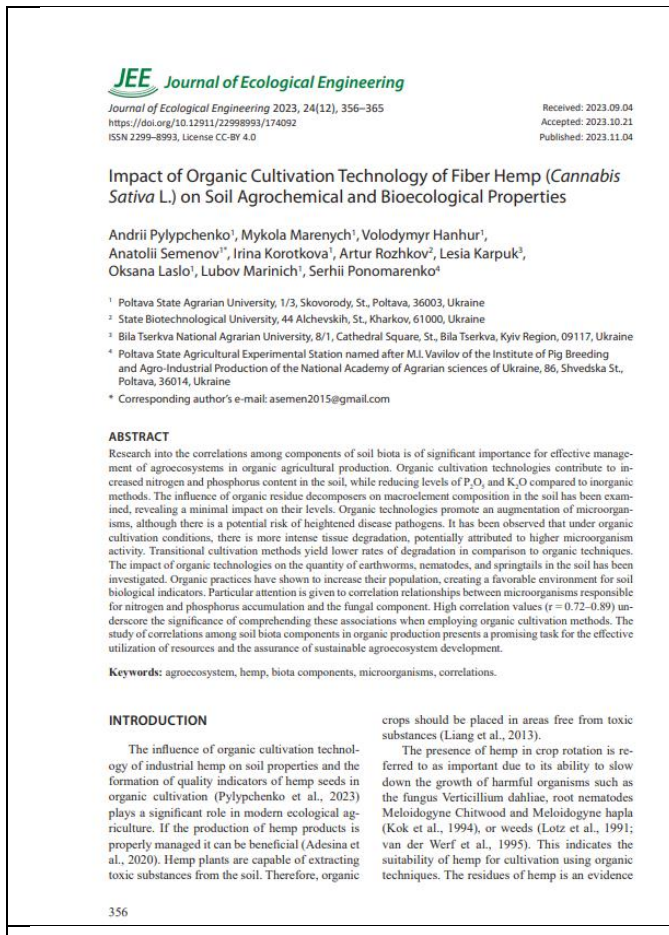

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Impact of Organic Cultivation Technology of Fiber Hemp (*Cannabis Sativa* L.) on Soil Agrochemical and Bioecological Properties

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ABSTRACT

Research into the correlations among components of soil biota is of significant importance for effective management of agroecosystems in organic agricultural production. Organic cultivation technologies contribute to increased nitrogen and phosphorus content in the soil, while reducing levels of P_2O_5 and K_2O compared to inorganic methods. The influence of organic residue decomposers on macroelement composition in the soil has been examined, revealing a minimal impact on their levels. Organic technologies promote an augmentation of microorganisms, although there is a potential risk of heightened disease pathogens. It has been observed that under organic cultivation conditions, there is more intense tissue degradation, potentially attributed to higher microorganism activity. Transitional cultivation methods yield lower rates of degradation in comparison to organic techniques. The impact of organic technologies on the quantity of earthworms, nematodes, and springtails in the soil has been investigated. Organic practices have shown to increase their population, creating a favorable environment for soil biological indicators. Particular attention is given to correlation relationships between microorganisms responsible for nitrogen and phosphorus accumulation and the fungal component. High correlation values (r = 0.72–0.89) underscore the significance of comprehending these associations when employing organic cultivation methods. The study of correlations among soil biota components in organic production presents a promising task for the effective utilization of resources and the assurance of sustainable agroecosystem development.

Keywords: agroecosystem, hemp, biota components, microorganisms, correlations.

INTRODUCTION

The influence of organic cultivation technology of industrial hemp on soil properties and the formation of quality indicators of hemp seeds in organic cultivation (Pylypchenko et al., 2023) plays a significant role in modern ecological agriculture. If the production of hemp products is properly managed it can be beneficial (Adesina et al., 2020). Hemp plants are capable of extracting toxic substances from the soil. Therefore, organic crops should be placed in areas free from toxic substances (Liang et al., 2013).

