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# *Industrial Hemp Varieties Productivity Potential in the Latvian Climatic Conditions*

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***Abstract*. Varieties grown for fibre-only will be established, managed and harvested differently than varieties grown for seeds or dual-purpose. The aim was analysed yield productivity and length of vegetation period dependency of the two types of hemp variety and identified perspective hemp variety for highest yield under different meteorological conditions in Latvia. Varieties/line from diverse European and Latvian origin (seed hemp varieties/ line 'Adzelvieši', 'Pūriņi', KA-2-2011, 'Finola', 'Henola' and fibre hemp varieties 'USO 31', 'Futura 75', 'Austa') were sown in randomized field experiments in Latvia. Biomass, stem, seed yield, fibre contents and vegetation period length were assessed across tree growing seasons from 2020 to 2022. Results show that hemp, seeds and fibre varieties/line, performed well giving high yield productivity between variety. Agrometeorological conditions for hemp growth and yield were favourable in 2022. In Latvian local climatic conditions, the seed hemp line KA-2-2011 and fibre hemp variety 'Futura 75' identified significant higher of biomass and stem yield as well as the seed hemp variety 'Henola' and fibre hemp variety 'Austa' significant higher of seed yield and fibre contents. The yield potential dependent from length of vegetation period length. The trial analyses identified positive and significant correlations between length of vegetation period and biomass (r = 0.97), stem yield (r = 0.98), and negative between length of vegetation period and seed yield (r = -0.89).**

***Keywords: hemp, variety, fibre, vegetation period, yield.***

## I. INTRODUCTION

Industrial hemp (*Cannabis sativa*) well adapted for growing in different European climates [1], [2]. In Europe the France is the largest agricultural area (with almost 18,000 ha), followed by the Lithuania (over 9,000 ha), Estonia (4555 ha) and 10th place the Latvia (875 ha) in 2019 [3]. According in Latvia date in 2022 of hemp area (1263 ha) already higher [4]. In Latvia is expected that in future its production will increase, because EU policy focuses more on the 'European Green Deal' goals.

Hemp is an eco-friendly and multipurpose crop that provides raw material to a large number of traditional and innovative industrial applications [5], [6]. Moreover, tasks set maximizing the use of Latvia's renewable natural raw materials in the production of various industrial, food and feed products in the Latvian Bioeconomy Strategy for 2030 require [7]. Depending on markets and infrastructure the most valuable parts of the plant may vary, but the majority of its potential products are produced from the

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fibre, seeds and flowers. Therefore, a host of agronomic characteristics are important for successful crop production, including seeds, stem yield and crop phenology.

Currently, according to the EU Plant variety database, there are 96 registered hemp varieties (cultivars), for fibre, seeds, and dual-purpose. Most of these cultivars have been originally developed in Hungary, Italy, France, Latvia, Lithuania, Romania, Holland, Poland, Spain, Russia, Slovenia, Czech Republic, and Serbia [8]. In this research includes Latvian origin varieties of populations 'Adzelvieši', 'Purini' and new perspective line KA-2-2011 that more typical for seeds purpose but cannot be excluded for dual-purpose.

The timing of the harvest of hemp plants grown for fibre has a major effect on fibre quality. Hemp grown for fibre is harvested when male plants are at 100% bloom [9], as that is when the primary bast fibre output peaks [10]. Hemp seed matures about three to four months after planting, depending on many factors including sowing time, latitude, ambient temperature, amount of rain or irrigation during the growth period, genetics of the hemp variety, and availability of soil nutrients. When stressed by environmental or edaphic factors, hemp plants may bloom earlier. Harvesting should begin when most of the seeds (90%) have matured [11].

The selection of hemp varieties is one of the keys to a sustainable yield in a growing system and depending on end-use, varieties is defined used differently. The previous study [12], [13] already analysed hemp varieties productivity different aspects under variable climatic conditions in Latvia. However not included important genetic characteristics of the variety the days to maturity (regional adaptation). The aim was analysed yield productivity and length of vegetation period dependency of the two types of hemp variety and identified perspective hemp variety for highest yield under different meteorological conditions in Latvia.

