

## **Product-oriented production of industrial hemp according to climatic conditions**

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**Abstract.** Cultivation area of industrial hemp in Europe has increased since 2012. It is expected that in future its production will increase, because European Union (EU) policy focuses more on the ‘green deal’ goals. Research into the effects of climate conditions (temperature and rainfall) on growth is important to select the best industrial hemp varieties for hemp products. The objective of the research is identifying industrial hemp varieties suitable for seed, fiber and shives production in varying pedo-climatic conditions in order to obtain products with the highest added value.

Four industrial hemp varieties were used for the research: ‘Purini’ (Latvia), ‘Bialobrzeskie’ (Poland), ‘USO -31’ (France-Ukraine), ‘Finola’ (Finland). Field trials were carried out in Eastern Latvia in 2010, 2011, 2012, 2013, 2019. Climatic indicators were recorded during the vegetation period from April to September. Yields of seeds, fibre, shives and total biomass were determined during the research. Factor analysis method was used to determine the impact of temperature and rainfall on the yield of seeds, fibres and shives. The study of climatic factors shows that the effect of temperature and rainfall on seed, shives and fiber yields strongly depends on the variety.

**Key words:** hemp growth, industrial hemp, climate conditions.

### **INTRODUCTION**

The history of use and cultivation of industrial hemp is exceptionally long. Hemp is a multi-purpose crop delivering fibers, shives, seeds and pharmaceuticals. This crop is unique for bioeconomy because the properties of hemp seeds, fiber, shives allow it to be widely used. Traditionally, hemp is used in textiles, bio composites, cosmetics, oil, pharmaceutical industry, building industry as insulation material etc. (Salentijn et al., 2015). Hempcrete is alternative building material which could replace traditional concrete materials and reduce the carbon footprints of buildings and help in saving

natural resources. Hempcrete will promote the development of sustainable construction materials and replace also synthetic-based products (Karche & Singh, 2019).

Hemp, adjacent to flax, is currently recognised as a significant source of natural fiber. Replacing fossil raw materials with natural, opens up new opportunities for the use of hemp fiber in the near future. Cultivation area in Europe has increased since 2012. The main cultivation states are France and Netherlands, while in Baltic States it is not so intense (Carus et al., 2013). It is expected that in future its production will increase, because EU policy focuses more on the ‘green deal’ goals.

Today, in the EU hemp is a niche crop. Because of its unique properties, particularly its environmental benefits and the high yield of natural technical fibres, hemp is a valuable crop for the bio-based economy (Carus et al., 2013).

Climatic conditions are one of the major factors influencing hemp yields (Baldini et al., 2020). The effects of these factors need to be studied at a particular cannabis site to assess the effects of climatic factors on yields (Amaducci et al., 2015). Much of the research has focused on the determination of the cannabidiol (CBD) content of cannabis in relation to climatic conditions, in particular temperature and rainfall (Mazian et al., 2018; Abdollahi et al., 2020a, Abdollahi et al., 2020b,). CBD is pharmacologically active substance, very important for use in medical applications (Glivar et al., 2020).

Different meteorological conditions during growth affect cannabis yield (Wei, 2007). The results of many experiments show that yields fluctuate significantly from year to year, even under practically the same agricultural conditions. In Latvia, with very volatile agrometeorological conditions, such fluctuations are inevitable. Yield stability indicators for different crops have been little studied, as even two identical years are not possible under field conditions (Kroģere & Pelēce, 2004). In Eastern Latvia there are large fluctuations of temperature and rainfall during the vegetation period (Baltiņa et al., 2011, Maļceva et al., 2011). The yield of hemp is significantly affected by climatic conditions. Of course, yield is affected not only by climatic conditions, but also by variety, soil, fertilizer and other factors. This study of 4 varieties allows to use the obtained data for the selection of a suitable variety in Eastern Latvia.

## MATERIALS AND METHODS

Four industrial hemp (*Cannabis sativa* L.) varieties (Table 1) were used for the research: ‘Purini’ (Latvia), ‘Bialobrzeskie’ (Poland), ‘USO-31’ (France-Ukraine), ‘Finola’ (Finland).

