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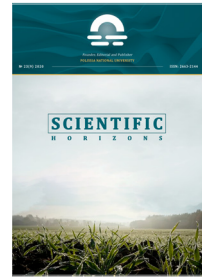
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INVESTIGATION OF THE INFLUENCE OF THE METHOD OF FIXING THE CUT-OFF TOOL INSERTS ON ITS STRESS STATE

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Abstract. Cut-off tools equipped with carbide inserts are commonly used in turning operations. Due to the very heavy conditions in which such blades work, they fail, as a rule, not as a result of their operation, but due to the breakage of carbide inserts. This study investigates the causes of such failures and methods to prevent such phenomena. A thorough analysis of the current state and research methods of stress state in cutting tools, including turning cutters, was carried out. Methods of stress reduction in carbide inserts were also analysed. This paper focuses on the study of the stress state in cut-off tools with brazed carbide inserts. The stress state in the carbide inserts and the influence of different fixation methods of carbide insert to the holder were considered. The main approach to stress studies was the photoelasticity method, which allows quickly and clearly obtaining and evaluating the results. Models of carbide inserts were made of optically sensitive material. It as a part of a complex model of a cut-off tool with a carbide insert with three different methods of fixation were loaded with a force by means of a specially designed stand simulating the cutting force. The study was carried out on a PPU-7 polarisation-projection unit. Isochromatic and isocline patterns were obtained. The estimation of the principal stresses was performed by the difference of shearing stresses for three cross sections of the insert: at the surface, in the middle and at the base. It was found that the best result is given by the method in which the insert on the side far from the cutting edge has a bevel made at an angle of 10°

Keywords: tension, cutting tool, photoelasticity, fixation



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INTRODUCTION

When making parts from a bar or a disc, which are fed through the spindle of a lathe, as a rule, the final operation is cutting. This operation is performed by special cut-off tools. Since the cutting operation is the last, the quality of this tool significantly affects the quality of the manufactured part. The work carried out by the cut-off tool takes place in heavy conditions. Cutting takes place over the entire width of the narrow blade, which, moreover, is fixed on three sides by the backing. Such conditions create a high load on the tool, both power and thermal, which, in turn, requires its

high strength and durability. Additionally, it is necessary to take into account the difficulty of chip removal in such conditions. Cutters which make grooves in details work in similar conditions. Since modern cut-off tools are equipped with carbide inserts, it is important to fix them, which would provide the lowest stresses in the inserts under loads during operation.

In practice, two basic designs of cut-off tools are used. At some the hard-alloy insert is brazed to a holder by means of a copper-based alloy, and at others it is replaceable and is fixed by the special clamp (Fig. 1).



Figure 1. Cut-off tools: a) brazed [1]; b) assemblable [2]

Cutters with brazed inserts are used in single and small-batch production, as well as when working on automatic machines, where high precision machining is required and the tool should not have any gaps. In other cases, prefabricated cutters of various designs are used. Such tool designs make it easy to replace a worn-out carbide insert without the need to sharpen it. In this study, the main attention was paid to cutters with brazed inserts.

The main reasons for failure of cut-off tools with brazed inserts are their breakage due to the appearance of microcracks at the stage of brazing, overloading the cutters in the wrong cutting modes and untimely sharpening of the tool. The study [3] claims that 40-50% of cutters with brazed carbide inserts fail due to breakage of the inserts, and not due to their wear during operation. Because such tools are quite expensive, it leads to significant unproductive material losses.

The *purpose* of the study is to optimise the method of fixing the brazed carbide insert of the cut-off tool through the investigation of the stress state for different fixing options and thus increase the efficiency of the cutters.

LITERATURE REVIEW

To prevent failure of the cutters due to breakage of the inserts, studies of the stress-strain state of the cutter are carried out, in particular, the carbide insert under the load of the forces arising in the cutting process. At the same time, both computational and experimental research methods are applied. Important for both computational and experimental study is the method and location of application of the load acting on the carbide insert. Thus, the study [4] suggests that the most dangerous zone during the loading of the insert is the area of the front surface outside the contact at a distance of 1.5-2.5 contact length. And this allows applying the St. Venant's principle to determine the

stresses in this zone, when instead of a distributed load a concentrated force is applied to the top of the wedge. To calculate the stresses that occur in the danger zone of the insert, the study provided special nomograms that allow determining the optimal geometric parameters of the cutting wedge. A more accurate distribution of loads and contact stresses on the front and rear surfaces of the cutter in conditions close to real is provided by the split cutter method. This method was used by a number of researchers, including V.A. Ostafyev [5], M.F. Poletik [6] and others. The disadvantage of this method is the inability to determine the stress distribution in the body of the insert. In addition, the method of a split cutter allows studying the distribution of contact stresses only in the conditions of orthogonal cutting.

The study [7] estimated the magnitude of the loads on the cutter during orthogonal cutting and the cutting process itself in real conditions using a Phantom v7.3 Vision Research high-speed camera. The results of these studies showed that the magnitude of stresses in the cutter blade is influenced not only by the magnitude of the vertical component of the cutting force P_z , but also by the magnitude of the horizontal component P_y . This is confirmed by studies conducted by S.Y. Liang and J.C. Su [8]. That is, when modelling the cutting process, the force acting on the cutting plate must be applied at a certain angle. The magnitude of stresses is also affected by the heat released during the cutting process, but, as stated in [9], during orthogonal cutting, the mechanical effect is the dominant factor. The main tool of analytical studies of the stress-strain state of a metal-cutting tool is the finite element method. The cross section of the body of the tool under study is divided into a finite number of triangular elements with rectilinear sides and the stress state of each of them is calculated. Due to the approach to the blade of the tool to increase the accuracy of calculations, the grid of triangular elements thickens. To model the cutting

process by the finite element method, special software products DEFORM, THIRD WAVE ADVANTEDGE (TWA), ABAQUS, LS-DYNA, ANSYS, FORGE and others are used. For example, in [10] the ANSYS programme was used to detect dangerous tensile stresses in carbide inserts in the process of replacing the cutting part from the group of high-speed steels with a carbide cutting part. The same software product was used in [11] to determine the cutting stress during the finishing turning of the hardened alloy AISI H13. Ukrainian scientists have developed the OCFEM model [12], which is used to solve the problem of modelling the process of orthogonal free cutting. Each of these models to some extent takes into account the influence of the magnitude of the cutting forces, cutting parameters, properties of the tool material, temperature, friction and other values. The main question is – how the results correspond to the real picture of the stress-strain state in the body of the tool.

