A)	Dry biomass, t ha^{-1}			
	Years (F_B)			Average
	2012	2013	2014	
Bialobrzeskie	11.95	12.91	15.56	13.47
Futura 75	21.33	17.14	14.81	17.76
Fedora 17	18.23	13.32	12.78	14.78
Santhica 27	17.39	11.57	13.47	14.14
Beniko	19.27	13.30	11.96	14.84
Ferimon	18.59	13.09	12.93	14.87
Epsilon 68	12.89	18.47	14.47	15.28
Tygra	20.87	14.66	13.40	16.31
Wojko	19.91	14.83	11.79	15.51
Uso 31	17.38	11,40	11.98	13.59
Average	17.78	14.07	13.32	15.06
LSD(F_A) $_{0,05}$ variety	3.15			
LSD(F_B) $_{0,05}$ year	1.92			
LSD(F_{AB}) $_{0,05}$ interaction between variety and year	4.03			

In 2012, the highest yield of dry biomass was produced from cultivars ‘Futura 75’ (21.33 t ha^{-1}) and ‘Tygra’ (20.87 t ha^{-1}), while the lowest – from cultivar ‘Bialobrzeskie’ (11.95 t ha^{-1}). Significantly higher average yield of dry biomass was obtained from ‘Futura 75’ (17.76 t ha^{-1}), ‘Tygra’ (16.31 t ha^{-1}), ‘Wojko’ (15.51 t ha^{-1}) and ‘Epsilon 68’ (15.28 t ha^{-1}), whereas the lowest – from cultivars ‘Bialobrzeskie’ and ‘Uso 31’ (13.53 t ha^{-1}). Meteorological conditions influenced total volume of the dry biomass yield.

Hemp use is economically important for production of fiber and sheaves. Studies showed that the content of them depends on the choice of cultivars, fertiliser, seed norm and growing conditions. Depending on the growing method, the fiber content in sod calcareous soil varied from 29.8 to 45.6% of dry matter yield.

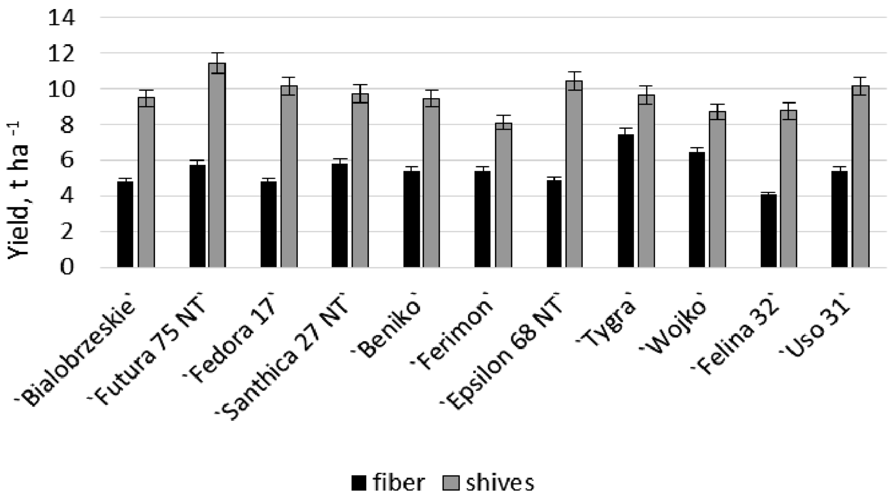

Figure 4. The yield of fibers and shives for hemp cultivars.

An average yield of fibre from the hemp cultivars was 4.88 t ha^{-1}. A higher yield during the testing years was from the cultivars ‘Tygra’– 6.12 t ha^{-1},‘Bialobrzeskie’ – 5.67 t ha^{-1}and ‘Santhica 27’–5.52 t ha^{-1} (Fig. 4). The nitrogen mineral fertiliser had a positive effect on the dry matter yield of hemp. This ensured also a yield of fibre. At a minimal rate of the nitrogen fertiliser F+N30 kg ha^{-1} the average yield of fibre for the cultivar 'Futura75' was 4.25 t ha^{-1}. In contrast to the unfertilised variants N0P0K0, the average increase in the fibre yield constituted 0.87 t ha^{-1}, or 25.7%. Increase in the fertiliser rate to F+N150 kg ha^{-1} ensured a fibre yield 6.15 t ha^{-1}. The increase constituted 2.72 t ha^{-1}, or 80.5%. Further increase in the fertiliser rates reduced a little the yield of fibre and sheaves (Fig. 5).