**Table 1.** Tested hemp cultivars registered in EU Plant variety database

Cultivar	Grown in research year	Country	Admission	Origin	Climate adaptation	Maturity group
Bialobrzeskie	2010 to 2013	PL	31.12.1967	Poland	Continental	Medium<140 days
Finola	2010 to 2013 and 2019	FI	05.02.2003	Finland	Continental	Early<115 days
USO-31	2011 to 2013 and 2019	CH	07.06.1999	Ukraine	Atlantic	Early<125 days
Pūriņi	2010 to 2013 and 2019	LV	27.02.2020	Latvia	Atlantic	Early<125 days

The hemp variety ‘Pūriņi’ is a variety selected in Latvia (Common catalogue of varieties of agricultural plant species. 2020 consolidated version; Latvian Plant Varieties Catalogue).

Field trials were carried out in Eastern Latvia in 2010, 2011, 2012, 2013, 2019. The methodology of field trials is presented in Table 2. Characteristics of the test site - Viļāni Parish ((N) 56°34.053'; (E) 26°58.868'), 110 meters above sea level, the terrain is mostly flat and slightly hilly, the climate is moderately continental, moderately warm and humid.

**Table 2.** The methodology of field trials

Year	2010	2011	2012	2013	2019
Soil type	sod -podzolic gley soil	sod -podzolic gley soil	sod -podzolic gley soil	sod -podzolic gley soil	sod -podzolic gley soil
Organic matter in soil	6.5%	6.5%	6.5%	6.5%	7.4%
Soil pH	7.0	7.0	7.0	7.0	6.6
P <sub>2</sub> O <sub>5</sub>	145 mg kg <sup>-1</sup>	145 mg kg <sup>-1</sup>	145 mg kg <sup>-1</sup>	145 mg kg <sup>-1</sup>	152 mg kg <sup>-1</sup>
K <sub>2</sub> O	118 mg kg <sup>-1</sup>	118 mg kg <sup>-1</sup>	118 mg kg <sup>-1</sup>	118 mg kg <sup>-1</sup>	112 mg kg <sup>-1</sup>
Soil tillage	field plowed in autumn 2009, cultivated in spring 2010	field plowed in autumn 2010, cultivated in spring 2011	field plowed in autumn 2011, cultivated in spring 2012	field plowed in autumn 2012, cultivated in spring 2013	field plowed in autumn 2018, cultivated in spring 2019
Sowing rate	70 kg·ha <sup>-1</sup>	70 kg·ha <sup>-1</sup>	70 kg·ha <sup>-1</sup>	70 kg·ha <sup>-1</sup>	60 kg·ha <sup>-1</sup>
Field area	20 m <sup>2</sup>	12 m <sup>2</sup>	20 m <sup>2</sup>	16 m <sup>2</sup>	15 m <sup>2</sup>
Repetitions	3	3	3	3	4
Harvesting	For each variety, 1 m <sup>2</sup> of hemp shall be harvested from each variant, tie in the beams and determine yields of seeds, fiber, shives and total biomass after drying				

Hemp samples were taken from each variety (Fig. 1) in 4 replicates. The yield of seeds, shives, fiber and biomass was determined for the samples collected after harvesting.



**Figure 1.** Hemp sample fields.

Hemp sowing dates for each variety are the same in current year but harvesting dates are different for each variety (Table 3) e.g. in 2011 difference is near 1 month.

The plots were not additionally treated with mineral fertilizer, therefore the effect of additional fertilizer on yield is excluded. During the growing season - April to September - there is a fixed temperature and precipitation to assess the impact of climatic conditions on hemp yield depending on the variety and to determine the suitability of the hemp variety for Eastern Latvia or similar climatic conditions. Data analysis was used to determine the most appropriate variety for a particular hemp product - seed, shives, fiber.

