# IMPACT OF NITROGEN FERTILIZER RATES ON INDUSTRIAL HEMP GROWTH AND DEVELOPMENT

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**Abstract**
The aim of this study was to evaluate an impact of nitrogen fertilizer rates on industrial hemp's (*Cannabis sativa* L.) growth and development in Latvia. The trial was carried out during 2012 on the Research and Study farm Peterlauki of the Latvia University of Agriculture in the sod calcareous soil. There were three industrial hemp cultivars 'Futura 75', 'Tygra' and 'Felina 32' tested under different fertilizer rates: N0P0K0 – control, N0P80K112 – background fertilizer (in text marked as F), F+N30, F+N60, F+N90, F+N120, F+N150, F+N180 kg ha$^{-1}$. Weather conditions were proper for good hemp biomass production. Depending on the selected cultivars, the optimal fertilizer rate was in the range of 90 – 150 kg ha$^{-1}$. Industrial hemp stalk length was significantly ($p<0.05$) influenced by the applied nitrogen fertilizer rate and cultivars. The highest stalk length was observed in the cultivar 'Futura 75' under all nitrogen fertilizer rates. The highest stalk length (3.18 m) had reached under the nitrogen fertilizer rate 150 kg ha$^{-1}$ at 138 growing day from sowing. At the beginning of growing season (June - July) the growth intensity of hemp stalk length is high. Within one month the stalk length grew up for 1.23 meters of cultivar 'Futura 75'. The intensive growth of hemp stalk declines when the flowering stage is reached. Flowering stage occurred in early August, and it was dependent on nitrogen fertilizer rate. Under higher nitrogen fertilizer rate the flowering stage reached later.
**Key words:** *Cannabis sativa* L., 'Futura 75', 'Tygra', 'Felina 32'.

## Introduction

The industrial hemp (*Cannabis sativa* L.) is one of the earliest domesticated and widespread crops all over the world. Industrial hemp is an extraordinarily useful plant that can provide more environmentally friendly products: food, fibre, fuel, medicinal and building products as textiles for apparel hemp, mats for thermal insulation in the construction industry, specialty pulp and paper for technical applications, press-moulded interior panels for the automotive industry, geotextiles for erosion control, needle-punched carpeting, used as animal bedding, seed and oil for food sector, natural body care products, gamma linolenic acid in the cosmetics and pharmaceutical industries, natural THC-based therapeutic drugs, etc. (Bosca et al., 1998).

Nowadays industrial hemp has become very important as a crop for biomass production. It is fast-growing and suitable for Latvia's agro-climate conditions. An interest in possibilities of the hemp growing in Latvia is increasing year by year, and it is considered as one of the most promising renewable biomass sources to replace non-renewable natural resources for manufacturing of wide range industrial products (Adamovičs, 2007).

Latvian hemp sowing areas were registered only in the year 2008 and in the year 2009, 250 ha were grown. In recent years, the amount of industrial hemp growers and cultivated areas have increased in Latvia. According to data provided by Association of Industrial Hemp of Latvia, plantation area of hemp was approximately 600 ha in Latvia in 2012.

Industrial hemp is an herbaceous annual belonging to the family Cannabinaceae. Normally, it is dioecious having both staminate (male) and pistillate (female) plants, each with distinctive growth characteristics. Staminate plants are tall and slender with few leaves surrounding the flowers, while pistillate plants are short and stocky with many leaves at each terminal inflorescence (Ehrensing, 1998). Also, through breeding and selection there have been developed plants that are monoecious with male and female flowers on one stalk. The plants woody stem develops ranging in height from 1.5 to over 2.5 meters and 5 – 15 mm wide in diameter at the soil surface (Adamovičs, 2007; Adamovičs et al., 2012; Grabowska et al., 2005). The cultivation is environmentally friendly with little harmful accumulation or emission of chemical inputs (Struik et al., 2000). The soil structure is improved with its rich leafage suppressed weeds and leaves left on the soil after harvesting (Adamovičs, 2007). Once it has developed a good root system, it can survive most drought conditions (MacKinnon, 1997). The roots of industrial hemp can reach up to 200 cm depth to reach the water table (Amaducci et al., 2008).