The presence of hemp in crop rotation is referred to as important due to its ability to slow down the growth of harmful organisms such as the fungus Verticillium dahliae, root nematodes Meloidogyne Chitwood and Meloidogyne hapla (Kok et al., 1994), or weeds (Lotz et al., 1991; van der Werf et al., 1995). This indicates the suitability of hemp for cultivation using organic techniques. The residues of hemp is an evidence

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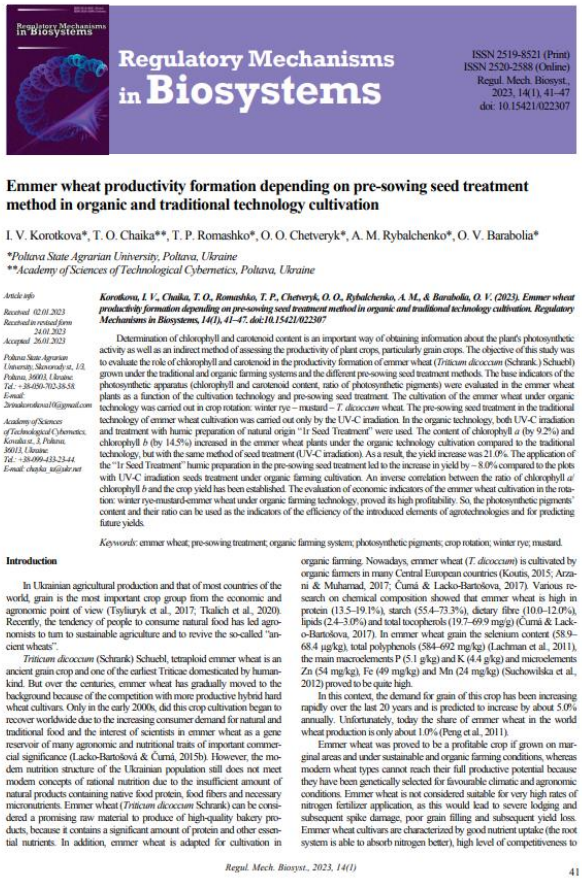

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Emmer wheat productivity formation depending on pre-sowing seed treatment method in organic and traditional technology cultivation

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Determination of chlorophyll and carotenoid content is an important way of obtaining information about the plant's photosynthetic activity as well as an indirect method of assessing the productivity of plant crops, particularly grain crops. The objective of this study was to evaluate the role of chlorophyll and carotenoid in the productivity formation of emmer wheat (*Triticum dicoccum* (Schrank.) Schuebl) grown under the traditional and organic farming systems and the different pre-sowing seed treatment methods. The base indicators of the photosynthetic apparatus (chlorophyll and carotenoid content, ratio of photosynthetic pigments) were evaluated in the emmer wheat plants as a function of the cultivation technology and pre-sowing seed treatment. The cultivation of the emmer wheat under organic technology was carried out in crop rotation: winter rye – mustard – *T. dicoccum* wheat. The pre-sowing seed treatment in the traditional technology of emmer wheat cultivation was carried out only by the UV-C irradiation. In the organic technology, both UV-C irradiation and treatment with humic preparation of natural origin "Ir Seed Treatment" were used. The content of chlorophyll *a* (by 9.2%) and chlorophyll *b* (by 14.5%) increased in the emmer wheat plants under the organic technology cultivation compared to the traditional technology, but with the same method of seed treatment (UV-C irradiation). As a result, the yield increase was 21.0%. The application of the "Ir Seed Treatment" humic preparation in the pre-sowing seed treatment led to the increase in yield by ~ 8.0% compared to the plots with UV-C irradiation seeds treatment under organic farming cultivation. An inverse correlation between the ratio of chlorophyll *a*/chlorophyll *b* and the crop yield has been established. The evaluation of economic indicators of the emmer wheat cultivation in the rotation: winter rye-mustard-emmer wheat under organic farming technology, proved its high profitability. So, the photosynthetic pigments' content and their ratio can be used as the indicators of the efficiency of the introduced elements of agrotechnologies and for predicting future yields.

Keywords: emmer wheat; pre-sowing treatment; organic farming system; photosynthetic pigments; crop rotation; winter rye; mustard.

Introduction

In Ukrainian agricultural production and that of most countries of the world, grain is the most important crop group from the economic and agronomic point of view (Tsyliuryk et al., 2017; Tkalich et al., 2020). Recently, the tendency of people to consume natural food has led agronomists to turn to sustainable agriculture and to revive the so-called "ancient wheats".