For biomass production, it is important to know the optimal plant density for sowing. Under the conditions of elevated plant density and the consequential interspecific competition, a part of the plants dies, the other stops growing, and only the remainder, that grows normally, contributes to the final product (Amaducci et al., 2012). In 2012, the established plant density after full emergence varied between 223–269 plants m^{-2}. The highest ($p < 0.05$) plant density was found in the plots where additional N fertiliser rate was not used (N0P0K0 – 259 plants m^{-2}) and in the plots where fertiliser N60 rate was used (F+N60 – 262 plants m^{-2}). The significant ($p < 0.05$) lowest plant density was found where fertiliser rate N90 was used (F+N90 – 241 plants m^{-2}).

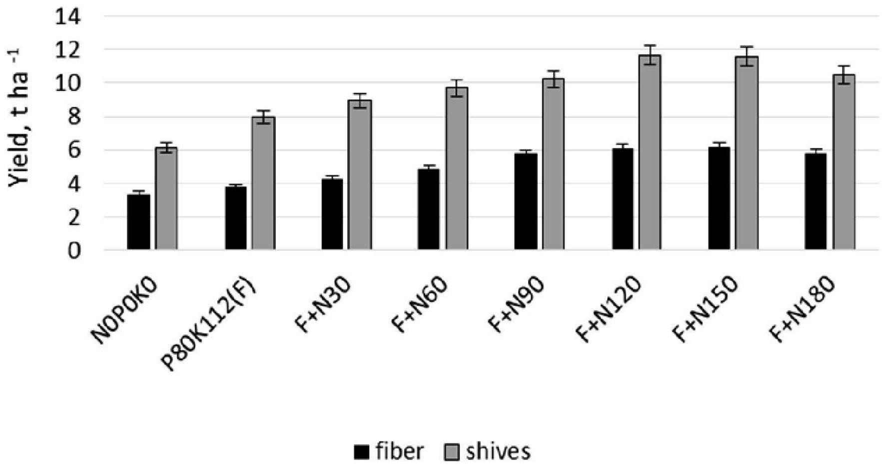

Figure 5. The yield of fibre and sheaves for cultivar 'Futura75', depending on fertiliser rates.

During vegetation period, the plant density decreases. At harvesting time, the highest plant density was found under N60 fertiliser rate (239 plants m^{-2}), but the lowest – under N180 fertiliser rate (212 plants m^{-2}). Some authors report that plant biomass yield decreases non-significantly if density is low (about 30–90 plants m^{-2}), while at high density (180–270 plants m^{-2}) about 50–60% of the initial stand was lost. In the other literature sources, it was found that nitrogen caused high industrial hemp plant mortality, probably due to competitive effects in the initial phase of the cycle (Amaducci et al., 2012; Ivanovs et al., 2015). Considering the average results, the influence of different nitrogen fertiliser rates on the biomass decrease was modest and non-significant ($p > 0.05$). On the average, during a three years' (2012–2014) period, the highest plant density was found in the plots where additional N fertiliser rate was not used (N0P0K0 – 380 plants m^{-2}), but the lowest plant density was found where fertiliser rates N150 and N180 were used (150 plants m^{-2}). On the average, the reduction in the density of fully emerged plants varied between 6.6–14.6% in the trial year. Nevertheless, the survived plants showed a high growth intensity and produced a sufficiently high biomass yield.

Industrial hemp stalk length was significantly ($p < 0.05$) influenced by the applied nitrogen fertiliser rate and cultivars. According to the research results, the plant height gradually increases with increasing N fertiliser rate, compared with the control (N0P0K0), but this growth increase varies between tested cultivars. The highest stalk length was observed for the cultivar 'Futura 75', 'Bialobrzeskie', 'Santhica 27' under all nitrogen fertiliser rates, compared with other tested cultivars.