Experimental methods for studying the stress-strain state of a metal-cutting tool include, for example, the holographic method. The study [13] used a holographic interferometry setup based on the HYTEC PRISM deformation and vibration measurement system to determine the deformations of lathes. This allowed combining the results of numerical and experimental studies and obtaining optimal parameters of cutting modes.

The main reason for the breakage of carbide inserts during machining is the occurrence of large tension stresses near the front surface of the insert, exceeding the strength limit of the material. Different studies have suggested different approaches to avoid such tensions. Thus, as a result of [14] it was found that in the process of increasing the thickness of the insert more than 5 mm, there is a significant reduction in tension stresses on the front and bottom surfaces of the insert. The calculation of internal stresses in the insert was performed using the ANSYS14.0 software. The stress in the carbide insert can also be reduced by using an

alternative to brazing method of attaching the insert to the holder. The method of diffusion fixing of a hard-alloy insert described in [15] provides, along with stress reduction, also rigid resistance under the cutting plate.

MATERIALS AND METHODS

The photoelasticity method, based on the properties of some transparent materials in which optical anisotropy and associated birefringence occur under the action of applied mechanical loads, can be used to study the stress-strain state of structures. Materials for making models for the study of photoelasticity must meet the following conditions: sufficient optical activity, transparency, isotropy and homogeneity, no initial optical effect, edge effect, linear relationship between stresses and strains and the sequence number, no noticeable creep, the possibility of labour-intensive machining in the process of making models. Although the photoelasticity method due to the development of numerical models is not often used, according to [16] it has great potential, because the information obtained by this method is formed at the micro level. This method is successfully used to study, for example, the stress-strain state of the fixing unit of the carbide cutting tool [17]. New optically sensitive materials with a wide range of optical, mechanical, and rheological properties have been developed, which allow considering a wide range of engineering problems in the study of the stress state [18].

In this study, the photoelasticity method was used to investigate the stress-strain state of a carbide insert during various methods of its fixation. The PPU-7 polarisation-projection unit was used in the study. Models of carbide inserts were made of optically sensitive material based on ED-6 epoxy resin cured with methyltetrahydrophthalic anhydride with an optical constant $\sigma_0^{1.0} = 1.88$ MPa. The geometric dimensions of the models are presented in Fig. 2.

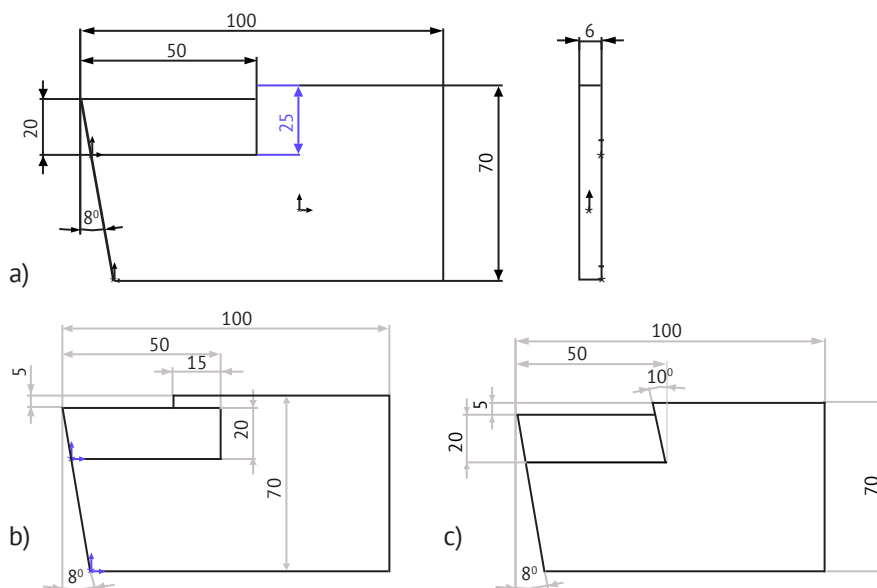


Figure 2. Geometrical dimensions of models of cut-off tools: a) standard variant; b) with additional fixation from above; c) with a bevelled back of the insert

The geometric parameters of the model are selected based on the geometric scale of the simulation (1):

$$\alpha = \frac{l_p}{l_m} = \text{const}, \quad (1)$$

where l_p i l_m – the lengths of any corresponding segments in kind and on a model.

The power scale can be selected arbitrarily (2):

$$\beta = \frac{P_p}{P_m} = \text{const}. \quad (2)$$

The scale of similarity of stresses will be related to the force scale β through the geometric scale α (3):

$$\delta = \frac{\sigma_p}{\sigma_m} = \frac{\beta}{\alpha^2} = \text{const}. \quad (3)$$

In accordance with the general principles of the similarity theory, the modulus of elasticity of a model having the dimension of stresses should be modelled on the same scale as stresses ϵ (4):

$$\frac{E_p}{E_m} = \delta = \text{const}, \quad (4)$$

where E_p i E_m – elastic moduli at the corresponding points in kind and on a model.

Poisson's ratios of materials in kind μ_p and materials on a model μ_m as dimensionless quantities should be equal to each other (5):

$$\mu_k = \mu_m. \quad (5)$$

The fulfilment of these similarity conditions is sufficient for the internal (which are investigated) stresses in the model to have a scale δ , a displacement scale α , and the deformations of the model and in kind coincide. This allows, based on the findings, evaluating the real state of the stressed state of a cutter with a carbide insert.

RESULTS AND DISCUSSION

In the course of the study, models of cutters were installed in a special stand and loaded with a force that mimics the cutting force (Fig. 3). The magnitude of the applied force was measured using a LMF universal dynamometer.