Triticum dicoccum (Schrank) Schuebl, tetraploid emmer wheat is an ancient grain crop and one of the earliest Triticae domesticated by humankind. But over the centuries, emmer wheat has gradually moved to the background because of the competition with more productive hybrid hard wheat cultivars. Only in the early 2000s, did this crop cultivation began to recover worldwide due to the increasing consumer demand for natural and traditional food and the interest of scientists in emmer wheat as a gene reservoir of many agronomic and nutritional traits of important commercial significance (Lacko-Bartošová & Čurná, 2015b). However, the modern nutrition structure of the Ukrainian population still does not meet modern concepts of rational nutrition due to the insufficient amount of natural products containing native food protein, food fibers and necessary micronutrients. Emmer wheat (*Triticum dicoccum* Schrank) can be considered a promising raw material to produce of high-quality bakery products, because it contains a significant amount of protein and other essential nutrients. In addition, emmer wheat is adapted for cultivation in organic farming. Nowadays, emmer wheat (*T. dicoccum*) is cultivated by organic farmers in many Central European countries (Koutis, 2015; Arzani & Muhamad, 2017; Čurná & Lacko-Bartošova, 2017). Various research on chemical composition showed that emmer wheat is high in protein (13.5–19.1%), starch (55.4–73.3%), dietary fibre (10.0–12.0%), lipids (2.4–3.0%) and total tocopherols (19.7–69.9 mg/g) (Čurná & Lacko-Bartošova, 2017). In emmer wheat grain the selenium content (58.9–68.4 µg/kg), total polyphenols (584–692 mg/kg) (Lachman et al., 2011), the main macroelements P (5.1 g/kg) and K (4.4 g/kg) and microelements Zn (54 mg/kg), Fe (49 mg/kg) and Mn (24 mg/kg) (Suchowilska et al., 2012) proved to be quite high.

In this context, the demand for grain of this crop has been increasing rapidly over the last 20 years and is predicted to increase by about 5.0% annually. Unfortunately, today the share of emmer wheat in the world wheat production is only about 1.0% (Peng et al., 2011).

Emmer wheat was proved to be a profitable crop if grown on marginal areas and under sustainable and organic farming conditions, whereas modern wheat types cannot reach their full productive potential because they have been genetically selected for favourable climatic and agronomic conditions. Emmer wheat is not considered suitable for very high rates of nitrogen fertilizer application, as this would lead to severe lodging and subsequent spike damage, poor grain filling and subsequent yield loss. Emmer wheat cultivars are characterized by good nutrient uptake (the root system is able to absorb nitrogen better), high level of competitiveness to

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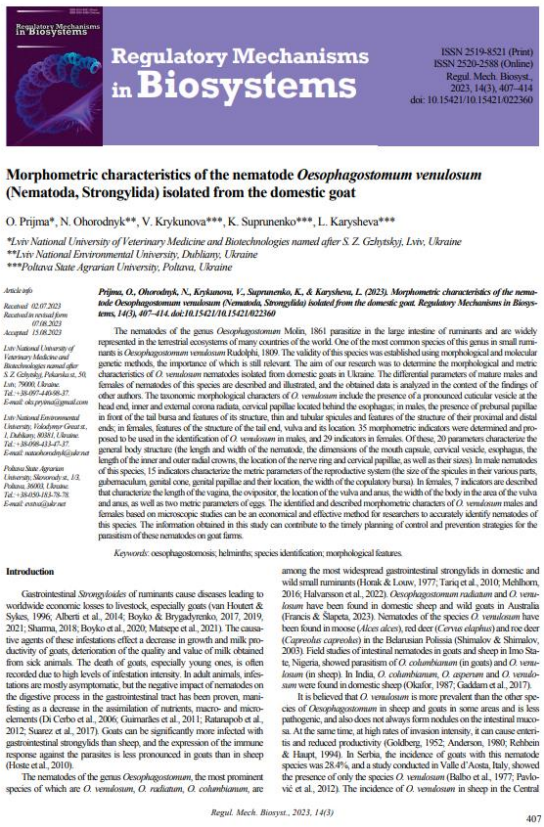

