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The Influence of Agrotechnical Factors on Productivity Hemp (*Cannabis sativa* L.)

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Abstract. The topicality of the topic is due to the need to develop the production of energy crops, in particular hemp, given the limited amount of available minerals for the needs of heat supply. Hemp is suitable for biofuel production as a profitable crop with a wide range of uses. For the purpose of the study, the authors assessed the influence of agrotechnical factors on the productivity of sowing and quality indicators of hemp seeds for the production of solid fuel in Latvia. The Polish hemp variety "Bialobrzeskie" and the Latvian hemp variety "Pūriņi" were evaluated for application of 3 doses of nitrogen fertilizers. Analyzes are used, which are classified as systemic, statistical and comparative. Research methods are applied: generally accepted in crop production, field and laboratory – to clarify the interaction of the object of research with agrotechnical and natural abiotic factors; calculated and weighted – to determine the productivity of crops; calculation and comparison; mathematical and statistical (dispersion) – for assessing the probability of research results. It was determined that for fibrous hemp, the dry matter yield of the stem ranges from 6.5 to 11.0 t/ha, and the seed yield is 0.7-1.4 t/ha. The productivity of hemp significantly depends on agrotechnical factors, in particular, on the variety and application of fertilizers, because these component technologies significantly affect the yield and quality indicators of seeds for the production of solid biofuel. The hemp variety "Pūriņi" is less productive than the hemp variety "Bialobrzeskie", even with the use of N_{100} nitrogen fertilizer dose. The dose of nitrogen fertilizers affects such energy parameters as ash content and the highest calorific value. The research revealed a significant ($P<0.05$) influence of the trunk fraction on productivity, the highest calorific value and ash content. The scientific novelty is that the impact of the variety and doses of nitrogen fertilizers on productivity, including the energy properties of hemp, has been evaluated, and the practical value is in the improvement of the technology of growing hemp by correctly selecting the variety and optimizing the dose of nitrogen fertilizers to create high-quality products for heating and use of waste-free technologies

Keywords: hemp, variety, doses of nitrogen fertilizers, productivity, ash content, highest calorific value, solid biofuel

INTRODUCTION

Solid fuel from biomass has a wide range of applications: production of heat, electricity, heating, etc. [1; 2]. This indicates that solid biofuels have greater potential than other biomass resources. It is important to use local resources for biofuel production, as this will reduce costs, support local producers and contribute to energy self-sufficiency and the development of the national economies of both Latvia and Ukraine.

Substitution of natural gas, oil, coal with agricultural waste (e.g. straw, chaff, etc.) and energy plants will become economically viable if the prices of non-renewable resources increase and the volume of mineral extraction decreases [3], therefore energy crops must be fully utilized of all factions.

For the development of new technologies for the development of alternative energy sources in Ukraine, the scientific and technical program of the National Academy of Sciences "Grape Crops" was launched. It was carried out by ten NSUs, in particular by employees of the Institute of Bask Cultures [4; 5].

It is common knowledge that internal combustion engines run on gasoline, gas, and diesel, and the prices of these primary fuels are constantly rising. In addition, the environment is polluted. All these troubles require the introduction of new methods and ways of

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creating fuel that will be efficient from an economic point of view, and clean from an environmental point of view. Currently, bioethanol and biodiesel are among the promising alternative fuels for cars and other types of transport [2].

The characteristics of the properties of power plants are determined by standards. They differ for each type of biofuel, and each country, including Latvia and Ukraine, has its own standards, but there are European Union standards. At the same time, it is difficult to determine the ideal requirements for the quality of the installation, since they may differ for different consumers, for example, owners of large and small furnaces. In addition, increasing the qualitative and quantitative indicators of crops without increasing the cultivated areas is an urgent issue. An important role is played by ecologically clean growing technologies, which ensure better tillage of the soil, the cultivation of appropriate varieties and the application of fertilizers according to the agrochemical parameters of the soil.

Hemp belongs to bioenergy crops. The calorific value of the stems of this plant is comparable to coal [5].

The world market contains more than 25,000 hemp industry products [4]. In addition, the demand for products from technical hemp on the world market is constantly increasing [6; 7].

At the same time, hemp seeds and fiber should be considered valuable raw materials for use in textile, cellulose, pharmacological, cosmetic, construction and other types of business, and the properties of this bioenergetic plant, the effect of agrotechnical measures on them should be studied in order to increase the productivity of hemp agrophytocenoses. Therefore, the aim of the work was to assess the influence of such agrotechnical factors as the type and dose of nitrogen fertilizers (and their optimization) on the yield and quality indicators of hemp for the production of solid fuel in Latvia.

Hemp seed (*Cannabis sativa* L.) is an annual (monoecious and dioecious) crop of the hemp family (Cannabaceae). Historically, the cultivation of *Cannabis sativa* L. began in China around 2700 BC. e., when the properties of hemp as a medicinal plant were discovered. After that, the cultivation of hemp spread throughout Asia, and by 2200-2000 BC. e. also in Europe [8-10]. A.V. Pylypchenko assures that the word "cannabis" appeared in Holland as a translation of the English word "canvas" (translated as a sail) [11].