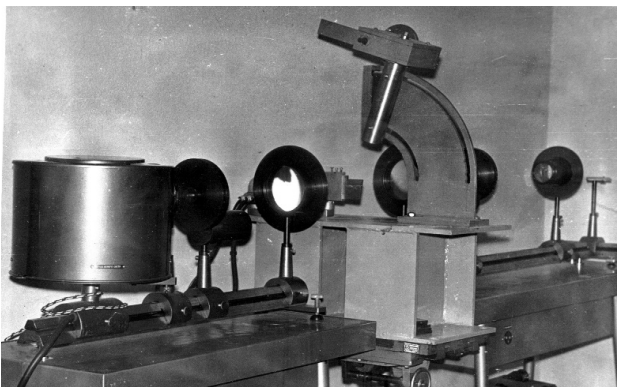


Figure 3. PPU-7 polarisation-projection unit with the stand for loading

For each method of fixing at the same loads $P_z=1000H$, isochromatic patterns (strips of the same colour connecting the points with the same difference of the main stresses) (Fig. 4) and isoclinal patterns (dark lines connecting the points with the same direction of the main stresses) were obtained. To determine the stresses along arbitrary lines, two parallel auxiliary sections were drawn on different sides of these lines at a sufficiently close distance from the main ones. The values of tangential stresses τ'_{xy} and τ''_{xy} , were determined along these sections, as well as the differences of these stresses $\Delta\tau_{xy} = \tau'_{xy} - \tau''_{xy}$ between the auxiliary sections.

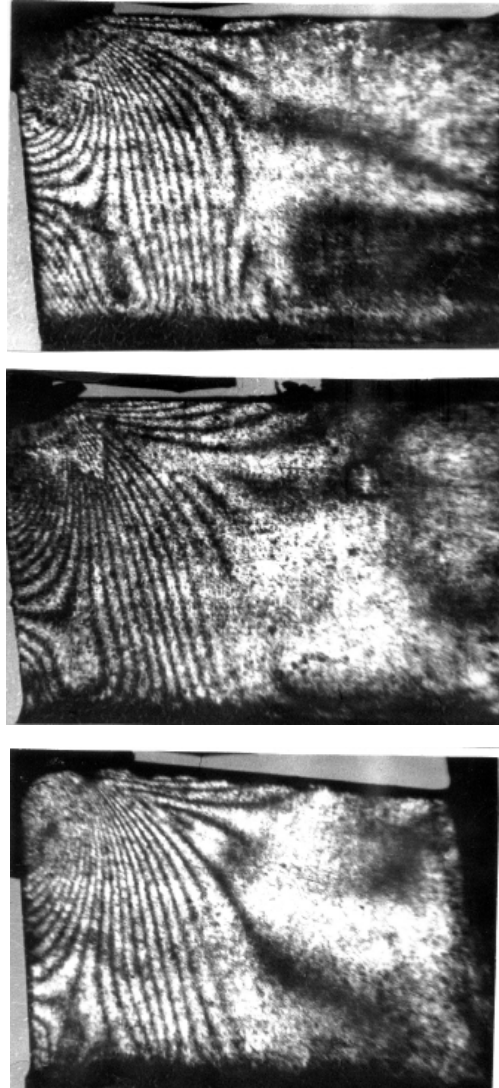


Figure 4. Isochromatic and isoclinal patterns with different fixation of the insert

The values of normal stresses σ_x and σ_y were determined using formulas (6-7):

$$\sigma_{xn} = \sigma_{x0} - \sum_{i=1}^n (\Delta\tau_{xy})_i \frac{\Delta x_i}{\Delta y}; \quad (6)$$

$$\sigma_{yk} = \sigma_{y0} - \sum_{r=1}^k (\Delta\tau_{xy})_r \frac{\Delta y_r}{\Delta x} + \gamma \sum_{r=1}^k \Delta y_r, \quad (7)$$

where n and k – the number of measured points along the x and y axes, respectively; σ_{x0} and σ_{y0} are known values of σ_x and σ_y at the starting point

of integration; Δx_i and Δy_r – intervals along the x and y axes, through which measurements were performed; Δx and Δy – the distances between the parallel auxiliary sections along the x and y axes; $\gamma \sum_{r=1}^k \Delta y_r$ – the product of volume weight by the length of the integration segment (taken into account if the model operates under its own weight).

Knowing the values σ_x , σ_y and τ_{max} for each section, the values of the principal stresses σ_1 and σ_2 were determined. The calculation of the dangerous section of the hard-alloy insert was carried out according to maximum-strain of failure. The equivalent stress σ_{eq} was determined for the case of a plane stress state (8):

$$\sigma_{eq} = \sigma_1 - \mu\sigma_2 \quad (8)$$

The calculation was performed for eight points for each of the three longitudinal sections of the insert: at the surface, in the middle, and at the base for all three methods of fixing the insert. According to the values of σ_{eq} the dependences of the location of dangerous sections and the value of σ_{eq} on the method of fixing the carbide insert were obtained. Figures 5-7 show graphs of the distribution of σ_{eq} (values are presented in bands) along the front surface of the inserts, along the middle section of the inserts, and along the base of the inserts for all three samples with different fixation of the carbide insert.