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Morphometric characteristics of the nematode *Oesophagostomum venulosum* (Nematoda, Strongylida) isolated from the domestic goat

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The nematodes of the genus *Oesophagostomum* Molin, 1861 parasitize in the large intestine of ruminants and are widely represented in the terrestrial ecosystems of many countries of the world. One of the most common species of this genus in small ruminants is *Oesophagostomum venulosum* Rudolphi, 1809. The validity of this species was established using morphological and molecular genetic methods, the importance of which is still relevant. The aim of our research was to determine the morphological and metric characteristics of *O. venulosum* nematodes isolated from domestic goats in Ukraine. The differential parameters of mature males and females of nematodes of this species are described and illustrated, and the obtained data is analyzed in the context of the findings of other authors. The taxonomic morphological characters of *O. venulosum* include the presence of a pronounced cuticular vesicle at the head end, inner and external corona radiata, cervical papillae located behind the esophagus; in males, the presence of prebural papillae in front of the tail bursa and features of its structure, thin and tubular spicules and features of the structure of their proximal and distal ends; in females, features of the structure of the tail end, vulva and its location. 35 morphometric indicators were determined and proposed to be used in the identification of *O. venulosum* in males, and 29 indicators in females. Of these, 20 parameters characterize the general body structure (the length and width of the nematode, the dimensions of the mouth capsule, cervical vesicle, esophagus, the length of the inner and outer radial crowns, the location of the nerve ring and cervical papillae, as well as their sizes). In male nematodes of this species, 15 indicators characterize the metric parameters of the reproductive system (the size of the spicules in their various parts, gubernaculum, genital cone, genital papillae and their location, the width of the copulatory bursa). In females, 7 indicators are described that characterize the length of the vagina, the ovipositor, the location of the vulva and anus, the width of the body in the area of the vulva and anus, as well as two metric parameters of eggs. The identified and described morphometric characters of *O. venulosum* males and females based on microscopic studies can be an economical and effective method for researchers to accurately identify nematodes of this species. The information obtained in this study can contribute to the timely planning of control and prevention strategies for the parasitism of these nematodes on goat farms.

Keywords: oesophagostomosis; helminths; species identification; morphological features.

Introduction

Gastrointestinal *Strongyloides* of ruminants cause diseases leading to worldwide economic losses to livestock, especially goats (van Houtert & Sykes, 1996; Alberti et al., 2014; Boyko & Brygadyrenko, 2017, 2019, 2021; Sharma, 2018; Boyko et al., 2020; Matsepe et al., 2021). The causative agents of these infestations effect a decrease in growth and milk productivity of goats, deterioration of the quality and value of milk obtained from sick animals. The death of goats, especially young ones, is often recorded due to high levels of infestation intensity. In adult animals, infestations are mostly asymptomatic, but the negative impact of nematodes on the digestive process in the gastrointestinal tract has been proven, manifesting as a decrease in the assimilation of nutrients, macro- and microelements (Di Cerbo et al., 2006; Guimarães et al., 2011; Ratanapob et al., 2012; Suarez et al., 2017). Goats can be significantly more infected with gastrointestinal strongylids than sheep, and the expression of the immune response against the parasites is less pronounced in goats than in sheep (Hoste et al., 2010).

The nematodes of the genus *Oesophagostomum*, the most prominent species of which are *O. venulosum*, *O. radiatum*, *O. columbianum*, are among the most widespread gastrointestinal strongylids in domestic and wild small ruminants (Horak & Louw, 1977; Tariq et al., 2010; Mehlhorn, 2016; Halvarsson et al., 2022). *Oesophagostomum radiatum* and *O. venulosum* have been found in domestic sheep and wild goats in Australia (Francis & Šlapeta, 2023). Nematodes of the species *O. venulosum* have been found in moose (*Alces alces*), red deer (*Cervus elaphus*) and roe deer (*Capreolus capreolus*) in the Belarusian Polissia (Shimalov & Shimalov, 2003). Field studies of intestinal nematodes in goats and sheep in Imo State, Nigeria, showed parasitism of *O. columbianum* (in goats) and *O. venulosum* (in sheep). In India, *O. columbianum*, *O. asperum* and *O. venulosum* were found in domestic sheep (Okafor, 1987; Gaddam et al., 2017).