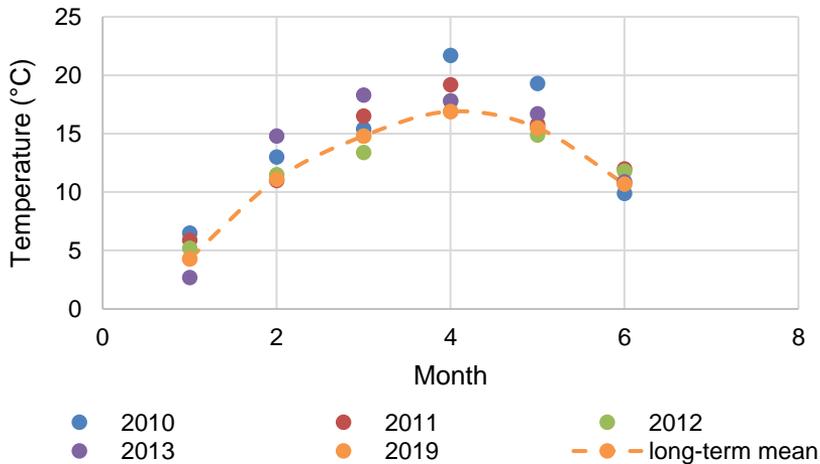
Yield and shives content were calculated as the arithmetic mean of three replicates. Analyses of plant samples were performed in the laboratory (RTA Chemistry Laboratory) using standard methods specified by the State of Latvia.

The shives and fiber content (%) was determined for the average hemp sample of each replicate, which was divided into two portions and dried to 8–10% moisture. 100 g of haulm from each sample were weighed onto the balance (accuracy  $\pm 0.001$  g) by grinding with LM-3 and brushing, shaking from the splint fiber to remove the shives.

Climatical parameters - temperature and rainfall - of location are shown in Figs 2, 3. Data used from Vilani Meteorological Observation Station. The last ten years have seen a high temperature in relation to the long term mean, more pronounced in the middle of vegetation.

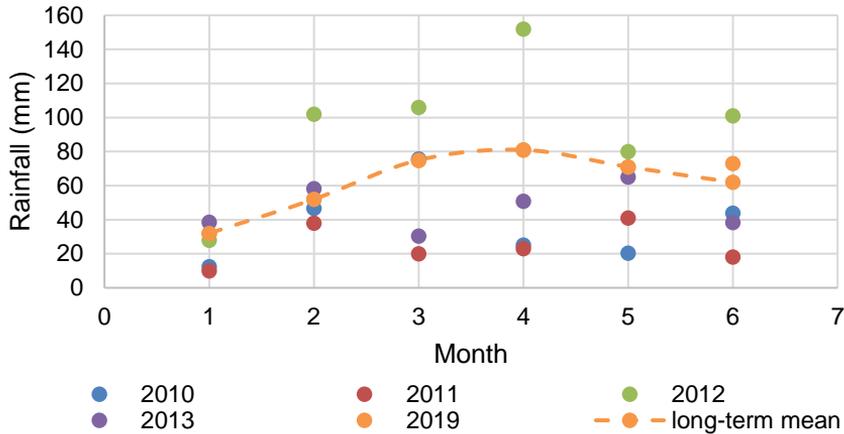
**Table 3.** Hemp sowing and harvesting dates

Variety	Year	Sowing data	Harvesting data
Finola	2010	May, 13	September, 1
Purini		May, 13	September, 7
Bialozeberskie		May, 13	September, 16
Finola	2011	May, 6	August, 24
Purini		May, 6	September, 6
Bialozeberskie		May, 6	September, 22
USO 31	2012	May, 6	September, 16
Finola		May, 9	August, 28
Purini		May, 9	September, 11
Bialozeberskie	2013	May, 9	September, 26
USO 31		May, 9	September, 19
Finola		2019	May, 13
Purini	May, 13		September, 15
USO 31	May, 13		September, 27



**Figure 2.** Monthly temperature during the growing season (1-April, 2-May, 3-June, 4-July, 5- August, 6-September) in 2010, 2011, 2012, 2013, 2019 and long-term mean at Vilani (Latvia).

The last ten years have generally seen lower rainfall relative to the long term mean, more pronounced in the middle and at the end of vegetation. An exception during the research was 2012, which was rainy in Latvia.



**Figure 3.** Monthly rainfall during the growing season (1-April, 2-May, 3-June, 4-July, 5-August, 6-September) in 2010, 2011, 2012, 2013, 2019 and long-term mean at Vilani (Latvia).