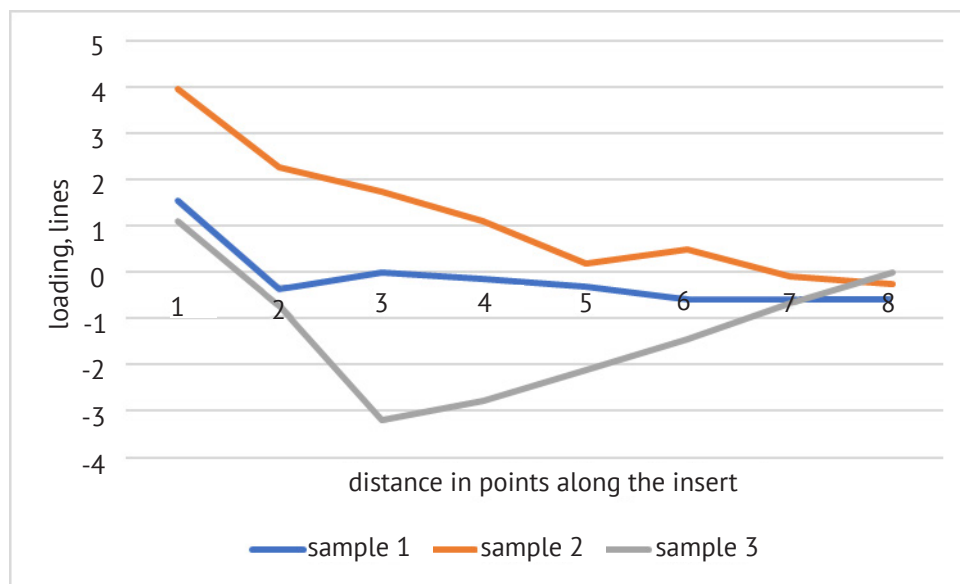


Figure 5. Distribution of σ_{eq} along the front surface of the inserts

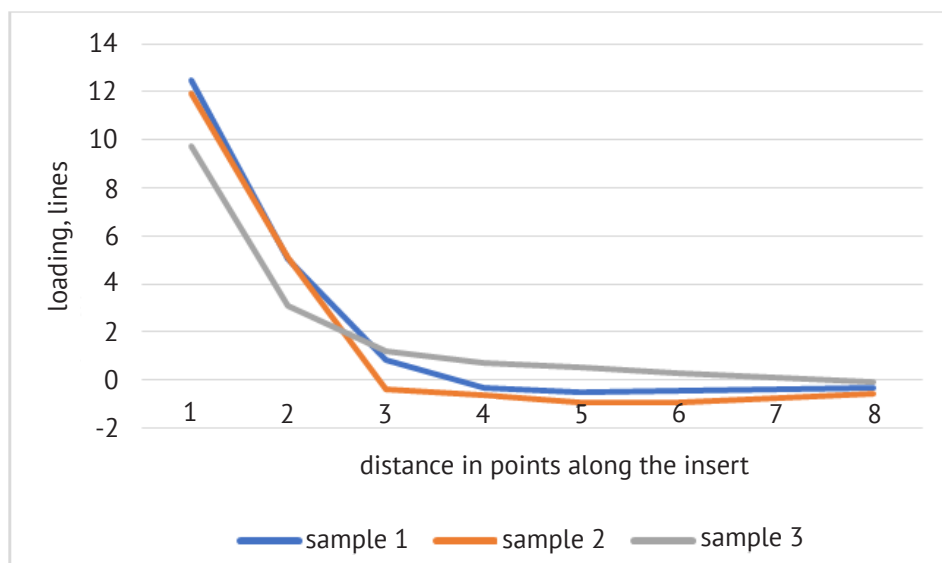


Figure 6. Distribution of σ_{eq} along the middle section of the inserts

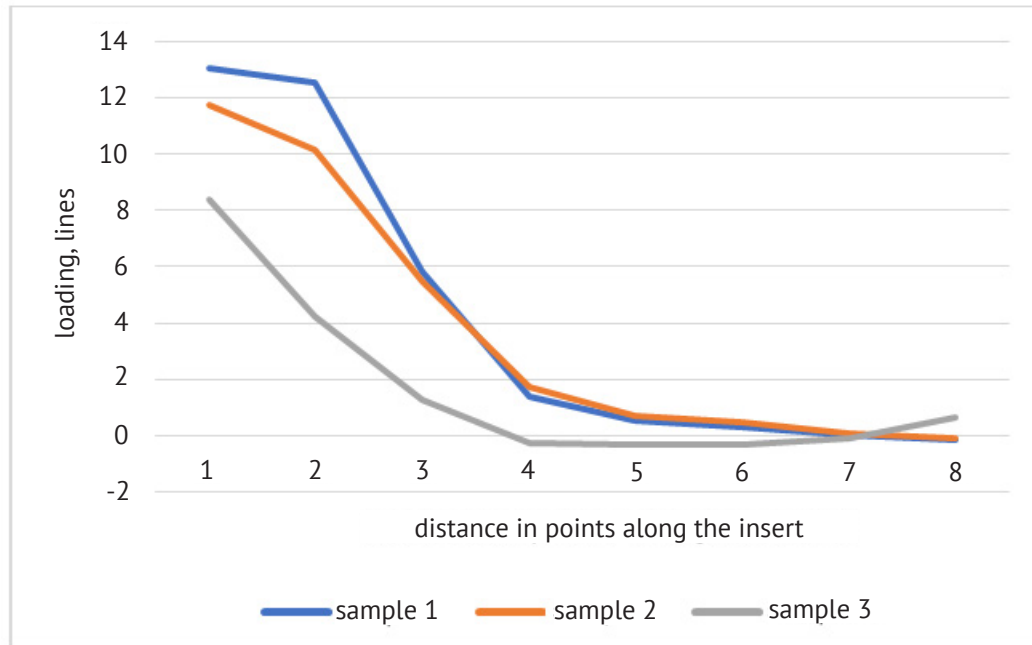


Figure 7. Distribution of σ_{eq} along the base of the inserts

Admittedly, the stresses according to the fixation method No. 3 are the smallest in all three sections. Therefore, it is proved that the method of fixing the carbide insert to the cutter holder affects the stress distribution in the tool. It allows choosing an optimum way of fixation due to which the stress will be the smallest and at the same time reduce probability of breakage of hard-alloy inserts during their operation.

CONCLUSIONS

Studies of the influence of the method of fixing the cutting carbide insert on the stress distribution allows

for the conclusion on the most appropriate fixation method in terms of strength. The results obtained show that the stress distributions for all three methods of fixing the carbide insert are similar. The greatest stresses occur near the blade of the cutting edge, they gradually decrease moving away from the blade. The location of the dangerous sections for all three types of fixation is approximately the same, but the values of stresses in them with different fixation can differ. The most expedient, from this point, is the third method of fixing, in which the amount of stress is the smallest.

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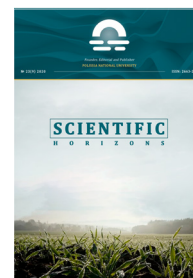
ДОСЛІДЖЕННЯ ВПЛИВУ СПОСОБУ ЗАКРІПЛЕННЯ ПЛАСТИНКИ ВІДРІЗНОГО РІЗЦЯ НА ЇЇ НАПРУЖЕНИЙ СТАН