It is believed that *O. venulosum* is more prevalent than the other species of *Oesophagostomum* in sheep and goats in some areas and is less pathogenic, and also does not always form nodules on the intestinal mucosa. At the same time, at high rates of invasion intensity, it can cause enteritis and reduced productivity (Goldberg, 1952; Anderson, 1980; Rehbein & Haupt, 1994). In Serbia, the incidence of goats with this nematode species was 28.4%, and a study conducted in Valle d'Aosta, Italy, showed the presence of only the species *O. venulosum* (Balbo et al., 1977; Pavlović et al., 2012). The incidence of *O. venulosum* in sheep in the Central

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RESPONSE OF THE ANTIOXIDANT SYSTEM OF WHEAT SEEDLINGS WITH DIFFERENT GENOTYPES TO EXOGENOUS PROOXIDANTS: THE RELATIONSHIP WITH RESISTANCE TO ABIOTIC STRESSORS

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Oxidative stress is an important component of heat- and drought-induced damage in plants. However, information on the relationship between the resistance of cultivated plants with different genotypes to environmental factors and their ability to maintain a pro-/antioxidant balance remains contradictory. This study aimed to compare the growth responses and adaptation ability of the antioxidant system in different wheat cultivars to oxidative stress agents hydrogen peroxide and iron(II) sulfate. Etiolated seedlings of common winter wheat (Triticum aestivum L.) Antonivka and Tobak (heat- and drought-tolerant), and Avgustina and Doskonala (not resistant to heat and drought) were used for the study. Three-day-old etiolated seedlings were exposed to 50 mM H_2O_2 or 5 mM $FeSO_4$ for one day. It was found that seedlings of Antonivka and Tobak cultivars treated with H_2O_2 or $FeSO_4$ were able to maintain relatively intensive growth, accumulated significantly lower amounts of endogenous hydrogen peroxide and lipid peroxidation products, significantly increased anthocyanin content and had a higher activity of SOD and catalase as compared with non-resistant cultivars. The non-tolerant cultivars' response to stress agents was only to increase proline content with a simultaneous decrease in SOD activity and anthocyanins content. The identified varietal markers of the antioxidant system adaptive strategy can be used to develop new approaches for screening wheat cultivars with cross-resistance to major abiotic stressors.

K e y w o r d s: oxidative stress, antioxidant system, H_2O_2, ferrous sulphate, heat tolerance, drought resistance, Triticum aestivum seedlings.

Exposure of plants to most (if not all) stressors leads to an imbalance between the generation and deactivation of reactive oxygen species (ROS). Even relatively small changes in this balance can lead to the disruption of cellular processes of redox regulation [1, 2], and significant accumulation of ROS in tissues leads to the well-known effect of oxidative stress, which causes lipid peroxidation (LPO) and oxidative damage to proteins and nucleic acids [3].

Oxidative stress is one of the main causes of plant damage during drought and high temperature. During heat stress, this effect is a consequence of the increased fluidity of the chloroplast and mitochondrial membranes, which leads to disruption of electron transport in these organelles [4]. The effects of activation of ROS-generating enzymes (primarily NADPH-oxidase) under heat stress are also known [5, 6]. Drought also has a similar effect on plants. Restriction of carbon dioxide influx into cells due to stomatal closure leads to an over-reduction of the electron transport chain in chloroplasts and increases the likelihood of ROS formation [7]. The significant contribution of mitochondria to the development of oxidative stress under drought conditions is also known. Thus, the carbonylated protein content in the mitochondria of wheat leaf cells under severe drought conditions was an order of magnitude