The results were processed using descriptive and variation statistics, regression and correlation methods. The strength of the mutual link of independent and dependent random variables (correlation) can be assessed by means of a correlation coefficient. In case of a single factor mathematic model, the Pearson's equation is used for its estimations:

$$r = \frac{\sum_{i=1}^m (x_i - x)(y_i - y)}{(m-1)S_x * S_y}, \tag{1}$$

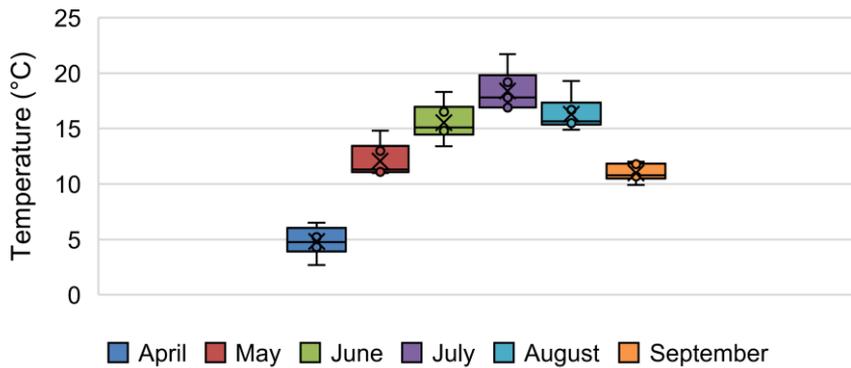
where  $x_i, y_i$  – independent variables and pairs of corresponding dependent variables;  $x, y$  – mean arithmetic values of independent and dependent variables;  $S_x, S_y$  – selection dispersions of variables.

## RESULTS AND DISCUSSION

Climate data analysis is an important factor influencing hemp yields. The variability of climatic factors in the vegetation period for ruminants from 2010–2013 and 2019 is given in Figs 4, 5.

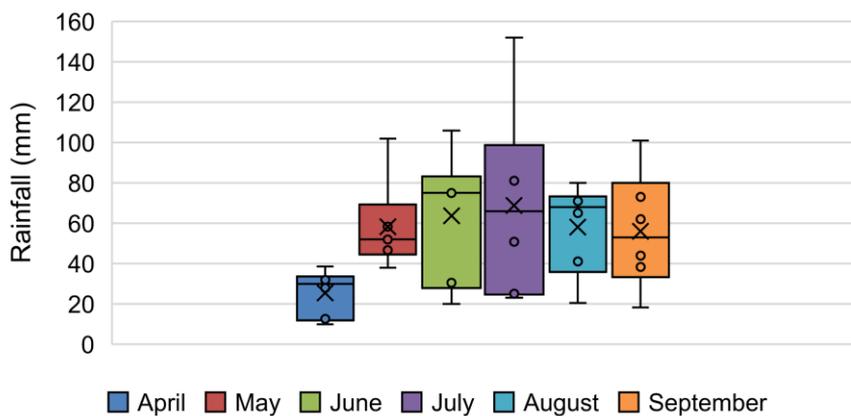
Unusually low temperatures were observed only in June. So the temperature fluctuations in the summer months become more pronounced year by year.

Rainfall is very variable. In May, rainfall is more frequent than the average for this month, but in June it is higher than the average. In the summer months, there is a marked inequality over the years. The pronounced variability of rainfall during the growing season becomes sharper. To avoid plant stress and obtain viable yields, adequate moisture during active growth is required. Hemp is sensitive to drought conditions and needs an adequate supply of water (Cole & Zurbo, 2008).



**Figure 4.** Temperature variability in the vegetation period by months from 2010 to 2013 and 2019.

During sowing - usually April, early May - the average air temperature is 5 °C, which is favourable conditions for seed germination. Precipitation in April is generally lower than in other vegetation months and no sharp changes are observed. As there is sufficient moisture in the soil after the winter period, the conditions for germination are favourable. During the study period, April and May 2010 had low rainfall, which hindered germination. As the dry and hot weather continued in May and June, this had a negative effect on plant development. Assessing the fluctuations of climatic conditions, it can be concluded that higher risk factors for germination may be caused by rising temperatures and low rainfall in May.