The highest stalk length (318 cm) was reached under the nitrogen fertiliser rate F + N150 on the 138 growing day since sowing. The stalk length of other cultivars under the same nitrogen fertiliser rate was lower, cultivars 'Tygra' and 'Wojko' 32'–258 centimetres (Fig. 6).

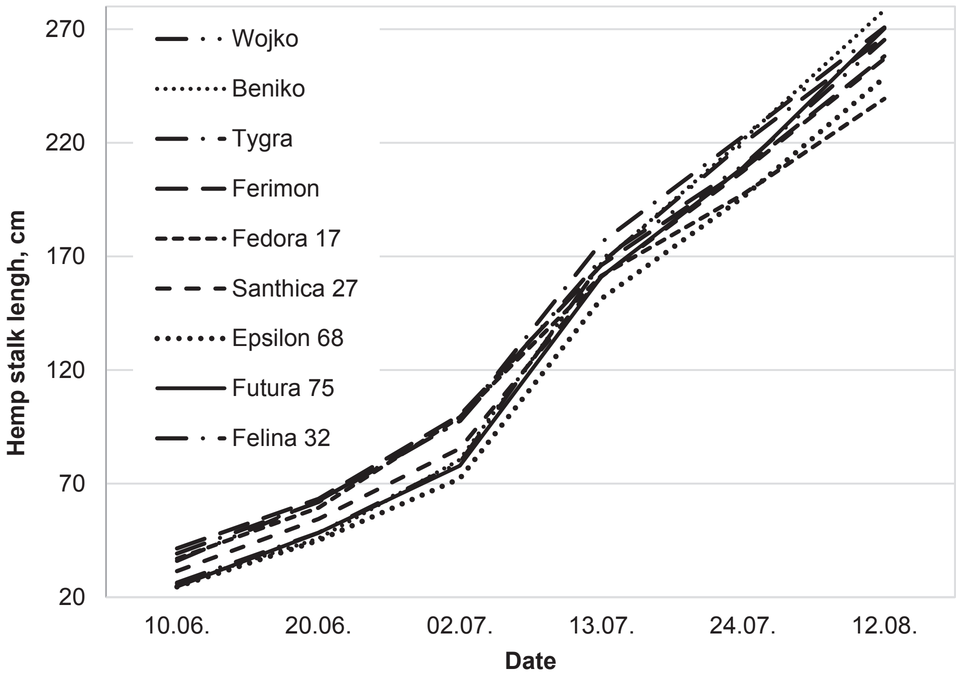

Figure 6. Average hemp stalk length, cm.

Analysed the relationships between hemp stalk length and biomass yield, we found out a significant ($p < 0.05$) close linear positive correlation ($r = 0.83$; $n = 24$) and it is reflected in the regression equation

$$y = 0.087 - 8.761, \tag{2}$$

In 2013, we found out a significant ($p<0.05$) linear positive correlation ($r = 0.53$; $n = 24$) what is reflected in the regression equation:

$$y = 0.2171x - 49.461, \tag{3}$$

Here we can conclude that hemp biomass yield depends not only on the nitrogen fertiliser rate, but also on such factors as plant density, meteorological conditions and other investigated factors that have not been studied.

The nitrogen fertiliser rate effect on the dry matter yield was significant ($p < 0.05$) for all years.

CONCLUSIONS

All explored hemp cultivars are productive and provide high biomass yield in Latvian agroclimatic conditions. The cultivars 'Futura 75', 'Tygra', 'Epsilon 68' and 'Santhica 27' were the most productive.

The nitrogen fertiliser rate effect was significant ($p < 0.05$) for biomass production. The lowest dry matter yield was observed under N0P0K0 fertiliser rate, but the highest dry matter yield was obtained using F+N150 kg ha^{-1}. When N rate was increased up to 180 kg ha^{-1}, the decrease of hemp fresh biomass and dry matter yield was observed. Hemp biomass depends on stalk length. There were positive linear correlations found for proof of this effect.

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