Archaeological materials show that the first fabrics were woven from nettle and hemp fibers at least 1000 years ago [12]. In the Middle Ages, there were specialists in the production of hemp twisters, and they had their own association. Edible hemp seeds were found in the Tulsa barrow in the XI-XIII centuries.

L.G. Nikolaychuk [7] notes that technical hemp is considered a traditional Ukrainian plant material, but it was forbidden to sow these plants in Ukraine at the time, because they were classified as narcotic.

N.V. Sholoyko, V.I. Popov, and T.I. Lysenko [10] claim that by 1990, technical hemp occupied more than 10% of the agricultural land structure. Ropes, canvas and hemp oil were produced from this crop. Cultivation of these plants was highly profitable. Starting from the 1990s, hemp crops as a cash crop were practically destroyed.

The main components of the *Cannabis sativa* L. harvest include stems with short fibers and seeds. The seeds are used as sowing material, or after advanced processing they are used for the needs of the food, confectionery, pharmaceutical, cosmetic and paint industries [11; 13; 14].

The breeders of the Institute of Bast Crops of the National Academy of Sciences of Ukraine created the Victoria variety and in 2009 submitted it for variety testing, because tetrahydrocannabinol (THC) was not detected there. In terms of productivity, it was not inferior to the standard variety (ЮСО-31), and provided 1.5 thousand hryvnias/ha of economic effect (net profit) [5].

Due to the fact that Latvia is a member of the EU, and Ukraine aspires to join this organization, they both need to develop the hemp industry. This is a huge area that will require extensive scientific research and analysis over many decades.

The agroecological characteristic of hemp is important. Hemp suppresses weeds with its abundant leaves and is an indispensable crop in organic farming [4; 5; 11].

Hemp is a rare crop of Ukraine. After their cultivation, indicators of the sanitary state of the soil improve. Polish specialists at the 4th conference in Rouen, which took place in 1996, in a scientific report on the topic "Remediation of land contaminated with radionuclides" provided digital material that showed a decrease in the content of salts from the group of heavy metals in various types of soil sown hemp Therefore, the production of hemp and the manufacture of products from them (fiber, seeds and seeds) is environmentally safe for mankind, because there is no radiological burden on the living organism [15]. Hemp grows quickly (i.e., no initial treatment with herbicides is required), removes heavy metals from the soil (bioremediation), and provides high-quality non-food products in the face of climate change [9; 16]. Hemp and its products are environmentally friendly [15; 16]. The demand for products from technical hemp on the world market is constantly increasing [11; 17; 18]. During the last decade, the demand for non-narcotic plants of this culture has increased by several hundred billion dollars [7], although there are already about 50.000 types of hemp products on the world market [10]. Therefore, it is advisable to invent ways to increase the volume of its production in order to satisfy the demand for quality products.

MATERIALS AND METHODS

Testing of seeded hemp was carried out in Latvia on turf-gley soil type (organic matter content 35-38 g/kg, pH 7.0-7.3, available plant phosphorus content – 83-145 mg/kg P_2O_5, potassium content – 65-118 mg/kg K_2O). The area of the sown experimental plot of hemp was 20 m^2 in three repetitions. The seed sowing rate is 70 kg/ha.

In the spring, after leveling and cultivating the field, before sowing (or on the day of sowing) complex mineral fertilizer (N:P:K – 6:26:30 – 300 kg/ha) was applied as the main fertilizer. The experiment studied the effect of doses of nitrogen fertilizers on the productivity of hemp. Nitrogen (N) fertilizers (ammonium nitrate (N 34%)) were applied as follows: 0 kg/ha N, 60 kg/ha N, 100 kg/ha N as a pure ingredient (labeled N_0, N_{60}, N_{100}) when hemp formed 3-6 pairs of leaves. No pesticides were used for hemp.

The granulometric composition of the soil was determined by the pipetting method (ISO/DIS 11277), the humus content was determined by the Tyurin method (LV ST ZM 80-91). The soil reaction was determined potentiometrically (ISO 10390), the content of phosphorus and potassium was determined by the Egner-Rieme (DL) method (LV ST ZM 82-97). Data analysis of the hydrothermal coefficient (HTC):

– HTC from 1.0 to 2.0 – sufficient humidity;
– HTC>2.0 – excessive hydration;
– HTC<1.00 – not enough moisture;
– HTC from 1.0 to 0.7 – dry;
– HTC from 0.7 to 0.4 – very dry;
– HTC in Rezekne District, Latvia, for hemp seeding averaged 1.0 to 2.0 over the growing season.

The study evaluated the Polish hemp variety "Bialobrzeskie" (monoecious) and the Latvian (local) hemp variety "Pūriņi" (dioecious), which has been grown for more than 200 years at the Piksares farm in Valmier County, Ruina Rural District. These are promising and productive varieties, suitable for the agro-climatic conditions of Latvia.

Since February 27, 2020, the hemp variety "Pūriņi" has been included in the Catalog of plant varieties of Latvia as a variety for the preservation of genetic resources of field plants.