The requirement for a well-drained site is necessary as industrial hemp plants are particularly sensitive to wet, flooded, or waterlogged soil (Olsen, 2004). Industrial hemp grows best in humid environment, in temperature between 14 °C and 27 °C. It has a high water requirement, especially during the first six weeks of growth (MacKinnon, 1997). It grows by average of 50 cm a month (Adamovičs, 2007).

Nitrogen is the element that is most widely used in agriculture, and it is the most important element which limits plant growth and development (Masclaux-

Daubresse et al., 2010). 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 nitrogen fertilizer stimulates hemp plant growth in field conditions (Maļceva et al., 2011). A lack of nitrogen will result in a lower yield because steps of growth (internodes' length, canopy area) will be missed, and therefore the efficiency of radiation use is reduced.

In the literary sources it was found that hemp fertilization methodology varies in different countries according to the existing soil and climatic conditions. For example, in the United States quoted nitrogen fertilization rates about 60 kg ha$^{-1}$, while in EU countries nitrogen fertilization rates vary between 40 – 200 kg ha$^{-1}$ depending on soil composition (Ehrensing, 1998). Recommendations for hemp growing developed in the EU are not considered to be suitable for Latvian climatic and soil conditions. Recommendations of suitable nitrogen fertilizer rates for hemp breeding in Latvia are not developed.

The aim of this study was to evaluate impact of nitrogen fertilizer rates on industrial hemp's (*Cannabis sativa* L.) growth and development in Latvia.

## Materials and Methods

The trial was carried out on the Research and Study farm Peterlauki of the Latvia University of Agriculture in the sod calcareous soils in 2012. The content of available P in the soil plough layer was 52 mg kg$^{-1}$, content of K – 128 mg kg$^{-1}$, pH KCl 6.7, and organic matter content – 25 g kg$^{-1}$.

Hemp was sown by sowing-machine on the 4$^{th}$ of May. Seed rate 50 kg ha$^{-1}$ or 250 germinate able seeds per 1 m$^2$. The trial was randomly spaced, triplicate. The plot size was 7 m$^2$. In the field rotation, industrial hemp followed previous crop – spring barley.

All tested industrial hemp cultivars are monoecious – male and female flowers are present on the same plant. Cultivar 'Futura 75' is considered as late – maturing in France, 'Felina 32' is considered semi-late in France. Hemp was tested under seven different nitrogen fertilizer application rates: control – N0P0K0; background fertilizer (in text marked as F) – N0P80K112; F+N30; F+N60; F+N90; F+N120; F+N150; F+N180 kg ha$^{-1}$. Factor A – nitrogen fertilizer rate. Factor B – cultivar.

During growing season the industrial hemp stalk was estimated. Total height of hemp stalk was measured from the soil surface to the tip of plant (±0.5 cm). On average, there were measured 10 plants per plot, seven times during the growing season. The main task of research presented here was to evaluate hemp growth and development under different nitrogen fertilizer rates - how fast hemp stalks grow and reach growth stages – vegetative stage: the first pair of leaves and flowering, and seed stages. No pesticides like insecticides, herbicides, desiccants were used.

Industrial hemp was harvested by a trimmer (leaving the stubble of 5 – 8 cm) on October 10$^{th}$, 2012.

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

Meteorological data was obtained from Dobele Hydro-meteorological Station (HMS). Precipitations were taken during the growing season near to the trial fields on the farm Peterlauki. Meteorological conditions of the 2012 growing season can be described as not very warm but with large temperature fluctuations (Fig. 1.) and wet with periodic substantial rainfall (Fig. 2.).