## II. Material and Methods

*Experimental place.* The field trial was carried out in Institute of Agricultural Resources and Economics, Department of Plant Breeding and Agroecology at Vilani in the middle of Latgale (56˚34‘10"N, 26˚58'01"E) Latvia from 2020 to 2022. Experimental material for the study consisted of 8 hemp genotypes: seed hemp varieties/ line 'Adzelvieši', 'Pūriņi', 'KA-2-2011', 'Finola', 'Henola' and fibre hemp varieties 'USO 31', 'Futura 75', 'Austa'. Hemp was grown in a Humic Gleyic Podzol.

TABLE 1. THE MAIN AGROCHEMICAL PARAMETERS OF THE ARABLE SOIL LAYER

| Year | Organic matter contents, % | Soil acidity ($pH_{KCl}$) | Available $P_2O_5$, mg $kg^{-1}$ | Availa-ble $K_2O$, mg $kg^{-1}$ |
|---|---|---|---|---|
| 2020 | 7.41 | 6.61 | 151 | 112 |
| 2021 | 6.60 | 7.30 | 199 | 183 |
| 2022 | 7.0 | 6.85 | 169.5 | 143.5 |

The field trials were laid out in a randomized block design of four replicates, the one plot size was 25$m^2$. Seeds were sown during the first and second decade of May using an experimental sowing machine (SN-16) with an inter-row distance of 12.5 cm and seeding rate – 60 kg $ha^{-1}$. Complex fertilizer Yara Mila NPK(S) 18-11-13(7) 300 kg $ha^{-1}$ was applied after the first cultivation of soil, 35 days after sowing, were fertilized with 60 kg $ha^{-1}$ of nitrogen, as recommended in a previous study [14].

Four sub-plot of 1 $m^2$ from one plot were selected, for each variety/line, weighted green biomass yield and then dry straws (humidity average10%) was weighted and plant sample breaked by laboratory tool LM-3; obtained fibre was weighted and fibre contents in the straw was calculated by the formula (1):

$$Fc = Wf \times 100 / Wstr \quad (1)$$

where: Fc – fibre content in the straw, %,
Wf – weight of obtained fibre, g,
Wstr – weight of straw before scutching, g.

The hemp stems are obtained and weighted after drying the green stalks from one sub-plot. Harvesting was carried out using a grain harvester Sampo SR 2035 and reaper KD-210 (duplex type). Seeds were cleaned with "MLN" sample cleaner. The yield of seeds was weighed and then re-calculated to weight by 100% purity and 12% humidity.

*Meteorological conditions.* Agro-meteorological conditions characteristics were used by Rezekne hydrometeorological station.

TABLE 2. METEOROLOGICAL CONDITIONS

| Month | Long-term average | 2020 | 2021 | 2022 |
|---|---|---|---|---|
| Temperature, ºC | | | | |
| April | 4.3 | 5.02 | 5.4 | 5.0 |
| May | 11.1 | 9.07 | 10.7 | 10.0 |
| June | 14.8 | 18.07 | 19.2 | 17.3 |
| July | 16.9 | 16.03 | 21.5 | 17.3 |
| August | 15.5 | 16.07 | 15.7 | 19.5 |
| September | 10.7 | 13.06 | 9.8 | 9.0 |
| Precipitation, mm | | | | |
| April | 32 | 27.01 | 22.4 | 40.9 |
| May | 52 | 84.7 | 95.5 | 70.2 |
| June | 75 | 73.1 | 51.0 | 108.5 |
| July | 81 | 66.3 | 8.2 | 44.7 |
| August | 71 | 60.0 | 116.8 | 87.6 |
| September | 62 | 43.3 | 35.9 | 17.3 |

*Statistical analysis.* Software Excel (Microsoft, USA) was used for data statistical analysis. The difference between the yields properties were determined using analysis of variance (ANOVA). Significant differences among the measured characteristics of hemp were compared by Fisher's protected least significant difference (LSD) tests ($p \leq 0.05$). The correlation coefficient used to understand relationships the days to flowering and vegetation period length dependency among agronomic important yield traits.

## III. RESULTS AND DISCUSION

Hemp genotypes of the biomass yield showed higher biomass yield in 2022. In 2021 (Table 1.), less precipitation and higher average daily temperature were observed in June and July, which is affects shorter of plant height, early flower blooming and as result lower biomass yield.