On the website of the International Union for the Protection of New Varieties of Plants, it is stated that the variety "Bialobrzeskie", which was used in the study, is included in the catalog of EU varieties. It was bred in Poland (Instytut Krajowych Wlokien Naturalnych or Inst. of Natural Fibers (PL)) on December 31, 1967, and was also registered in Austria, the Czech Republic, and Slovenia in 1968. This variety was obtained by crossing several monoecious and dioecious hemp: [(('LKCSD'/'Kompolti') // 'Bredemann 18') /3/ 'Fibrimon 24'].

The analysis of plant samples was carried out according to established standard methods:

– the dry substance of the sample was determined at 105°C; drying to a constant mass;
– heat capacity exceeding V=const, established from dried samples at 105°C – Qh. (LVS CEN/TS 14918) with calorimeter IKA C 5003;
– ash content of dry matter – A – (IS0 1171 – 81).

In the course of the research, analyzes were used, which are classified as systemic, statistical, and comparative, and the available information was summarized.

RESULTS AND DISCUSSION

Hemp, with its high calorific value and relatively high dry mass yield, is a good feedstock for bioenergy production, especially if it is available in combination with other energy sources.

We have established the volumes of hemp production in two countries with different soil and climate zones, Latvia and Ukraine.

In Ukraine, according to the State Statistics Service [19], the area under hemp has undergone changes over time. For the period from 2015 to 2020, the largest area (2.8 thousand ha) was allocated to this culture for seed purposes in farms of all categories in 2016. A little less was sown in 2017 (2.6 thousand ha) and very little (0.1 thousand ha) in 2018. In 2020, this indicator improved significantly, 1.6 thousand ha were planted and then seeds were collected from an area of 1.6 thousand ha (Fig. 1).

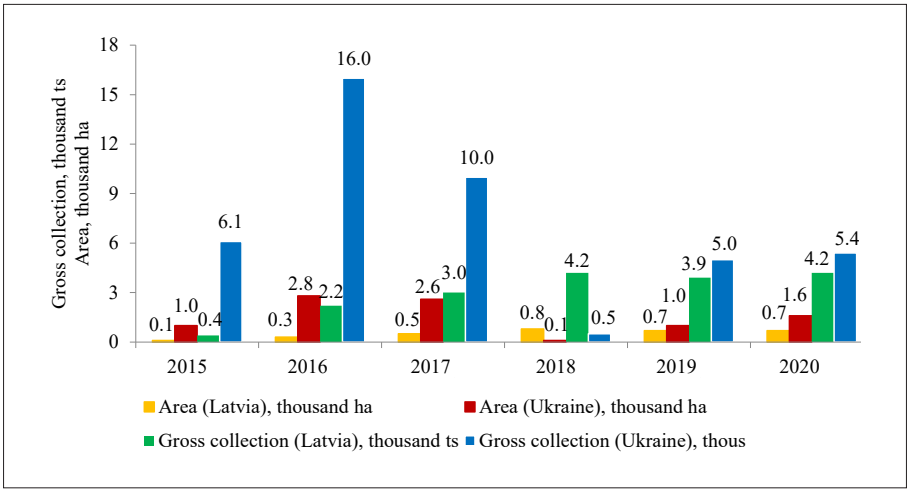

***Figure 1**. Hemp sowing area and gross seed collection in Latvia and Ukraine*
***Source:** constructed by the authors based on data [19; 20]*

An important indicator of the volume of agricultural production in the states is the gross harvest. It depends both on the amount of harvested area and on the productivity formed by the culture. In Latvia, the largest gross

collection of seeds (4.2 thousand tons) was recorded in 2018 and 2020 [20]. Ukrainian farmers collected the largest amount of seeds (16.9 thousand tons) in 2016 thanks to the larger area for collecting hemp seeds. In general, during the analyzed period (2015-2020), the area of hemp seed cultivation in Ukraine increased by 60% (Table 1).

Table 1. *Production of hemp for seeds in Latvia and Ukraine*

Indicators	Country	Avarage for 2015-2020	2020 in % till 2015
Area, thousand ha	Latvia	0.5	600.0
Gross collection, thousand c	Ukraine	1.5	60.0
Productivity, c/ha	Latvia	3.0	950.0
Indicators	Ukraine	7.2	-11.5
Area, thousand ha	Latvia	4.7	42.9
	Ukraine	5.3	-41.7

Source: *calculated by the authors based on data [19; 20]*

A somewhat different situation is inherent in the production of hemp in Latvia. During the period from 2015 to 2020, the area (from 0.1 to 0.8 thousand hectares) under this crop for seed purposes increased (see Fig. 1), and therefore the gross harvest of bioenergy crop seeds increased. It should be noted that the Latvian government provides subsidies to hemp producers. In order to receive payments in Latvia, it is possible to grow varieties listed in the EU Variety Catalogue: "Beniko", "Bialobrzeskie", "Epsilon 68", "Fedora 17", "Felina 32", "Futura 75", "Kompolti", "Kompolti hybrid TC", "Santhica 23", "Santhica 27", "Santhica 70", "Uso31" and others.

The yield of seeds also underwent significant changes and on average for Ukraine ranged from 3.5 t/ha (under fairly dry conditions in 2020) to 7.5 t/ha in the favorable rainfall and temperature regime of 2018 (Fig. 2).