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Анотація. Оснащені твердосплавними пластинками відрізнi різці є дуже поширеним інструментом, який використовується в токарних операціях. Через дуже важкі умови, у яких працюють такі різці, вони виходять з ладу, як правило, не в результаті їх спрацювання, а внаслідок поломок твердосплавних пластин. У даній роботі досліджувалися причини таких поломок і методи для запобігання таким явищам. Проведений ґрунтовний аналіз сучасного стану та методів досліджень напруженого стану в ріжучих інструментах, зокрема токарних різців. Аналізувалися також методи зменшення напружень у твердосплавних пластинках. Дана робота зосереджена на вивченні напруженого стану у відрізнiх різцях з напайними твердосплавними пластинками. Водночас вивчався напружений стан у твердосплавних пластинках і вплив на нього різних способів закріплення твердосплавної пластинки до державки. Основним методом досліджень напруженого стану був метод фотопружності, який дозволяє досить швидко та наочно отримати й оцінити результати. Були виготовлені з оптично-чутливого матеріалу моделі твердосплавних пластинок, які у складі складної моделі відрізнiго різця з твердосплавною пластинкою з трьома різними способами закріплення, за допомогою спеціально розробленого стенду, навантажувалися силою, що моделювала силу різання. Дослідження проводилися на поляризаційно-проекційній установці ППУ-7. Були отримані картини ізохром та ізоклин. Розрахунок головних напружень виконувався методом різниці дотичних напружень для трьох перерізів пластинки: біля поверхні, посередині і біля основи. Встановлено, що найкращий результат дає спосіб, за якого пластинка на віддаленій від ріжучої кромки стороні має скіс, зроблений під кутом 10°

Ключові слова: напруження, різець, фотопружність, закріплення



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BLOOD LIPID PROFILE AS A DIAGNOSTIC MARKER OF ACUTE PANCREATITIS IN DOGS

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Abstract. Acute pancreatitis is a common non-communicable pathology in dogs, the untimely diagnosis and treatment of which is lethal (27-58% of cases). One of the most common medical tests for acute pancreatitis is to determine the concentration of triglycerides and other fractions of blood lipids. The purpose of the study was to investigate changes in lipid fractions and other biochemical parameters in dogs with acute pancreatitis. For the experiment, two groups of dogs of 10 individuals each were formed. The control group included healthy animals, the experimental group – dogs with acute pancreatitis. It was found that in dogs with acute pancreatitis, the concentration of triglycerides increased by 67% compared with healthy individuals. Cholesterol and phospholipid concentrations also increased by 23 and 9%, respectively. Inflammatory processes in the pancreas led to the development of cytolytic processes in its acini, as well as hepatocytes of the liver, as indicated by increased activity of indicator enzymes ALT, AST, LF and bilirubin. In addition, in sick dogs, the protein-synthesising function of the liver was impaired: a reduced proportion of albumin was registered against the background of increased total serum protein. Acute pancreatitis leads to a decrease in insulin synthesis, which is manifested by hyperglycaemia – in sick dogs, glucose levels are probably twice as high as in healthy animals. In pancreatitis, the violation of digestion and absorption of nutrients caused by intensive use of high-energy compounds (in particular, creatine phosphate) and an increase in creatinine (3.8 times). At the same time, the catabolism of proteins increased and the products of their intermediate and final metabolism – ammonia and urea – accumulated (by 60 and 57%, respectively), which is a sign of reduced filtration capacity of the kidneys. In addition, in acute pancreatitis within the physiological norm, the concentration of calcium decreased, and inorganic phosphorus – increased

Keywords: triglycerides, cholesterol, phospholipids, indicator enzymes, pancreas



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INTRODUCTION

Pancreatitis is a fairly common pathology in dogs. Factors underlying the pathogenesis of pancreatitis are diverse: stress, eating disorders, inflammatory processes of the gastrointestinal tract, liver disease, etc. [1]. This disease can be a secondary complication of infectious and parasitic pathologies, especially those that have a strong development and involve in the general pathogenesis of the systemic inflammatory response of the organism [2]. In particular, pancreatitis is often accompanied by babesiosis, heartworm disease, distemper, and viral enteroinfections in dogs, which are typical pathologies of infectious origin in the Polissya region of Ukraine [3; 4]. There are two forms of pancreatitis: acute and chronic. Acute form is characterised by a high percentage of deaths – 27-58% [5], chronic – significantly worsens the quality of life of animals and creates inconvenience for their owners.

The pathogenesis of pancreatitis is not fully understood. Most theories explain the apoptosis of pancreatic cells by oxidative stress, the action of products of nitrogen metabolism – ammonia and creatinine, impaired blood supply to the gland [6]. There is a hypothesis that links the occurrence of pancreatitis with calcium deficiency in the blood caused by the synthesis of its salts with fatty acids. As a result of negative reverse regulation, the secretion of parathyroid hormone increases, which causes an increase in the content of calcium in the cells of the gland and leads to their further destruction [7]. Due to the cytolysis of glandular cells of the pancreas, the activity of enzymes increases in the blood, but decreases in the intestine. Affected dogs have impaired digestion and absorption of nutrients and develop characteristic symptoms such as loss of appetite, vomiting, flatulence, diarrhoea, or constipation [8].

Pancreatitis also causes destructive changes in other organs, including the liver, kidneys, lungs, which significantly complicates the diagnosis of this pathology. For example, any liver dysfunction also leads to an increase in cytolytic phenomena and the release of enzymes into the blood, disorders of the inclusion of triglycerides and cholesterol in lipoproteins [9]. Acute pancreatitis develops quite rapidly, so in the case of incorrect diagnosis and therapy, irreversible changes may appear in the animal body. However, the diagnosis of pancreatitis, even in the acute form, is associated with certain difficulties, as there are no specific markers of the disease. Thus, the main marker of pancreatitis in humans and some animals is the activity of pancreatic α -amylase, but in dogs its activity in the blood does not reflect the degree of pathological process in the pancreas [10; 11].

At the present stage, one of the most effective criteria for diagnosing pancreatitis in dogs is to determine the activity of Specific Canine Pancreatic Lipase Immunoreactivity (Spec cPL or cPLI) [12; 5]. The

sensitivity of this method is 80-85%. However, the activity of the enzyme may increase in other pathological conditions – duodenitis, the presence of a foreign body in the small intestine, its mechanical damage – all these factors disrupt the integrity of the intestine and provoke the release of pancreatic lipase into the blood. In addition, the definition of Spec cPL requires equipment for immunochemical testing and is not always available to veterinary laboratories. The transfer of pancreatic lipase into the blood causes a decrease in its excretion into the intestinal cavity, resulting in reduced breakdown and absorption of triglycerides.

The concentration of triglycerides and cholesterol is one of the markers of acute pancreatitis [13; 14]. Inflammatory processes in the pancreas are characterised by an increase in the concentration of proteins of the acute phase of inflammation, in particular C-reactive protein [15-17].

The purpose of the study was to investigate the content of lipid fractions and other serum biochemical parameters as a complex of biochemical markers for acute pancreatitis in dogs.