Yastreb T.O., Kokorev A.I., Makaova B.E., Ryabchun N. I., **Sakhno T. V.**, Dmitriev A. P., Kolupaev Yu.E. Response of the antioxidant system of wheat seedlings with different genotypes to exogenous prooxidants: the elationship with resistance to abiotic stressors. **Ukr. Biochem. J.**, 2023, Vol. 95, N 6 C.81-96.
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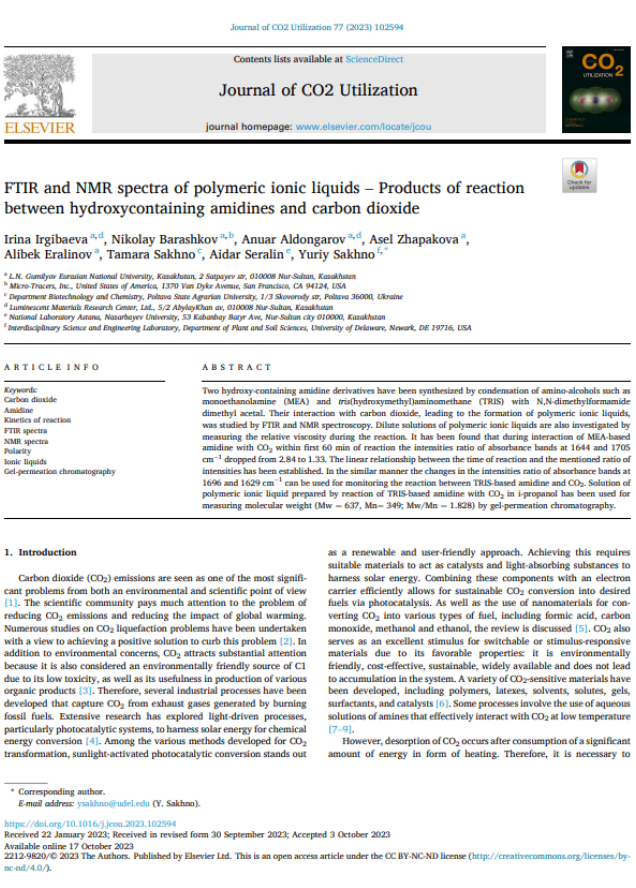

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FTIR and NMR spectra of polymeric ionic liquids – Products of reaction between hydroxycontaining amidines and carbon dioxide

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ABSTRACT

Two hydroxy-containing amidine derivatives have been synthesized by condensation of amino-alcohols such as monoethanolamine (MEA) and *tris*(hydroxymethyl)aminomethane (TRIS) with N,N-dimethylformamide dimethyl acetal. Their interaction with carbon dioxide, leading to the formation of polymeric ionic liquids, was studied by FTIR and NMR spectroscopy. Dilute solutions of polymeric ionic liquids are also investigated by measuring the relative viscosity during the reaction. It has been found that during interaction of MEA-based amidine with CO_2 within first 60 min of reaction the intensities ratio of absorbance bands at 1644 and 1705 cm^{-1} dropped from 2.84 to 1.33. The linear relationship between the time of reaction and the mentioned ratio of intensities has been established. In the similar manner the changes in the intensities ratio of absorbance bands at 1696 and 1629 cm^{-1} can be used for monitoring the reaction between TRIS-based amidine and CO_2. Solution of polymeric ionic liquid prepared by reaction of TRIS-based amidine with CO_2 in i-propanol has been used for measuring molecular weight (Mw – 637, Mn– 349; Mw/Mn – 1.828) by gel-permeation chromatography.

1. Introduction

Carbon dioxide (CO_2) emissions are seen as one of the most significant problems from both an environmental and scientific point of view [1]. The scientific community pays much attention to the problem of reducing CO_2 emissions and reducing the impact of global warming. Numerous studies on CO_2 liquefaction problems have been undertaken with a view to achieving a positive solution to curb this problem [2]. In addition to environmental concerns, CO_2 attracts substantial attention because it is also considered an environmentally friendly source of C1 due to its low toxicity, as well as its usefulness in production of various organic products [3]. Therefore, several industrial processes have been developed that capture CO_2 from exhaust gases generated by burning fossil fuels. Extensive research has explored light-driven processes, particularly photocatalytic systems, to harness solar energy for chemical energy conversion [4]. Among the various methods developed for CO_2 transformation, sunlight-activated photocatalytic conversion stands out as a renewable and user-friendly approach. Achieving this requires suitable materials to act as catalysts and light-absorbing substances to harness solar energy. Combining these components with an electron carrier efficiently allows for sustainable CO_2 conversion into desired fuels via photocatalysis. As well as the use of nanomaterials for converting CO_2 into various types of fuel, including formic acid, carbon monoxide, methanol and ethanol, the review is discussed [5]. CO_2 also serves as an excellent stimulus for switchable or stimulus-responsive materials due to its favorable properties: it is environmentally friendly, cost-effective, sustainable, widely available and does not lead to accumulation in the system. A variety of CO_2-sensitive materials have been developed, including polymers, latexes, solvents, solutes, gels, surfactants, and catalysts [6]. Some processes involve the use of aqueous solutions of amines that effectively interact with CO_2 at low temperature [7–9].