**Figure 5.** Variability of rainfall during the vegetation period by months from 2010 to 2013 and 2019.

The study observed that weather conditions is quite different in different years. Therefore, varieties that are less sensitive to temperature and humidity fluctuations during sowing and in the early stages of plant development should be selected for cultivation. Relatively warm and wet September can extend the vegetation period, so in the future it will be possible to choose varieties not only with a short, but also with an average vegetation period.

Fiber yield is higher at moderate humidity and lower temperatures Figs 6, 7. With temperature increase there is a significant decrease in the fiber yield for ‘Finola’ and ‘Purini’, a slight decrease for ‘USO-31’, while the fiber yield of ‘Bialobrzeskie’ is not affected by temperature fluctuations. ‘Bialobrzeskie’ also has higher absolute numbers of fiber yield, regardless of the year of observation. In turn, the increase in moisture increases the fiber yield for ‘Finola’ and ‘Purini’, slightly decreases it for ‘USO-31’, and does not affect ‘Bialobrzeskie’.

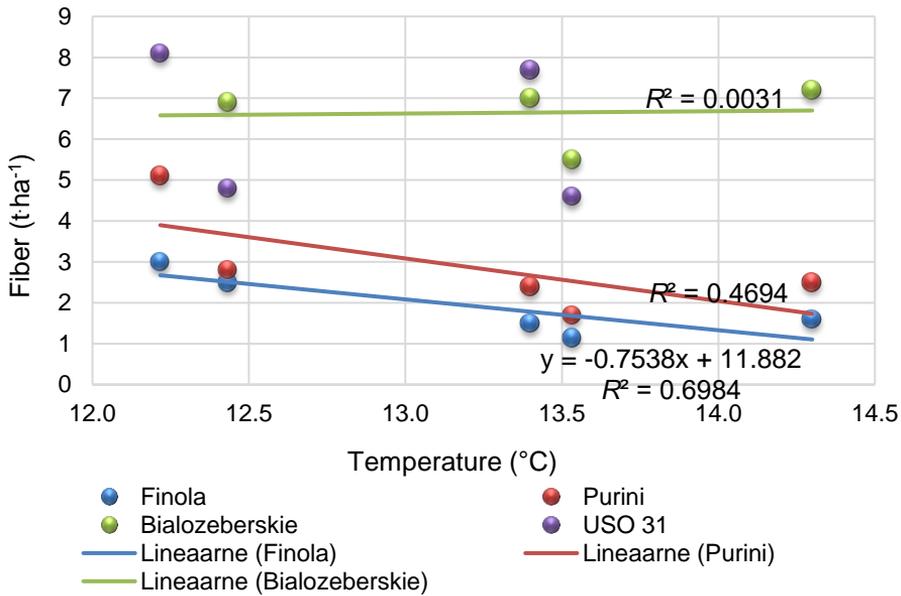


Figure 6. Fiber yield dependence of temperature.