In research included the seed hemp genotypes have dioecious and fibre hemp varieties monoecious plants. In research proved that significant highest of yield performed and depended from hemp variety (Table 3.). Biomass yield of seed varieties ranged from 13.50 to 20.27 t $ha^{-1}$ and fibre varieties from 25.47 to 37.33 t $ha^{-1}$. The genotypes were harvested with significant ($p \leq 0.05$) higher biomass and stem yield of the seed line KA-2-2011 and fibre variety of the 'Futura 75'. Compared results were observed that for seed hemp varieties of the biomass yield and stem yield significant lower like for fibre hemp varieties. The fibre content was influenced by variety heritability and a significant ($p \leq 0.05$) highest were recorded of 'Henola' at 36.3% and 'Austa' at 42.32%. Similar results to [1], [12] – [16] that biomass and fibre yield are known to vary widely between hemp varieties, agronomic practices and environmental conditions. According to [1], [16], hemp is a high-yielding crop that was reported to produce up to 20 t $ha^{-1}$ of dry biomass per cropping season in diverse environments (Italy, Latvia, Poland), under favourable conditions. If compared with Sweden, [17] reported that the total biomass yield of the three monecious hemp varieties ('Felina', 'Fedora', and 'Futura') varied between 7.8 and 14.5 t d.m. $ha^{-1}$. In the study by [18] in Switzerland with 29 varieties, stem dry matter yield range from 5 to 13 t $ha^{-1}$ and seed yield from 250 to 1200 kg $ha^{-1}$.

The highest seed yield was observed of the variety 'Henola' (Table 3.). In study seeds yield of seed hemp varieties/line ranged from 2.02 to 3.25 t $ha^{-1}$ and fibre varieties from 0.50 to 0.94 t $ha^{-1}$. The hemp fibre varieties have a significant lower seed yield in Latvian climatic conditions. In addition, were observed that hemp seeds are sensitive to seed loss by the winds and birds. The seeds dehisce easily during maturity stage. According to [19] the morphology of certain closely grouped fertile heads of certain varieties (e.g., 'Finola', 'USO') can limit this phenomenon. Thus, in practice, harvesting start before at the seeds attain maturity. This minimizes the wind risk of seed loss.

An alternative to single-use fiber production is the dual-purpose production of seeds and stems, which is currently the main production strategy in Europe and more suitable variety have 'Futura 75' [20] from varies what included in study. But from these results were identified genotype more suitable for dual purposes of the new line KA-2-2011 with and more highest stem yield and seed yield.

TABLE 3. HEMP OF THE AGRONOMIC IMPORTANT TRAITS

| Varieties/lines | Biomass yield, t $ha^{-1}$ | | | | Stem yield, t $ha^{-1}$ | Fiber content, % | Seed yield, t $ha^{-1}$ |
|---|---|---|---|---|---|---|---|
| | 2020 | 2021 | 2022 | Average | | | |
| Seed varety/line | | | | | | | |
| Adzelvieši | 14.9 | 11.9 | 13.7 | 13.50c | 7.53c | 23.99b | 2.02b |
| Pūriņi | 21.0 | 17.8 | 19.4 | 19.40a | 10.80ab | 23.13b | 2.27b |
| KA-2-2011 | 21.6 | 17.4 | 21.8 | 20.27a | 13.17a | 23.76b | 2.19b |
| Finola | 13.7 | 10.8 | 19.0 | 14.50bc | 7.80c | 25.80b | 2.41b |
| Henola | 19.5 | 16.4 | 21.2 | 19.03ab | 9.07bc | 33.76a | 3.25a |
| *LSD0.05* | | | | *4.76* | *2.95* | *6.79* | *0.61* |
| *p-value* | | | | *0.03* | *0.01* | *0.03* | *0.01* |
| Fibre variety | | | | | | | |
| USO-31 | 21.6 | 17.1 | 19.5 | 25.47b | 19.40b | 32.28 | 0.94 |
| Futura 75 | 32.9 | 23.1 | 36.5 | 37.33a | 30.83a | 33.44 | 0.50 |
| Austa | 21.90 | 15.6 | 22.9 | 27.30a | 20.13b | 42.32 | 0.86 |
| *LSD0.05* | | | | *11.09* | *9.57* | *11.09* | *0.94* |
| *p-value* | | | | *0.08* | *0.05* | *0.09* | *0.52* |

The hemp vegetation period length is indirect factor for yield potential. According to correlation coefficient the days to flowering ($r_f$) and vegetation period length ($r_v$) relationships with agronomic important yield traits are similar and after results significant influence of the hemp yield.

The positive significant ($p \leq 0.01$) relationship showed between the vegetation period length with biomass yield ($r_v$=0.96) (Fig. 1.) and stem yield ($r_v$=0.98) (Fig. 2.). In research all included varieties have highest biomass and stem yield with later vegetation period.