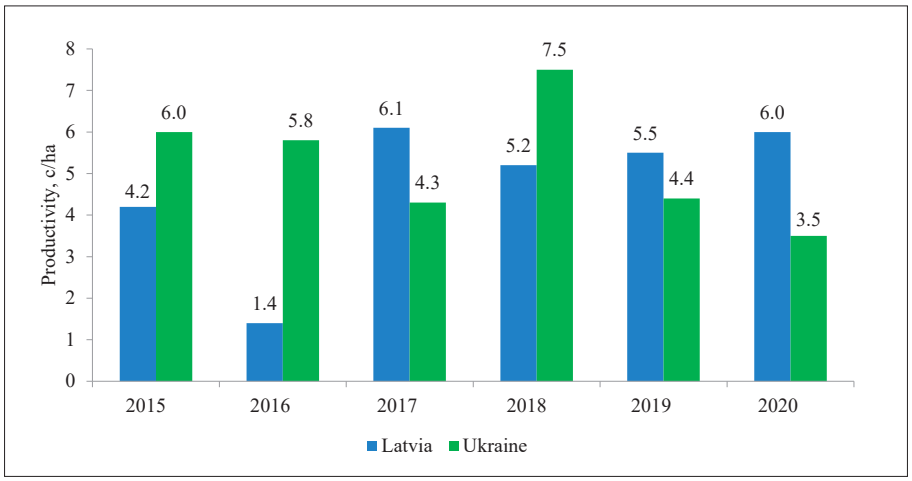

Figure 2*. Yield of hemp seeds in Latvia and Ukraine*

Source: *constructed by the authors based on data [19; 20]*

This indicator was marked somewhat lower for Latvian farms. The amplitude of its fluctuation was established for the studied period from 1.4 in 2016 to 6.1 c/ha in 2017.

On average, for 2015-2020, each harvested hectare of hemp produced 4.7 tons of seeds in Latvia and 5.3 tons of seeds in Ukraine. The difference of 0.6 c/ha (12.8%) can be explained by different types of soil, insufficient amount of heat in Latvia, although there is significantly more precipitation than in Ukraine. All these factors ensure the proper growth and development of hemp plants.

Under today's conditions, hemp cultivation in Ukraine and Latvia began to expand, in addition, medicinal products for the treatment of various diseases began to be produced [10; 11].

In the agro-climatic conditions of Latvia, hemp cannot be grown for the production of narcotic products, as delta-9-tetrahydrocannabinol (THC) is only a few tenths of a percent in these plants cultivated in the EU, and varieties have been created that do not contain cannabinoids at all [16].

The breeders of the Institute of Bask Crops of the National Academy of Sciences of Ukraine [21] bred monoecious non-narcotic varieties of hemp for the production of seeds in the western regions, at the same time, their potential under different cultivation models has not been sufficiently studied. The yield between varieties ranges up to 25%, depends on the sowing rates for the wide-row sowing method.

L.S. Bezugla [22] claims that modern Ukrainians consider hemp a narcotic plant, although it has been grown in Ukraine since ancient times as a food, fodder, and technical crop. Hemp seeds are intended for the production of valuable oil, and meal – as a product for feeding livestock. Hemp fiber is suitable for the production of

ecological textiles, firewood – as bedding for animals, mulch – for covering the ground cover under plants and even for the production of building materials [17; 22; 23].

It is noted that there are varieties of hemp intended for a specific purpose. So, it is better to use the Fedora 17 variety for seed production, the Futura 75 variety for fiber production. These two varieties can be used for dual purpose production in individual countries.By the way, seeds of Fedora 17 and Markant varieties were formed even in the northern part of Latvia. In Italy, the Czech Republic and France, from 0.3 to 2.4 Mg/ha of seeds were formed [24].

Currently, the pulp and paper industry consumes almost half of the world's forest material. At the same time, hemp produces almost four times more paper than wood. In addition, this culture is adapted to most climatic zones. The shelf life of hemp paper reaches 1,500 years. For Europe and the USA, it is necessary to produce 6 million tons of pulp from long fiber annually. For this purpose, it is necessary to set aside up to 1 million hectares of land for hemp [4; 25]. Hemp is a valuable raw material in the paper industry [8; 16; 26], thermal insulation materials in construction.

Hemp shavings are a waste that can be used in the production of chipboard for the construction industry, as the flexural strength of the produced board reaches 2.4 MPa for the coarser group of particles with a thermal insulation coefficient of 0.057±0.002 W/(mK) [25].

V.M. Durach and L.G. Nikolaychuk [4; 27] consider the traditional and most promising for Ukraine the textile industry, which is focused on the production of textile products, clothes, shoes, etc. for firefighters, oil workers, soldiers of the Armed Forces of Ukraine and soldiers of various formations. Hemp fiber turned out to be strong and was useful for making clothes, sails and paper. It has been established that the first copies of the Bible were written on hemp paper. Hemp oil was widely used in food and cosmetics, hemp extracts were used to treat various diseases [7-9]. Hemp oil has a wide range of applications: from food to cosmetics, hemp extracts are also used to treat many diseases. The oil content of hemp seeds can exceed 35%. It can be used as biodiesel fuel and to produce other industrial products (such as plastics).