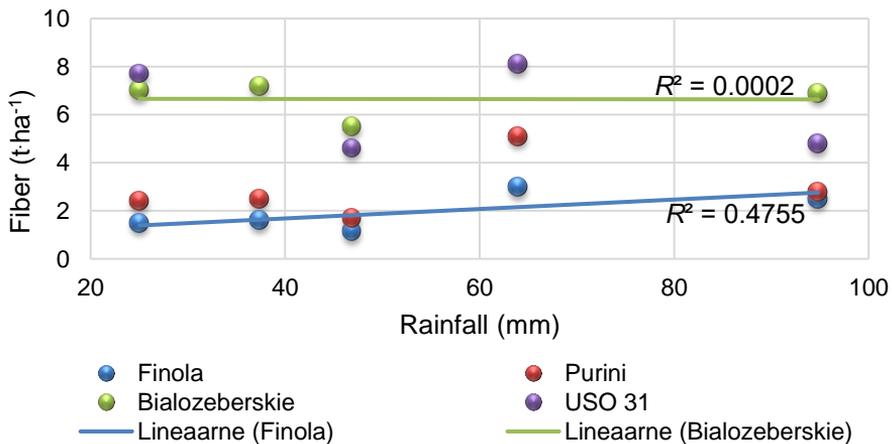
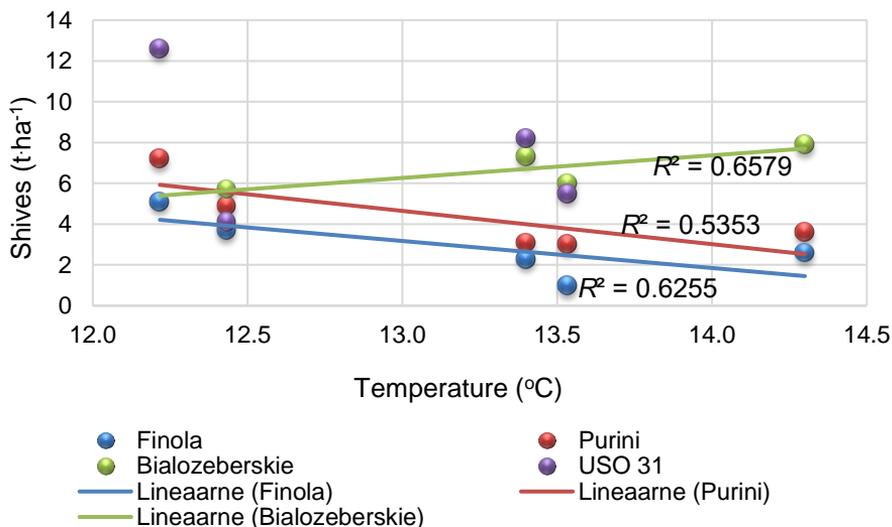


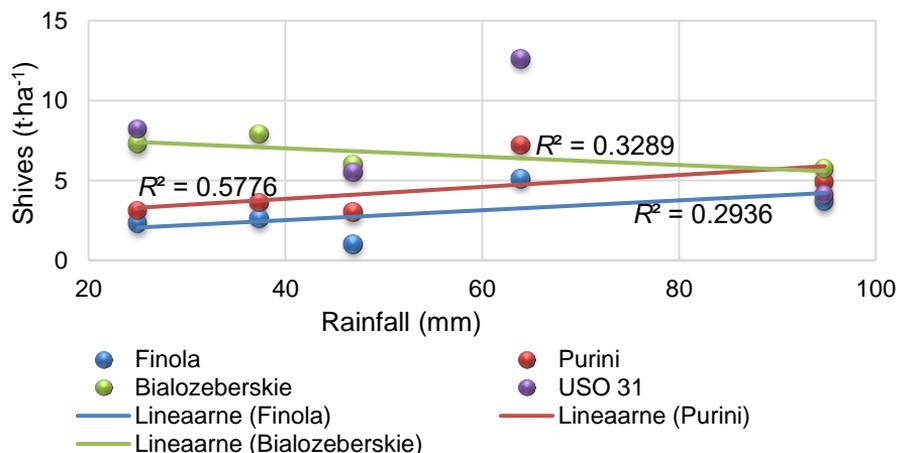
Figure 7. Fiber yield dependence of rainfall.

Similar high level data dispersion and correlations have been observed in the yield of shives (see Fig. 8, and 9. ), with the exception of ‘Bialobrzeskie’, where the yield of shives increased due to higher temperature, but slightly decreased due to humidity.



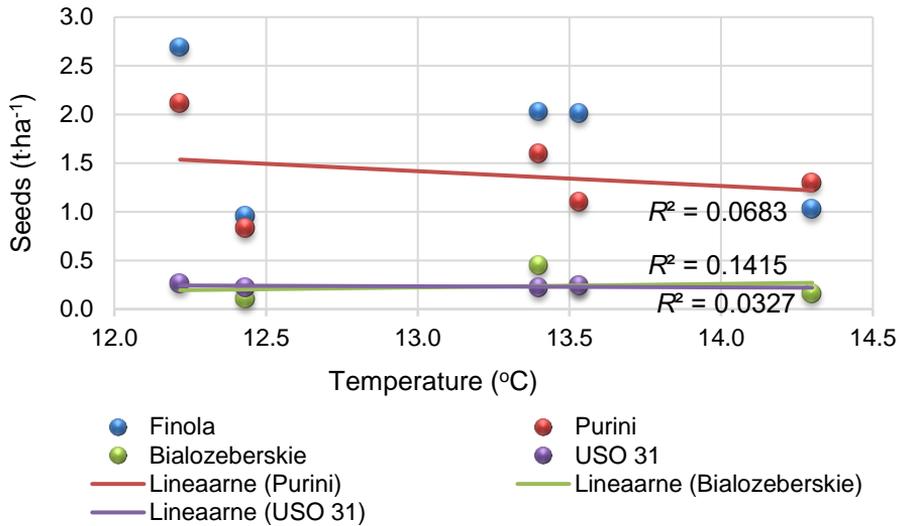
**Figure 8.** Shives yield dependence of temperature.