However, desorption of CO_2 occurs after consumption of a significant amount of energy in form of heating. Therefore, it is necessary to

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Formation of the Quality Indicators of Hemp (*Cannabis sativa* L.) Seeds Sown under Organic Growing Technology

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ABSTRACT

The oil content of hemp seeds is controlled by the genotype and in the conducted studies did not depend on the growing technology; however, this factor had a synergistic effect with others. The protein content of hemp seeds during the years of research did not depend on weather conditions. Like other quality indicators, it had a slight variation, which indicates the significant role of the genetic characteristics of the varieties. On average, over the years of research, the protein content of the variants grown according to conventional technology was 25.2%, and according to transitional technology, it was 0.03% higher, which was within the limits of statistical error. The organic technology ensured the protein content at the level of 25.3%, and the use of the BioStymix-Niva microbial biodegrader - biodestructor contributed to the further growth of the indicator to 25.4%. The oil content of hemp seeds is not limited by other important characteristics, such as the yield of the hemp stems or the fiber content. Only the Glyana variety showed inverse correlations with plant height, hemp stems and seed productivity, they were of medium strength (r = -0.60 – -0.43). In the Zolotoniski 15 variety, only one inverse relationship was recorded, i.e. plant height (r = -0.57). No correlation was established between protein content and oil content in seeds. Correlations may change depending on other factors of cultivation, including weather conditions, elements of technology, etc., but the evaluation of varieties for cultivation according to these characteristics can significantly increase the efficiency of the production of cannabis products.

Keywords: organic technologies, hemp seeds, oil, protein, correlations.

INTRODUCTION

After many years of unprecedented restrictions, the agricultural culture of ancient civilization is gradually returning to the fields and attracts the deserved attention of science and industry. Not only a narrow approach to the revival of hemp growing, but also a much deeper problem, namely greening of crop production, food and technical industry, improvement of the environment, renewal of raw resources and a large number of aspects of human activity, is gaining special relevance. In this context, the basis is a scientifically based, rational system of hemp cultivation, which is based on the selection of varieties for targeted cultivation as well as development of organic cultivation technologies, taking into account agrobiological and agro-ecological features. Hemp has the potential for environmentally friendly sustainable cultivation (Small and Marcus, 2002) and the majority of US farmers surveyed, namely 75%, expressed interest in certified production (Dingha, 2019). According to Lithuanian scientists, this crop meets

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Research of Problems Flicker Level of LED Lamps and Luminaires for General Lighting

Abstract. *The paper presents the results of the study of flickering brightness and stroboscopic effect of commercial samples of light-emitting diode (LED) lamps and lamps entering the market from various manufacturers of lighting products. The criteria for assessing the compliance of the flicker level and the probability of detecting the stroboscopic effect are the short-term parameter of flicker and the indicator of the visibility of the stroboscopic effect. The level of flickering was also evaluated in accordance with the recommendations of the standard of the American Institute of Electrical and Electronics Engineers (IEEE). When measuring the flicker parameters in the frequency range up to 80 Hz and the stroboscopic effect with light modulation up to 1.2 kHz, the spectrometer MK 350S was used and the metrics recommended in international standards. It has been shown that most of the tested LED lamps and luminaires for general lighting meet the requirements regarding the safe level of flickering brightness and the visibility of the stroboscopic effect. The studied samples mainly meet the higher requirements recommended in the American standard IEEE 1789:2015. On the basis of the obtained results, the conclusions were drawn that the modern technological capabilities of the production of LED products are able to provide the market in accordance with the established requirements. The achieved level of light flickering of LED sources is lower than that of any other types of sources for general lighting powered by an alternating current network.*