The by-products of oil production are valuable animal feed as well as fertilizer. Plant leaves remain in place as a source of nitrogen in the soil. After hemp is harvested, it is processed in the textile industry, and the remaining wood is used as biomass feedstock for pulp production, i.e. hemp is fully utilized. From hemp, it is possible to obtain ecologically clean building materials with low density, which provide high tensile and compressive strength, as well as good heat and sound insulation properties [6; 28]. Hemp straw showed the highest calorific value (18.29 MJ/kg) compared to other sources of hea [29]. Hemp is a profitable crop with a wide range of uses in Latvia and other countries (Fig. 3).

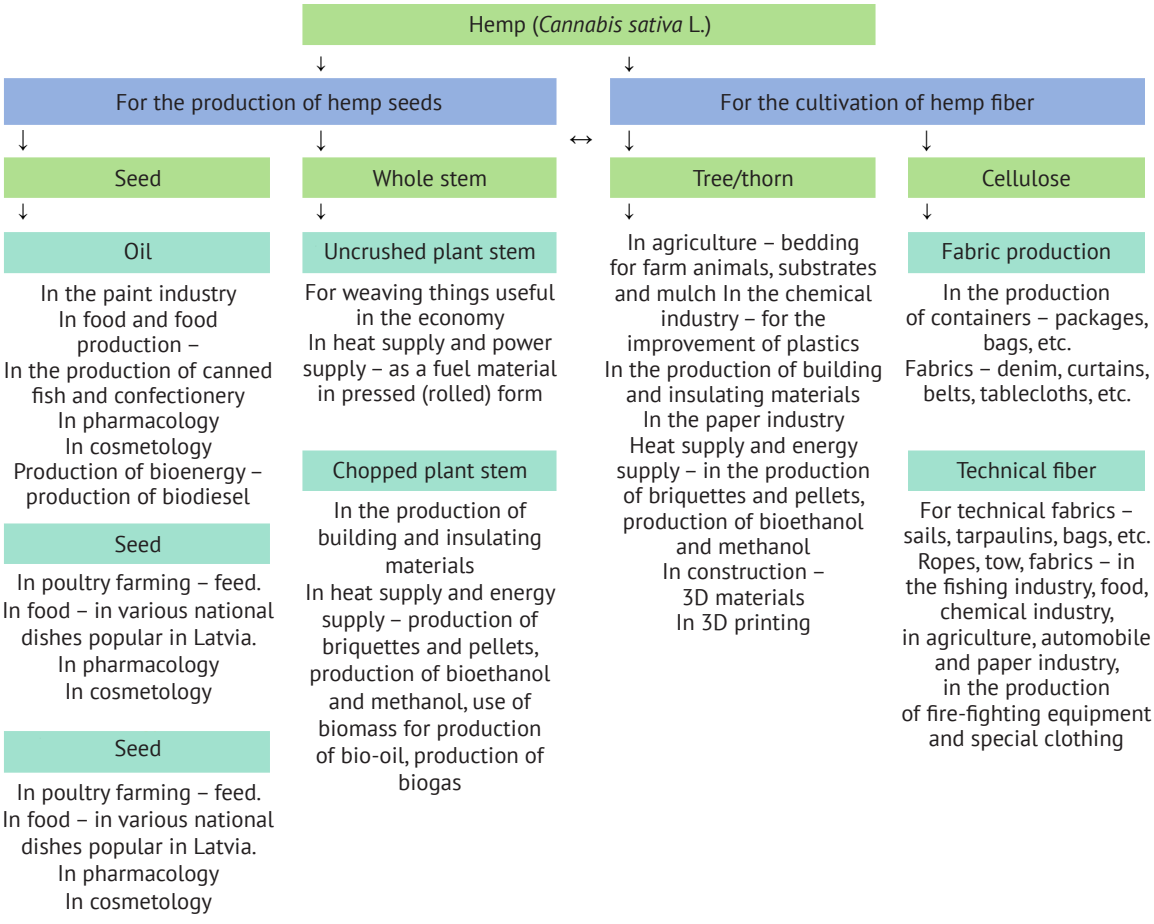

Figure 3. *Options for the use of cannabis Cannabis sativa L. (L. Poiša)*

Hemp briquettes are characterized by a faster loss of mass during combustion compared to common wood chip briquettes. This is explained by the fact that the amount of thermal energy is released much faster in hemp briquettes. Measurements of briquettes made from hemp shavings showed a significant heat of combustion (approximately 18,000 kJ/kg (for wood 17,000 kJ/kg)). The total amount of heat per unit area of the mixture of sapropel and hemp shavings is 48 MJ/m^2, but the effective amount of combustion is 13 MJ/kg [30].

So, more heat will require less fuel. This is important for choosing the type of fuel suitable for the climatic conditions of Latvia, where the meteorological duration of winter is about 80 days, when the temperature can be below -30°C.

Several studies have shown that plants with a wide range of uses have greater prospects and therefore lower costs [8; 31; 32], again proving the economic viability of hemp cultivation. 1 ha of hemp absorbs approximately 2.5 tons of CO^2, which significantly reduces the greenhouse effect [8; 16]. Hemp is also suitable for biofuel and biogas production in Latvia, as its productivity is relatively good, so it is also economically beneficial.