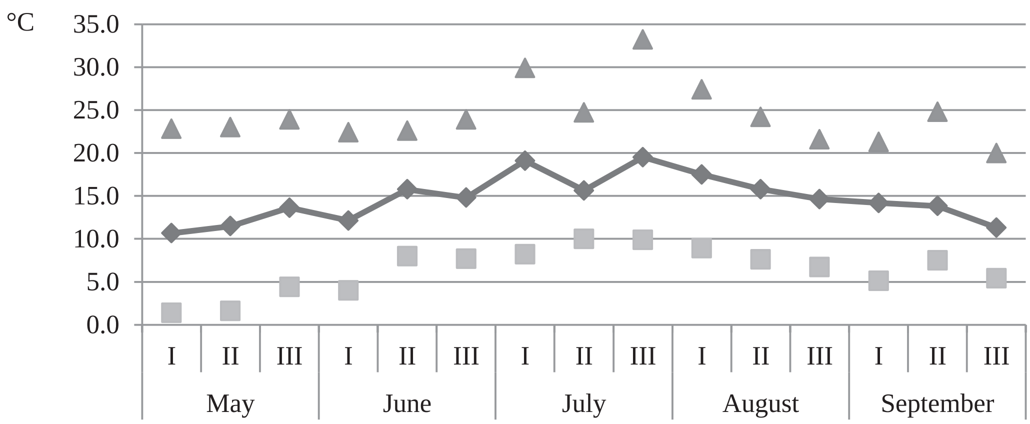


Figure 1. Temperature during the growing season, 2012 (°C):

Average MIN MAX

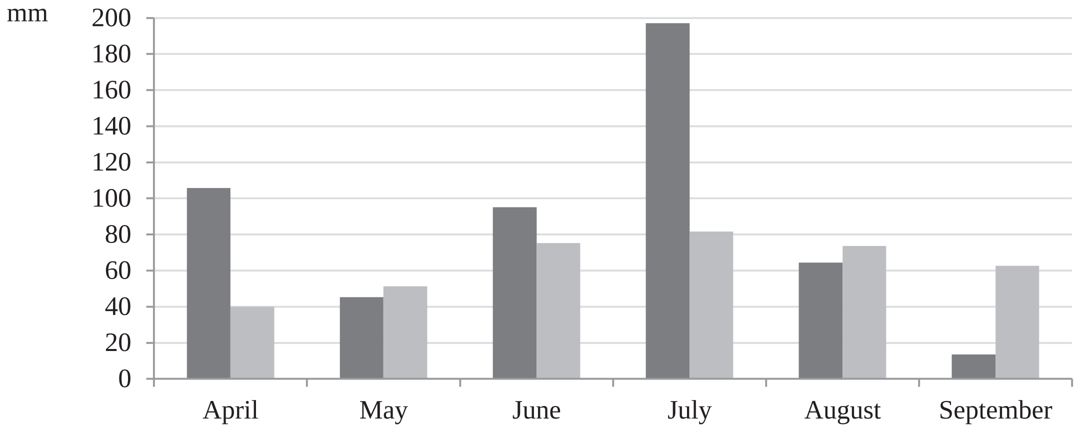


Figure 2. Precipitations during growing season, 2012:

■ 2012 ■ longterm, mm

**Results and Discussion**

The industrial hemp seeds germinate best when mean daily temperatures are 8 °C – 10 °C (Adamovičs, 2007). In 2012, the month of May was warm with an average temperature 11.9 °C (Fig.1.) and rich with precipitation month sum was 45.2 mm (Fig. 2.). According to the data, presented in Figure 1 and Figure 2, we can see that there was enough wet and good temperature for hemp seed germination in May. Meteorological conditions promoted seed germination. Industrial hemp emerged within a few days after sowing and reached growth stage – the first pair of true leaves (1002) (Mediavilla et al., 1998) in one week after sowing on the 11th of May. There was not any evident difference between the seedlings of different cultivars.