The objective of the study was to determine the concentration of triglycerides, cholesterol, phospholipids, total protein, glucose, bilirubin, activity of indicator enzymes ALT (alanine aminotransferase), AST (asparagine aminotransferase), LF (alkaline phosphatase, blood phosphatase, with those in healthy animals).

MATERIALS AND METHODS

The studies were conducted during 2018-2020 based on the research and production veterinary clinic and the Department of Parasitology, Veterinary and Sanitary Expertise, Zoohygiene of Polissya National University. For experiments, two groups of dogs, 10 heads each, were formed. The groups included 5 females and 5 males, each group had both sterilised and non-sterilised individuals. The age of the animals ranged from 3 to 8 years. The animals were of different breeds and crossbreeds.

The control group included clinically healthy dogs that underwent a preventive examination in the clinic. Experimental group included dogs diagnosed with acute pancreatitis according to history, clinical examination, special and laboratory studies.

The clinical study was performed according to general methods: examination, thermometry, palpation, percussion, auscultation. In the experimental group, the characteristic clinical signs of pancreatitis were: deterioration or loss of appetite, signs of nausea, vomiting, diarrhoea or constipation, sometimes fever. Pain was determined in the abdominal cavity of sick dogs. Such signs are not specific exclusively to pancreatitis, and specific and laboratory methods of animal study were used to further clarify the diagnosis.

Special methods included ultrasound using the SonoScape S11 ultrasound diagnostic scanner with

Doppler system (SonoScape Medical Corp., Russian Federation). Animal testing was carried out in the morning, on an empty stomach, when there is the least amount of unnecessary factors that interfere with the detection of the pancreas. The disappearance of the contours of the abdominal cavity in the upper right and

the presence of a “signal loop” are diagnostic markers of pancreatitis. Determining criteria for the presence of pancreatitis were hypoechoic parenchyma of the pancreas, hyperechogenic peripancreatic adipose tissue, bile duct obstruction (Fig. 1-2) [18].

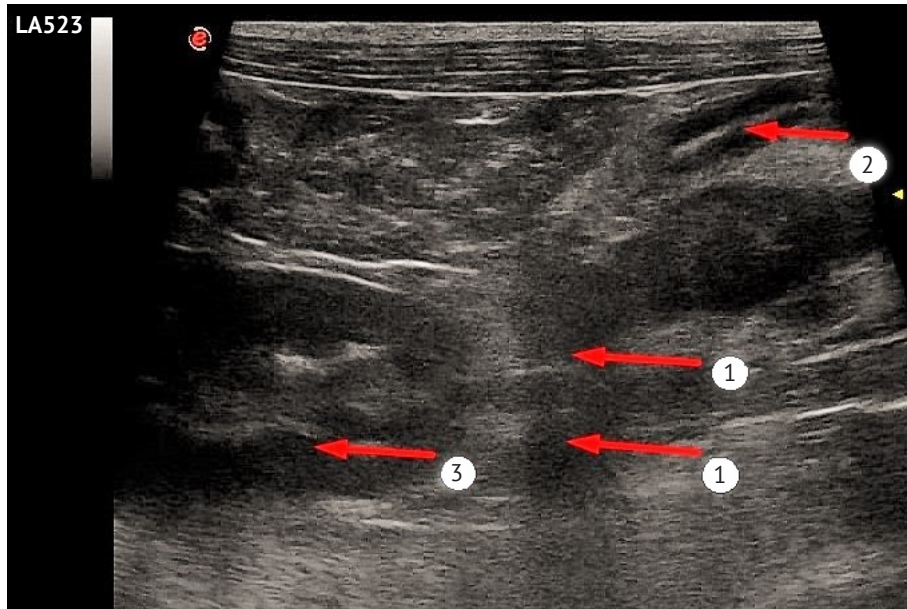


Figure 1. Sonogram of the right dorsal abdomen of the dog with acute pancreatitis: 1 – blurred borders and hypoechoic structure of the pancreas, 2 – splenic vein, 3 – duodenal area filled with gases (“signal loop”)

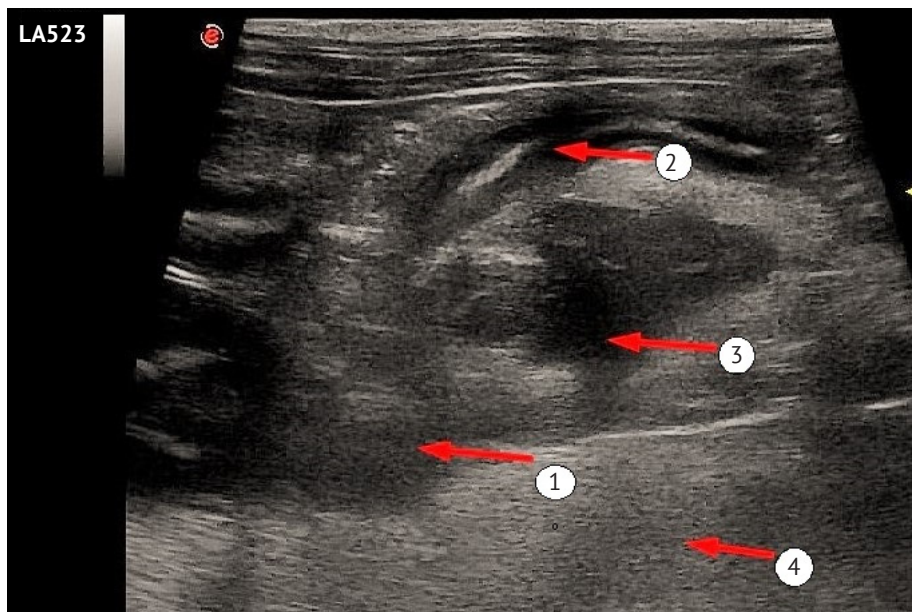


Figure 2. Sonogram of the pancreas of the dog with acute pancreatitis: 1 – erased boundaries of the right lobe of the pancreas, 2 – splenic vein, 3 – aorta, 4 – peripancreatic hyperechogenic adipose tissue

Blood from animals of both experimental groups was collected from the subcutaneous forearm vein (vena subcutanea antebrachii) in accordance with the rules of asepsis and antiseptics. Disposable puncture needles

and Vacusera vacuum tubes with lithium heparin and clean ones were used. For experimental studies, blood serum was used to determine the concentration of total protein, albumin, glucose, total bilirubin, creatinine,

cholesterol, the activity of the enzymes alanine aminotransferase (ALT), aspartate aminotransferase (AST) (Reitman-Frenkel method), alkaline phosphatase (LP) (kinetic method), calcium (by the colorimetric method of a colour compound in the reaction of calcium with o-cresolphthalein in an alkaline medium), inorganic phosphorus (Briggs colorimetric method). The studies were carried out using a semi-automatic biochemical analyser Chem 7 (Erba, Czech Republic) with a line of reagents from DAC (Republic of Moldova).