The yield of technical hemp stalks depends on the variety, applied fertilizers, as well as a number of other factors. In Latvia, the following varieties of hemp are productive: "Bialobrzeskie", "Epsilon 68" and "Futura 75" with an average yield of dry mass of 14 t/ha [33].

It has been established that the growing season of hemp in Latvia lasts from 110 to 140 days, depending on the variety. For fibrous hemp, the dry matter yield of the stem ranges from 6.5 to 11.0 t/ha, the seed yield is 0.7 to 1.4 t/ha.

It is worth noting that the quality of grown hemp products is strongly influenced by weather conditions. The studied culture is used to increase the amount of fuel and improve its energy properties.

Increasing the rate of nitrogen fertilization had a different effect on "Pūriņi" and "Bialobrzeskie" hemp (Table 2). "Pūriņi" was more sensitive, which is explained by differences in the development of hemp of this variety. In hemp, with the beginning of flowering, the intensity of growth decreases. The average yield of dry hemp stem for the local hemp variety "Pūriņi" was higher when using the dose of nitrogen fertilizers N_{100} – 9.94 t/ha, but lower when using N_0 – 5.94 t/ha. A similar trend was observed for the hemp variety "Bialobrzeskie" – above N_{100} – 13.70 t/ha, below – N_0 – 9.80 t/ha.

Nitrogen mineral fertilizers help increase the size of plant cells, as well as increase their water content, increasing the gross weight. An indicator of the effectiveness of applying nitrogen fertilizers is a high yield of gross products.

Table 2. *The average yield of hemp depending on the doses of fertilizers*

Part of a plant	Variety	Variety Norms/doses of fertilizers		
		N_0	N_{60}	N_{100}
Dry matter	Pūriņi	5.91	8.18	9.94
	Bialobrzeskie	12.01	14.6	16.12
	Average	8.96	11.39	13.03
	Pūriņi	$RS_{0.05A}$=0.698; $RS_{0.05B}$=0.698; $RS_{0.05AB}$=1.209		
	Bialobrzeskie	$RS_{0.05A}$=0.898; $RS_{0.05B}$=1.101; $RS_{0.05AB}$=1.556		
Shiva	Pūriņi	4.46	6.43	7.61
	Bialobrzeskie	7.81	8.87	9.91
	Average	6.13	7.65	8.76
	Pūriņi	$RS_{0.05A}$= 0.54; $RS_{0.05B}$=0.54; $RS_{0.05AB}$=0.94		
	Bialobrzeskie	$RS_{0.05A}$=0.64; $RS_{0.05B}$=0.78; $RS_{0.05AB}$=1.11		

Note*: $RS_{0.05A}$ – factor – growing year at the significalt level 95%; $RS_{0.05B}$ – factor – fertilizers norms/doses at the significalt level 95%; $RS_{0.05AB}$ – factors interaction at the significalt level 95%*

The hemp variety Futura, which is a late monoecious, can form a large amount of biomass and a suitable level of seed collection [34]. Scientists of the Rural University of Athens [35] came to the conclusion that the introduction of a technical increased dose of nitrogen under hemp, up to 240 kg/ha, provides a greater yield of biomass, dry weight of the stem and mass of the inflorescence by 37.3%, 48.2% and 16% respectively, if the unfertilized background is taken as the control. An increase in the linear growth of plants in the height and length of the inflorescence (from 1.66 to 1.76 m and from 66.2 to 82.9 cm, respectively) was noted. The average weight of seeds was almost the same for all tested doses of nitrogen fertilizer. The best indicators of plant growth and development are characteristic of the Tygra and Futura 75 varieties.

It was determined [36] that the collection of hemp fiber and its quality are significantly influenced by the norms of sowing seeds and providing plants with the main macronutrients. It has been established that in order to obtain the yield of hemp, which will be characterized by high-quality fiber (more than 2200 kg/ha), it is necessary to plant them with a seeding rate that will ensure a density of 329 plants/ha. Nitrogen should

be applied in doses of 251-273 kg/ha, phosphorus – 85-95 kg/ha, and potassium – 212-238 kg/ha.

It is well known that the most important climatic factors that significantly affect the productivity of plants are the supply of moisture, heat, photosynthetically active radiation (PAR), carbon dioxide. V.M. Kabanets [37], on the basis of research carried out in Ukraine, concluded that the optimum density of hemp stalks is 1.65 million units/ha. At this density, the smallest inflow of PHAR energy was found, which is extremely necessary for the full-fledged generative productivity of the weed component of the agrophyocenosis of the second wave. Based on the correlation analysis, it was established that the yield level of seeds and stems of *Cannabis sativa* L. depends significantly on the presence of mobile phosphorus in the soil and somewhat less on potassium. Under the conditions of organic farming, such dependence is not observed [38].

The correct selection of precursors is one of the most important factors not only in organic farming, but also in reducing the spread of diseases and pests, as well as one of the factors in ensuring high productivity with adequate quality.

It is noted that almost any previous plant is suitable for hemp, the main thing is that a sufficient amount of organic fertilizers is applied before it [39], or, according to other scientists [40], hemp can be grown after any plant without fertilizers and without weed control.