Hemp grows best when mean daily temperatures are between 14 °C and 27 °C (Ehrensing, 1998). Summer was characterized as cold and rich with precipitations, but the growing season temperature was suitable for hemp's growth and development. Hemp requires abundant moisture throughout the growing season, particularly while young plants are becoming established during the first six weeks of growth (Ehrensing, 1998; Grabowska et al., 2009). In the middle of vegetation season from June till July, there were periodical and strong rainfalls, causing water accumulation on the soil surface. It could also explain the high proportion of investigated factors (44.6%) whose effect on the hemp's growth and development has not been studied. According to the observation data of some researches (Olsen, 2004), hemp doesn't grow and develop well and suffer of stagnant water on the soil surface.

According to the information of scientific literature, industrial hemp growth and development is dependent on the applied nitrogen fertilizer rates (Ehrensing, 1998; Masclaux-Daubresse et al., 2010). To obtain a high industrial hemp stalk length, we need to provide plants with the necessary nutrients.

Industrial hemp stalk length was significantly ($p<0.05$) influenced by the applied nitrogen fertilizer rate and cultivars (Tab.). According to the research results, there was seen that plant height gradually increases with increasing N fertilizer rate, compared with the control (N0P0K0), but this growth increase varies between tested cultivars.

The highest stalk length was observed in the cultivar 'Futura 75' under all nitrogen fertilizer rates, compared with other tested cultivars. The highest stalk length (3.18 m) was reached under the nitrogen fertilizer rate F + N150 at 138 growing day from sowing. The stalk length of other cultivars under this nitrogen fertilizer rate was lower, cultivars 'Tygra' and 'Felina 32' – 2.58 meters (Tab.).

The highest stalk length of cultivar 'Tygra' was obtained under nitrogen fertilizer rate N90 (2.60 m), but cultivar 'Felina 32' - under nitrogen fertilizer rate N120 (2.71 m). In researches of Lithuania, the cultivar 'Felina 32' stalk length varies from 2.18 – 2.49 m under fertilizer rates N5P15K30 (Jankauskienė and Gruzdeviene, 2009; 2010).

The lowest stalk length of all cultivars was obtained under control treatment (N0P0K0), where nitrogen fertilizer was not applied, and it demonstrates the need of nitrogen for industrial hemp growing and developing.

According to the obtained data, the choice of industrial hemp cultivar affected the stalk length by 35%, but the applied nitrogen fertilizer rate – by 10%. The interaction of both factors affected the stalk length at about 10%.

Industrial hemp's need for nitrogen was high and increasing the nitrogen fertilizer rate to 150 kg ha$^{-1}$

Table

**Total length of hemp stalk, m**

| N fertilizer rate (A) | Industrial hemp cultivars (B) | | | Average (A) |
|---|---|---|---|---|
| | ‘Futura 75’ | ‘Tygra’ | ‘Felina 32’ | |
| N0P0K0 | 2.92 | 2.39 | 1.76 | 2.36 |
| N0P80K112 (F) | 3.04 | 2.41 | 1.85 | 2,43 |
| F + N30 | 2.93 | 2.41 | 2.59 | 2.64 |
| F + N60 | 2.96 | 2.41 | 2.59 | 2.66 |
| F + N90 | 3.04 | 2.61 | 2.63 | 2.76 |
| F + N120 | 3.04 | 2.58 | 2.71 | 2.78 |
| F + N150 | 3.18 | 2.58 | 2.58 | 2.78 |
| F + N180 | 3.14 | 2.57 | 2.44 | 2.72 |
| Average (B) | 3.03 | 2.50 | 2.40 | 2.64 |
| $LSD_{0.05A}$=0.37; $LSD_{0.05B}$=0.22; $LSD_{0.05AB}$=0.63 | | | | |