The concentration of triglycerides was determined by enzymatic colorimetric method (PAP) using a set of reagents "Triglycerides PAP" manufactured by "Diagnosticum" company (Hungary).

The concentration of phospholipids was determined by extraction of the lipid fraction with isoamyl alcohol, followed by mineralisation. Inorganic phosphorus in interaction with ammonium molybdate

forms phosphomolybdic acid, the optical density of which was measured at wavelengths $\lambda = 630$ nm.

The obtained results were statistically processed using the Statistica 13.3 software package. Data were checked for normal distribution using the Distribution Fitting module. The arithmetic mean value, its standard error were determined. Estimation of regression equality was performed according to Fisher's method (ANOVA) for a significance level of 0.05.

RESULTS AND DISCUSSION

Destruction of pancreatic cells in acute pancreatitis is accompanied by the excretion of some enzymes into the blood (instead of the small intestine), while some nutrients remain undigested and partly excreted in the faeces, and partly enter the blood [1]. The severity of acute pancreatitis correlates with the concentration of various lipid fractions, in particular serum triglycerides (Fig. 3).

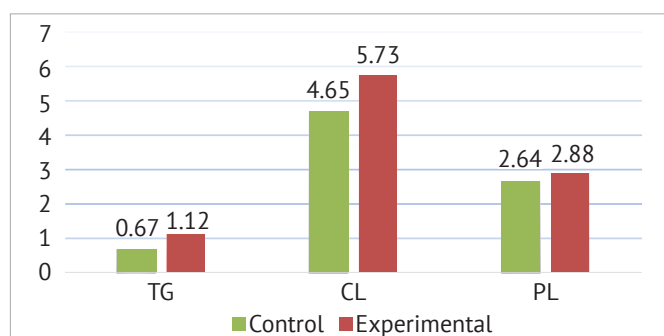


Figure 3. The content of triglycerides (TG), cholesterol (CL), and phospholipids (PL) in the serum of dogs with acute pancreatitis, mmol/l

The concentration of all studied fractions of serum lipids in dogs of the experimental group tended to increase compared to those in the control. The largest difference between the groups was observed in the concentration of triglycerides ($p < 0.05$). Thus, in animals with pancreatitis, the concentration of this fraction was almost twice that of healthy animals. The smallest changes were found in the concentration of phospholipids – 9%. Notably, in different animals, especially in the experimental group, there was a high degree of variance, which indicates the individual mechanisms of regulation of lipid metabolism in dogs with this pathology.

Pancreatitis is a pathology that affects most parts of the metabolism and the functional capacity of many organs. This primarily applies to the liver. To assess the condition of the liver, markers of its functional activity were determined (Table 1). The concentration of total protein in the dogs of the experimental group was higher ($P \geq 0.05$) than in the control group, but was within the reference range. At the same time, the concentration of albumin in sick dogs significantly decreased. Glucose concentration in the control group was within physiological values. In animals of the experimental group, its content was twice the control index ($P \leq 0.05$).

Table 1. Biochemical markers of liver function in healthy dogs and with acute pancreatitis

Indicator	Healthy dogs (n=10)	Dogs with acute pancreatitis (n=10)
Total protein, g/l	62.4±7.27	69.8±6.42
Albumins, g/l	32.6±4.27	22.8±3.91*
Glucose, mmol/l	5.8±1.29	11.7±2.37*
Total bilirubin, μ mol/l	7.2±0.93	29.5±3.15**
ALAT, u/l	31.6±3.41	72.7±6.84*
AST, u/l	29.7±12.60	74.9±19.81*
LF, u/l	71.5±22.74	101.4±25.38

Note: * $P \leq 0.05$, ** $P \leq 0.01$ for healthy dogs

The content of total bilirubin in the serum of experimental animals significantly exceeded physiological values and was 4.1 times higher than in control group. The activity of both transaminases (ALT and AST) in sick dogs significantly increased compared to the control group, exceeding the upper limit of physiological values. LF activity had a similar trend, but its growth in the dogs of the experimental group was not as rapid as

the activity of transaminases and was 41.8% compared with control group.

The excretory system is another system of organs in which the intensity of metabolic processes during pancreatitis has increased. To assess the functional capacity of this system, the content of creatinine, urea, and ammonia was studied (Table 2).

Table 2. Some biochemical markers of the functional state of the kidneys in healthy dogs and with acute pancreatitis

Indicator	Healthy dogs (n=10)	Dogs with acute pancreatitis (n=10)
Creatinine, $\mu\text{mol/l}$	63.5 \pm 10.31	238.5 \pm 38.76**
Urea, mmol/l	6.9 \pm 1.91	22.5 \pm 4.52*
Ammonia, $\mu\text{mol/l}$	27.3 \pm 3.51	42.8 \pm 6.33*

Note: * $P \leq 0.05$, ** $P \leq 0.01$ for healthy dogs

The concentration of creatinine in the serum of dogs in the experimental group was 3.8 times higher than in the control group ($P \leq 0.01$). Furthermore, the content of ammonia (one of the end products of protein metabolism) in the blood of experimental dogs was 1.6 times higher ($P \leq 0.05$) than in control animals. The

content of urea, which is synthesised by the liver from ammonia, was also higher in sick dogs – an increase of 1.57 times ($P \leq 0.05$). Calcium ions and phosphates play an important role in the pathogenesis of acute pancreatitis (Table 3).

Table 3. The content of calcium and inorganic phosphorus in the serum of healthy dogs and with acute pancreatitis

Indicator	Healthy dogs (n=10)	Dogs with acute pancreatitis (n=10)
Calcium, mmol/l	2.74 \pm 0.38	2.18 \pm 0.51
Inorganic phosphorus, mmol/l	1.53 \pm 0.29	2.05 \pm 0.62

Calcium content in sick animals was lower than in healthy ones ($P \geq 0.05$) and was at the lower limit of physiological values. Inorganic phosphorus, on the other hand, was higher in dogs with acute pancreatitis than in healthy ones ($P \geq 0.05$), but did not exceed the reference values.