Streszczenie. *W artykule przedstawiono wyniki badań jasności migotania i efektu stroboskopowego komercyjnych próbek lamp z diodami elektroluminescencyjnymi (LED) oraz lamp wprowadzanych na rynek od różnych producentów produktów oświetleniowych. Kryteriami oceny zgodności poziomu migotania i prawdopodobieństwa wykrycia efektu stroboskopowego są krótkookresowy parametr migotania oraz wskaźnik widoczności efektu stroboskopowego. Oceniono również poziom migotania zgodnie z zaleceniami standardu Amerykańskiego Instytutu Inżynierów Elektryków i Elektroników (IEEE). Do pomiarów parametrów migotania światła w zakresie częstotliwości do 80 Hz oraz efektu stroboskopowego z modulacją światła do 1,2 kHz wykorzystano spektrometr MK 350S oraz metryki zalecane w normach międzynarodowych. Wykazano, że większość badanych lamp i opraw LED do oświetlenia ogólnego spełnia wymagania dotyczące bezpiecznego poziomu migotania jasności oraz widoczności efektu stroboskopowego. Badane próbki spełniają głównie wyższe wymagania zalecane w amerykańskiej normie IEEE 1789:2015. Na podstawie uzyskanych wyników wyciągnięto wnioski, że współczesne możliwości technologiczne produkcji wyrobów LED są w stanie zapewnić rynek zgodnie z założonymi wymaganiami. Osiągany poziom migotania światła źródeł LED jest niższy niż innych typów źródeł oświetlenia ogólnego zasilanych z sieci prądu przemiennego. (**Badanie problemów poziomu migotania lamp i opraw LED do oświetlenia ogólnego**)*

Key words: flickering, LED, stroboscopic effect.
Słowa kluczowe: migotanie, LED, efekt stroboskopowy.

Introduction

In 2021, the European Union (EU) Commission Regulation 2019/2020 entered into force [1] which sets new requirements for lighting equipment. One of the features of this Regulation is that it introduces completely new requirements for the safe level of flicker and stroboscopic effect of LED light sources for the first time.

Flickering is a problem inherent in electric light sources powered by alternating current. The problem of flickering has gained new relevance after the widespread introduction of LEDs into lighting technology. Compared to incandescent lamps (IL) and luminescent lamps (LL), the flickering of LEDs is significantly different due to the extremely fast reaction of the change in their light flux to the change in current.

A change in the light flux over time can have both a visual and a non-visual effect on the observer. There are three types of visually noticeable phenomena associated with the change in light flux over time [2]:
-flicker-the perception of visual instability caused by a light stimulus, the brightness or spectral distribution of which fluctuates over time, for a static observer in a static environment;
-stroboscopic effect-change in motion perception induced by a light stimulus the luminance or spectral distribution of which fluctuates with time, for a non-static observer in a static environment;
-phantom array effect (ghosting)-change in perceived shape or spatial positions of objects, induced by a light stimulus the luminance or spectral distribution of which fluctuates with time, for a non-static observer in a static environment.

The general name of these phenomena is proposed in [2]-temporal light artifacts (TLA). Light sources that create TLA not only reduce the quality of lighting (create discomfort), but can pose a health hazard-cause fatigue, eye strain, reduce the performance of visual work, provoke headaches, migraines, create neurological problems such as epileptic seizures, strengthen autistic behavior of children, etc. [3-6].

Currently, several methods are widely used to estimate the level of flicker. At the same time, the following critical characteristics are taken into account [6]:
-MD brightness modulation depth (or flicker percentage), which is defined as:

$$(1) \qquad MD\% = \frac{L_{max} - L_{min}}{L_{max} + L_{min}} \cdot 100$$

where: L_{max}, L_{min}-are the maximum and minimum brightness values (Fig. 1), FI flicker index, which takes into account the waveform and is defined as:

$$(2) \qquad FI = \frac{Area1}{Area1 + Area2}$$

where: Area1, Area2-are the areas under the curve that are above and below the average value of radiation intensity, respectively (Fig. 1), frequency f with which the radiation intensity changes, Hz.

In [7] it is noted that it is now important to understand how the TLA of LED light sources affect human health and

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