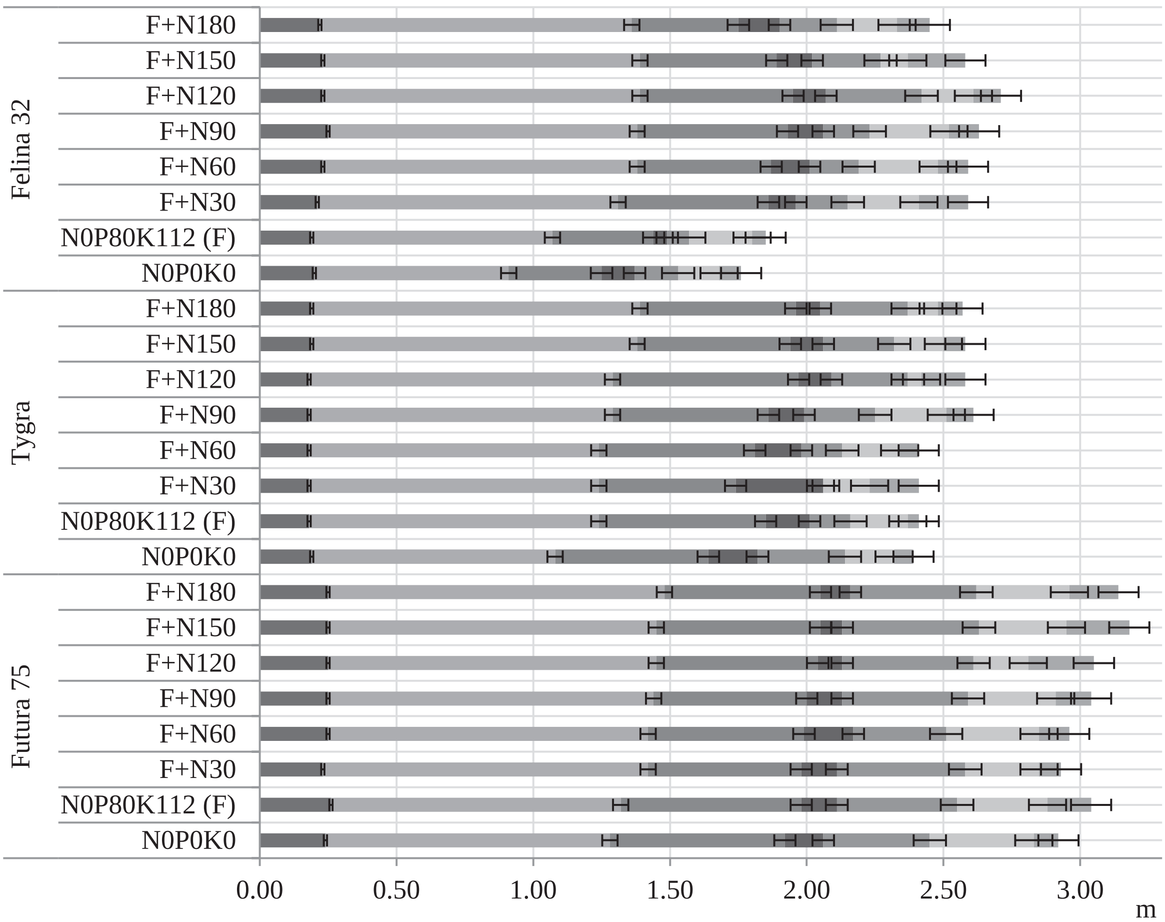


Figure 3. Industrial hemp cultivars’ stalk growth dynamic during the growing season under different nitrogen rates, m:

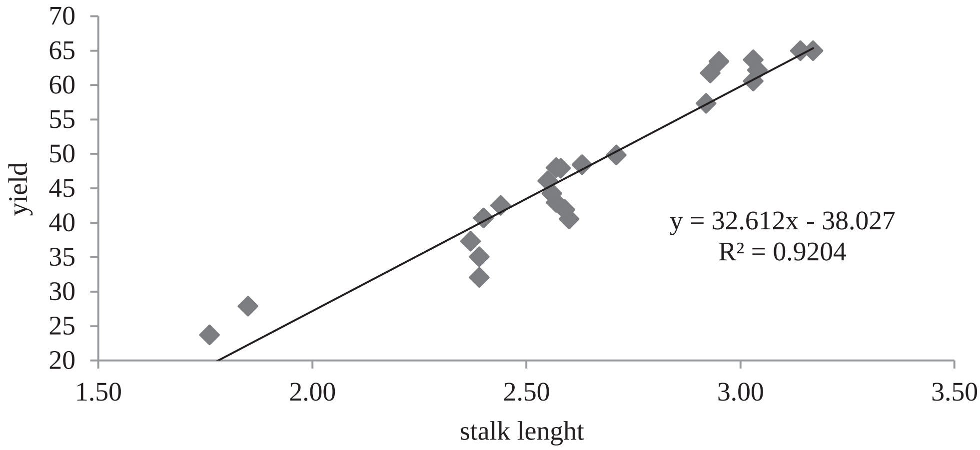


Figure 4. Effect of hemp stalk length on hemp over-green biomass yield.

the stalk length was increased for the cultivar 'Futura 75' during a trial period. But the cultivar 'Felina 32' the highest stalk length reaches under fertilizer rate 120 kg ha$^{-1}$. The cultivar 'Tygra' reaches the highest stalk length under 90 kg ha$^{-1}$, but by increasing a fertilizer rate, the stalk length decreases. Thus, we can conclude that with each applied kilo of nitrogen fertilizer the effectiveness increases until it reaches the maximum stalk length.

Assessing the growth intensity of industrial hemp varieties, the fastest growth of all cultivars was observed at the beginning of vegetation period, regardless fertilizer rates (Fig. 3.).

At the beginning of growing season (June - July) the higher growth intensity of hemp stalk length was observed for cultivars 'Futura 75' and 'Tygra' under higher nitrogen fertilizer rates. Within one month the stalk length grew up for 1.23 meters of the cultivar 'Futura 75' and for 1.20 meters of the cultivar 'Tygra' (Fig. 3). It shows that during the first six weeks of vegetative growth period industrial hemp's need for nitrogen is high.

The intensive growth of hemp stalk declined when the flowering stage was reached. Flowering stage occurred in early August, and it was dependent on nitrogen fertilizer rate. Under higher nitrogen fertilizer rate the flowering stage was reached later. During the period of flowering stage, a strong decrease of growth intensity, up to 10 – 15% of all growing season was observed.

The over-green biomass yield of industrial hemp depends on the stalk length during the growing season (Fig.4.).

A significant ($p<0.05$) close linear positive correlation between stalk length and over-green biomass yield ($r=0.96$; $n=24$) was observed, and the relationship is reflected in the regression equation $y=32.612x-38.027$; $R^2=0.92$. It shows that in 92% of cases the changes in yield might be explained by the changes in the stalk length. A decrease in the hemp stalk length will also decrease over-green biomass yield.

## Conclusions

1. Industrial hemp stalk length was significantly ($p<0.05$) influenced by the applied nitrogen fertilizer rate (kg ha) and tested cultivars. Depending on the selected cultivars, the optimal fertilizer rate is in the range of 90 – 150 kg ha$^{-1}$.
2. The highest stalk length was observed in the cultivar 'Futura 75' under all nitrogen fertilizer rates. The highest stalk length (3.18 m) was reached under the nitrogen fertilizer rate of 150 kg ha$^{-1}$ at 138 growing day from sowing.
3. The higher growth intensity of industrial hemp cultivars' stalk length was during first six weeks of growing season (beginning of June - July). Within one month the stalk length grew up for 1.23 meters. The intensive growth of hemp stalk declined when the flowering stage was reached (early August). Under higher nitrogen fertilizer rate the flowering stage was reached later.
4. The industrial hemp stalk length has a significant impact on the obtained hemp yield. By increasing the stalk length, the yield increased, too.

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