At high rainfall (above 80 mm during the growing season) and low temperatures (around 12.5 °C during the growing season) there is the lowest amount of shives.



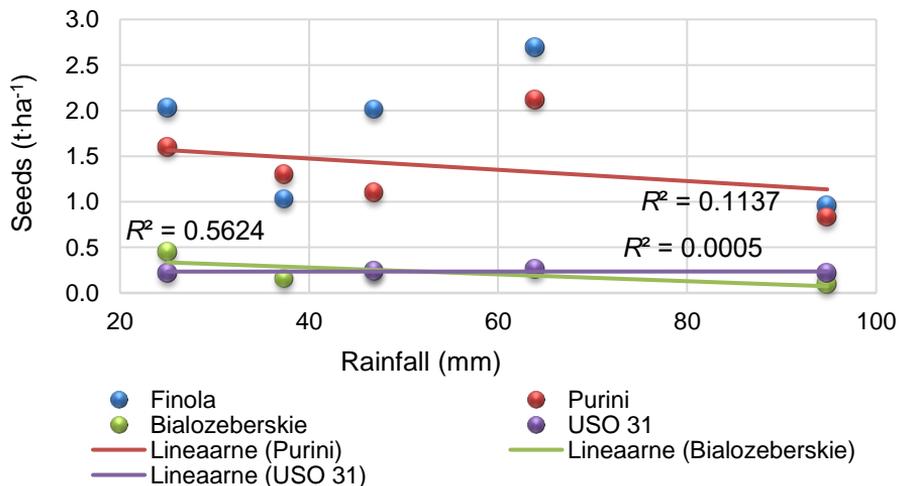
**Figure 9.** Shives yield dependence of rainfall.

Thus, under the same growing conditions, the variety ‘Bialobrzeskie’ is more stable and less dependent of climatic conditions in terms of fiber and shives production. ‘Bialobrzeskie’ also gives a higher total yield per ha.



**Figure 10.** Seeds yield dependence of temperature.

For all varieties, the seed yield decreases at rainfall higher than 80 mm, which is above the long-term averages (Figs 10, 11). ‘Finola’ gives higher seed yield in changing climatic conditions. The highest yield of green mass was observed at higher humidity, but no conclusions can be drawn about the effect of temperature. Similar high level data dispersion and correlations have been observed in the yield of seeds. Insufficient moisture hinders the development of hemp. The literature (Nelson, 2000) indicates that it is even necessary to irrigate hemp fields to obtain higher yields.



**Figure 11.** Seeds yield dependence of rainfall.

## CONCLUSIONS

The analysis of climatic factors shows that the effect of temperature and rainfall on seed, shives and fiber yields strongly depends on the variety. Thus, it is possible to identify a variety of hemp in order to obtain a specific product containing hemp.

The yield of hemp is more strongly influenced by the amount of rainfall, at high rainfall only the biomass does not decrease. Decreased yields at high humidity and low temperatures are often explained by fungal growth on plants.

The effect of temperature could not be determined in the analysis of some parameters. This can be explained by the fact that in Latvia as a whole the temperature is insufficient for the full development of hemp.

In the changing climatic conditions of Eastern Latvia, it is better to grow early varieties with a short vegetation period primarily for seed production. 'Finola' can be recommended for seed production from the studied varieties. 'Bialobrzeskie' is suitable for fiber and shives. The yields of hemp fibers and shives are variable, so they could only be by-products.

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