Chemical weeding of hemp with the herbicide Targa Super reduces weediness of the crop and increases the yield of stems. The improvement of this indicator (by 2.1-2.6 t/ha) is facilitated by such a measure as foliar feeding of plants with the microfertilizer Ecolist universal against the background of the main application of mineral fertilizers in the dose of $N_{60}P_{60}$. For harvesting hemp seeds (with a moisture content of 14-24%), the combine of the brand "Case" has proven itself better compared to the combine of "PALESSE" [5].

All plants need nutrients. Hemp has a high need for macronutrients – nitrogen, phosphorus and potassium; additional nutrients - sulfur, calcium and magnesium; trace elements – iron, manganese, zinc, chlorine, boron, copper and nickel. The availability of nutrients for plants depends on the quality of the soil, fertilizers and weather conditions, so it is necessary to ensure optimal growing conditions, which can be done by following appropriate agricultural techniques.

Nitrogen (N) is the main limiting factor for plant growth and development in natural and agricultural ecosystems. Increasing the rate of application of nitrogen fertilizers in the field also increases plant productivity [41]. Nitrogen can have a beneficial effect on the yield and its quality only if it is used to fertilize crops in a balanced mode with the rest of the nutrients, taking into account the biological features of the crop and the characteristics of the soil. The presence of nutrients in the plant and the quality of the obtained products depend on fertilizers, which also significantly affect the composition of ash.

At the same time, according to the conclusion of scientists [42], an increase in the density of plant stands from 30 to 120 plants/m^2 increased the yield of stems by 29%, and nitrogen application from 0 to 60 kg/ha d.r. – by 32%. Nitrogen fertilizers did not significantly affect the seed productivity of hemp.

The studied plants have long roots, up to 2.5 m, which reduces soil erosion. The plant is used to increase the productivity of the next crop in the crop rotation cycle by 10-15%, to restore the fertility of unproductive soil for agricultural purposes and to improve diversity in EU agriculture.

Hemp seeds are still used in Latvian national dishes in various ways [43; 44].

The root system of hemp contributes to the improvement of soil productivity. This may indicate that well-cultivated soils and appropriate agrotechnical measures have a positive effect on the productivity of these plants. It has been proven [44] that the accumulation and transformation of fresh organic substances formed by plant residues of hemp depend on technological measures in organic agriculture. They help soil microorganisms to transfer stress loads from the effects of mineral fertilizers and pesticides.

Meteorological conditions in Latvia are favorable for both early and late sowing of hemp.

The dose of nitrogen fertilizers affects such energy parameters as ash content and the highest calorific value. For the "Bialobrzeskie" hemp variety, a significant effect on the calorific value (QA) of the dose of nitrogen fertilizers (η=23.1%) and parts of the stem (η=33.2%) and the interaction between parts of the stem and the dose of these fertilizers (η=17.2 %). The calorific value (QA) of the local hemp variety "Pūriņi" was significantly influenced by the agro-meteorological conditions of the experimental year (A), the dose of nitrogen fertilizers (C) and parts of the stem, but the greatest influence on (QA) was the interaction between factors A and C (η=46.6%) (Table 3).

Table 3. *The share of influence of factors* on quality indicators of hemp seeds in Latvia, η, %*

Indicators	Hemp varities				Hemp
	"Pūriņi"		"Bialobrzeskie"		
	A	Q_n	A	Q_n	Dry matter
Year of study (A)	72	15	18	ns	1.09
Plant component	3	12	36	33	66.09
(B)/grade (B)	19	18	5	23	23.01
N fertilizer (C)	0	0	26	10	4.09

Table 3, Continued

Indicators	Hemp varities				Hemp
	"Pūriņi"		"Bialobrzeskie"		
	A	Q_h	A	Q_h	Dry matter
Interaction (A×B)	3	47	11	ns	ns
Interaction (A×C)	1	4	1	17	ns
Interaction (B×C)	1	3	2	ns	ns
Interaction (A×B×C)	ns	1	0	12	ns

***Note**: * – the influence of the studied factors is reliable at the 95% significance level ($F_{fact}>F_{0.05}$); ns – the influence of the studied factors is insignificant at the 95% confidence level ($F_{fact}<F_{0.05}$); A – ashiness; Qh is the highest calorific value*

The study noted a significant (P<0.05) proportional effect of the part of the stem – for "Bialobrzeskie" – 33.2% and "Pūriņi" – 12.0%. Therefore, in order to achieve a higher calorific value, it is important to evaluate whether it is rational to use the whole stem or only the wood chips as fuel.

Polish scientists [45] investigated hemp biomass for its use as an energy crop. Physico-chemical properties of this plant, manifested in the process of burning straw and briquettes in low-power boilers, corresponded to current standards. However, excessively large emissions were recorded, which, taking into account the current regulations, does not allow the use of this product in heating devices, where the air supply goes under the grates.

The positive effect of nitrogen on the growth of hemp is manifested from the phase of 3 pairs of leaves, until this time hemp only needs a sufficient amount of nitrogen. Factors (genotype and seeding rate) significantly influenced the yield of above-ground biomass of hemp, as well as the calorific value per hectare [33].

Scientists [15] assure that it is necessary to use phosphorus-potassium fertilizers in the hemp fertilization system, which will ensure a significant decrease in the flow of radionuclides into the plant, and then from it into the products.