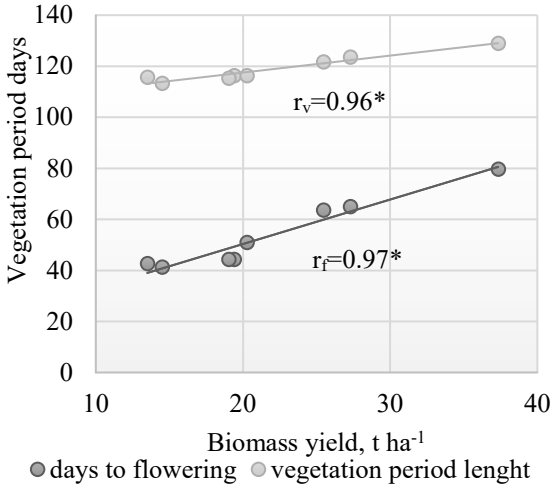


Fig. 1. Hemp varieties/line of the biomass yield relationships between vegetation periods days.

* − correlation significant at $p \leq 0.01$

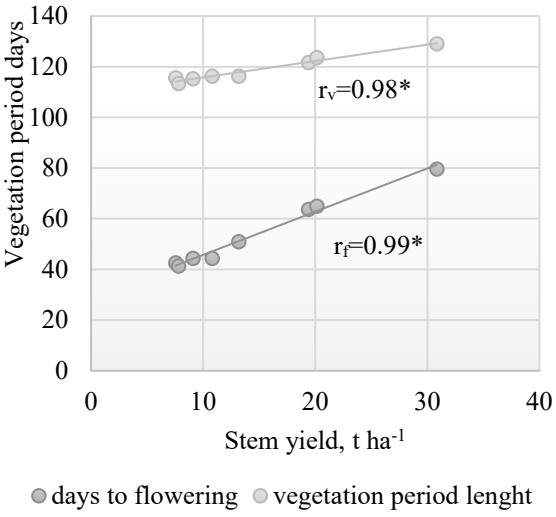


Fig. 2. Hemp varieties/line of the stem yield relationships between vegetation periods days.

* − correlation significant at $p \leq 0.01$

The negative significant ($p \leq 0.05$) relationship showed between the vegetation period length and seed yield ($r_v$= -0.89) (Fig. 3.). Dates proved that early hemp varieties have highest seed yield potential compared with fibre variety.

The positive relationship showed between the vegetation period length and fibre contents ($r_v$=0.64) (Fig. 4.). The fibre content more dependent from variety genetic characteristics but not from vegetation period length or days to flowering. Furthermore, a study by [21], [22] reveals that hemp varieties genetic development remains limited to a few main traits, examples, fibre content and flowering time. According to [23], fibre content and flowering time traits showed large heritable variation, controlled by robust genetic mechanisms that can be used in breeding programs.

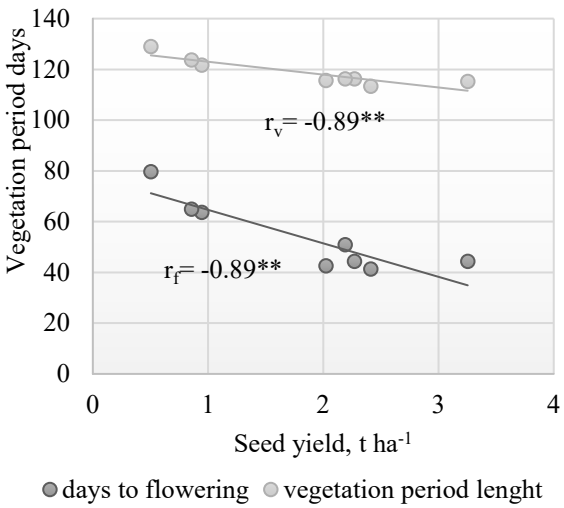


Fig. 3. Hemp varieties/line of the seed yield relationships between vegetation periods days.