The ash composition of biomass depends on the type and part of the plant, for example, trunk, bark, needles have different ash composition. Hemp straw has a lower ash content than grass, which is important for the use of solid vegetable biofuels in automatic furnaces. Therefore, it should be noted that the species have some qualities characteristic of the variety, which are not significantly affected by the meteorological conditions of the given vegetation period, but are affected by the interaction of various factors (fertilizer rate, variety, meteorological conditions, plant parts) [9; 23; 46].

Latvian farmers are interested in growing crops such as hemp and their varieties, as well as in the use of technologies that require less energy consumption. The low consumption of the latter largely determines the lower cost of production and the higher income of the owner.

With professional and competent determination, the farmer must achieve that the amount of pre-accumulated (primary) energy and energy used in the production process at each stage of cultivation is as small as possible, and the mass of accumulated solar energy (generated biomass) is as large as possible.

CONCLUSIONS

Hemp seeds have a wide range of uses, including the production of granules, pellets, briquettes, etc. For the production of solid renewable biofuel from seeded hemp, it is worth using their surplus, which will allow strengthening the hemp industry in Latvia and Ukraine as one of the components of energy independence of the countries.

In order to obtain a larger amount of biofuel formed by the researched crop, it is necessary to increase the level of production intensification, which will positively affect both yield and product quality.

The productivity of hemp crops is significantly affected by the application of nitrogen fertilizers. The average formed yield of dry hemp stems for the local variety "Pūriņi" was recorded higher when using a dose of nitrogen fertilizers N_{100} – 9.94 t/ha, but 40.2% lower on unfertilized sowing (N_0 – 5.94 t/ha), variety "Bialobrzeskie" hemp: above N_{100} – 13.70 t/ha, below N_0 – 9.80 t/ha (or 47.8% less). A significant (P<0.05) proportional effect of the share of the stem was noted – for "Biolobrzeskie" – 33.2% and "Puriņi" – 12.0%.

The advantage of using biomass energy is that it is renewable and reduces Latvia's dependence on imported energy resources. This corresponds to the Guiding Principles of Energy Development. In general, the cultivation of hemp for biofuel production in Latvia is desirable both from the point of view of agro-climatic conditions and economic profitability.

The volume of hemp production in Ukraine is limited, although the weather and climate conditions are favorable for increasing its gross harvest.

The productivity of hemp, both in Latvia and in Ukraine, depends significantly on agrotechnical factors, in particular on the type and dose of fertilizers, because these component technologies have the greatest impact on the yield level and quality indicators of seeds for the production of solid biofuel. There is research on the factors that influence the amount of hemp fiber, but not enough attention has been paid to varieties that grow very quickly, have a high capacity to accumulate a lot of straw and have a low ash content. Our further scientific work is aimed at solving these issues.

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Вплив агротехнічних факторів на продуктивність коноплі (*Cannabis sativa* L.)

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Анотація. Актуальність теми обумовлена необхідністю розвитку виробництва енергетичних культур, зокрема конопель, з огляду на обмежену кількість наявних корисних копалин на потреби теплозабезпечення. Для виробництва біопалива придатними є коноплі як рентабельна культура з широким спектром використання. За мету дослідження автори поставили оцінку впливу агротехнічних факторів на продуктивність посіву та якісні показники насіння конопель для виробництва твердого палива в Латвії. Оцінено сорт польської коноплі «Bialobrzeskie» та латвійський сорт коноплі «Pūriņi» за внесення 3 доз азотних добрив. Використано аналізи, які відносять до системних, статистичних і порівняльних. Застосовано методи дослідження: загальноприйняті у рослинництві польовий і лабораторний – для з'ясування взаємодії об'єкта досліджень з агротехнічними та природними абіотичними факторами; розрахунково-ваговий – для визначення продуктивності посівів; розрахунково-порівняльний; математико-статистичний (дисперсійний) – для оцінювання вірогідності результатів досліджень. Визначено, що для волокнистих конопель урожайність сухої речовини стебла коливається в межах 6,5–11,0 т/га, а насіння – 0,7–1,4 т/га. Продуктивність конопель істотно залежить від агротехнічних факторів, зокрема від сорту і внесення добрив, бо ці складові технології вагомо впливають на врожайність та якісні показники насіння для виробництва твердого біопалива. Сорт конопель «Pūriņi» менш продуктивний, ніж сорт конопель «Bialobrzeskie», навіть за використання дози азотних добрив N_{100}. Величина дози азотних добрив впливає на такі енергетичні параметри як зольність і найвища теплотворна здатність. Дослідження виявили достовірний ($P<0,05$) вплив частки стовбура на урожайність, найвищу теплотворну здатність та зольність. Наукова новизна полягає в тому, що оцінено вплив сорту і доз азотних добрив на продуктивність, в тому числі і енергетичні властивості конопель, а практична цінність – в удосконаленні технології вирощування конопель шляхом вірно дібраного сорту та оптимізації дози азотних добрив для створення високоякісної продукції на теплопостачання та використання безвідходних технологій

Ключові слова: коноплі, сорт, дози азотних добрив, урожайність, зольність, найвища теплотворна здатність, тверде біопаливо