** − correlation significant at $p \leq 0.01$

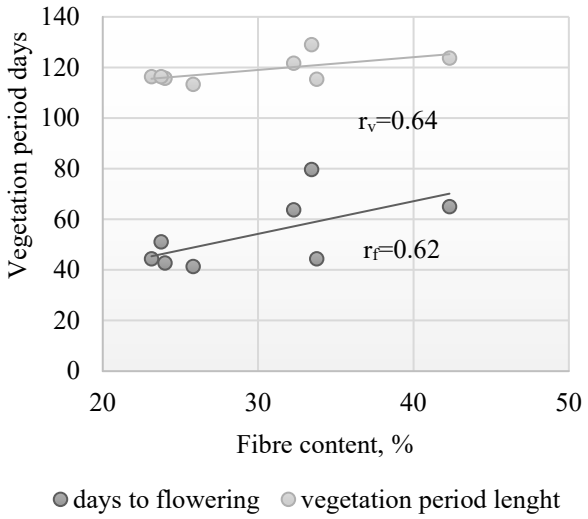


Fig. 4. Hemp varieties/line of the fibre content relationships between vegetation periods days.

In this study vegetation period of seed hemp varieties is between 113 and 116 days and fibre hemp varieties between 121 and 129 days. The seeds hemp varieties flowering start more early comparing to fibre hemp varieties (Table 4.). The fibre variety later days to flowering that also affect seed yield potential in Latvian conditions. The development of industrial hemp [24] largely depends on the amount of sunlight, particularly on the length of the day (long-day conditions increase the vegetative growth phase). According to [7], [8], hemp is a short-day plant, strongly photosensitive (flowers according to day length; not physiological maturity), and the day length influences the quantity of light received by the hemp plant, impacting the production of distinct hemp types.

Hemp classification [24] includes northern hemp – a dwarf variety with a short vegetation period of 60– 75 days, and southern hemp – tall-growing with a vegetation period of 140–160 days. However, at our latitudes in Latvia, the intermediate type is the most common similar like Polish hemp varieties [25] represent the intermediate type: they have a vegetation period of 120–140 days. However, were observed in Latvia vegetation period length is shorter of range of 110–130 days (Table 4.).

In the study the hemp variety / line was observed complete resistance to lodge in strong winds and rain during 2020 to 2022 vegetation period (Table 4.).

TABLE 4. HEMP VARIETIES/LINE OF THE VEGETATION PERIODS LENGHT AND LODGING

| Varieties/lines | Days to flowering | | | | Vegetation periode lenght, days | | | | Lodging |
|---|---|---|---|---|---|---|---|---|---|
| | 2020 | 2021 | 2022 | Average | 2020 | 2021 | 2022 | Average | |
| Seed hemp varieties/line | | | | | | | | | |
| Adzelvieši | 42 | 45 | 41 | 42.7 | 118 | 113 | 116 | 115.7 | 9 |
| Pūriņi | 46 | 43 | 44 | 44.3 | 118 | 112 | 119 | 116.3 | 9 |
| KA-2-2011 | 58 | 49 | 46 | 51.0 | 117 | 111 | 121 | 116.3 | 9 |
| Finola | 42 | 43 | 39 | 41.3 | 113 | 114 | 113 | 113.3 | 9 |
| Henola | 47 | 45 | 41 | 44.3 | 118 | 112 | 116 | 115.3 | 9 |
| Fibre hemp varieties | | | | | | | | | |
| USO-31 | 56 | 61 | 74 | 63.7 | 120 | 121 | 124 | 121.7 | 9 |
| Futura 75 | 72 | 77 | 90 | 79.7 | 126 | 130 | 131 | 129.0 | 9 |
| Austa | 56 | 61 | 78 | 65.0 | 126 | 119 | 126 | 123.7 | 9 |

## IV. CONCLUSIONS

In Latvian local climatic conditions, the potential seed hemp line KA-2-2011 and fibre hemp variety 'Futura 75' for significant higher of biomass and stem yield as well as the seed hemp variety 'Henola' and fibre hemp variety 'Austa' for significant higher of seed yield and fibre contents were identified.

The hemp yield dependent from length of vegetation period and days to flowering. The analyses identified positive and significant ($p \leq 0.01$) correlations between length of vegetation period and biomass ($r = 0.97$), stem yield ($r = 0.98$), and negative significant ($p \leq 0.05$) between length of vegetation period and seed yield ($r = -0.89$).

In Latvia results showed that suitable the intermediate type of hemp with optimal 110–130 days length vegetation period. However fibre hemp varieties with later vegetation period have lower seeds yield due to their late maturity.

The hemp varieties/ line were observed complete resistance to lodging in Latvian climatic conditions.

## V. ACKNOWLEDGEMENTS

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