Serum lipids are considered one of the informative markers in the diagnosis of acute pancreatitis in dogs [19]. Inflammatory processes in the pancreas lead to a decrease in the synthesis and excretion of enzymes that catalyse the hydrolysis of lipids of different fractions: triglycerides, cholesterol ethers and phospholipids. As a result, their inclusion in lipoproteins (the main transport form of lipids in the blood) is disrupted, so their content in the blood increases [2]. It is believed that a deficiency of exogenous lipids causes the release of endogenous lipids from the fat depot [13]. According to some studies, the degree of inflammation correlates with an increase in the content of all fractions of lipids, especially triglycerides [20]. Own results showed that in dogs with acute pancreatitis, the concentration of all studied lipid fractions increased. The maximum degree of growth (1.67 times) was demonstrated by triglycerides (fats), which are the main fraction of dietary lipids.

An analysis of the scientific literature has shown

that there is no single mechanism to explain such changes [11]. According to some authors, the increase in triglycerides is conditioned by a decrease in the synthesis of the enzyme lipase, which hydrolyses fats, and also by cytolysis of secretory cells of the pancreas, resulting in a significant part of lipase entering the blood [21; 13].

The increase in the concentration of other fractions – cholesterol and phosphatides in the blood of sick dogs was slightly lower, respectively – 1.23 and 1.09 times. Such changes may be due to the fact that the enzymes phospholipase, cholesterol are more synthesised by the mucous membrane of the small intestine [14]. Impaired absorption of cholesterol (basic metabolite, source of bile acid synthesis) reduces the intensity of emulsification [14]. Decreased absorption of phospholipids disrupts the development of chylomicrons and lipoproteins. This, in turn destabilises the transport of triglycerides through the blood to the fat depot [21].

Acute pancreatitis has a destructive effect on the cells of the islet tissue, resulting in reduced synthesis of pancreatic hormones [1]. Decreased insulin levels lead to hyperglycaemia. Thus, in dogs with pancreatitis, the concentration of glucose in the blood serum twice exceeded that in healthy animals. Hyperglycaemia has

another side – it reduces the amount of glucose that comes from the blood to tissues, including the liver. At the same time, it should be noted that glucose plays an important role in the detoxification functions of the liver [13]. In addition, pancreatitis increases the build-up of toxic products of incomplete digestion of nutrients. Impaired absorption of nutrients before their entry into the colon leads to the putrefactive processes, resulting in the development of toxic products of amino acid metabolism [8].

In the experiment, the increase in the intensity of protein catabolism led to the accumulation of intermediate and final products of nitrogen metabolism. In dogs with acute pancreatitis, the concentration of creatinine, urea, and ammonia increased. The concentration of creatinine increased the most rapidly – 3.8 times. Such changes are caused by an energy deficit in the muscles and, consequently, an increase in the use of creatine phosphate. The accumulation of creatinine in the blood of sick dogs indicates impaired renal function, in particular a decrease in their filtration capacity [5].

Urea concentration is a marker of the condition of both the kidneys and the liver. Urea is synthesised in the liver, but excreted by the kidneys in the urine. Increased urea in animals with acute pancreatitis, as in the case of creatinine, indicates renal congestion. In addition, an increase in the concentration of ammonia in the blood may be an indicator of the inability of the liver to fully utilise this toxic metabolite [22; 23]. This hypothesis about the stress of metabolic processes in the liver is confirmed by other indicators. Although the concentration of total protein in sick animals increased due to dehydration, the absolute content of albumin decreased, which is a sign of impaired liver protein synthesis. At the same time, an increase in the serum activity of the indicator enzymes ALT, AST and LF, which are markers of the cytolytic syndrome, was detected [15].

A study of the concentration of total bilirubin showed that in dogs with acute pancreatitis it is more than four times higher than in healthy dogs. It is an evidence of destructive phenomena in the liver parenchyma and bilirubin in the blood. Thus, acute pancreatitis causes liver and kidney dysfunction.

Calcium is one of the factors involved in the pathogenesis of acute pancreatitis [24]. Some of the calcium ions in the intestinal cavity form insoluble compounds with fatty acids and the concentration of this element in the blood decreases. In this study, the concentration in the blood of sick animals was 20% lower than in healthy, which coincides with the findings of similar studies [24]. Hypocalcemia reflexively causes

an increase in calcium excretion not only in plasma but also in cell compartments, in particular the pancreatic parenchyma [24]. The accumulation of Calcium in the cytoplasm of cells leads to the release of potassium ions into the intercellular space, disruption of membrane potential, metabolism, and cell death [6]. Decreased serum calcium and increased in cells is one of the factors in the further development of pancreatitis [25].

Along with the decrease in calcium content, there was an increase (within physiological limits) in the concentration of inorganic phosphorus in the blood of dogs with acute pancreatitis (+34% compared to healthy animals). The increase in inorganic blood phosphates is the result of the decomposition of phosphorous compounds, in particular high-energy (creatine phosphate and others), depletion of energy reserves for pancreatitis [25]. Notably, the real increase in the content of inorganic phosphates may be greater, because parathyroid hormone stimulates the excretion of phosphates in the urine and thus the visible content does not reflect the degree of its development.

CONCLUSIONS

1. In dogs with acute pancreatitis the concentration of the following lipid fractions increases in blood: the maximum growth is characteristic of triglycerides (+67%), cholesterol (+23%), and the smallest growth – for phospholipids (+9%). An increase in the concentration of triglycerides in the blood can be used as a diagnostic marker of acute pancreatitis.

2. The combination of metabolic changes caused by the development of acute pancreatitis leads to impaired renal function and accumulation of nitrogen metabolism products: creatinine – 3.8 times, ammonia (+60%), urea (+57%), which indicates a decrease in filtration capacity of the kidneys.

3. In acute pancreatitis in dogs, violations of the functional ability of the liver occur, the concentration of albumin decreases, the activity of indicator enzymes (ALT, AST, LF), bilirubin increases. This is a sign of the development of cytolytic syndrome in liver cells due to the accumulation of metabolic products of nitrogen-containing compounds.

4. The pathogenesis of acute pancreatitis leads to changes in calcium metabolism, resulting in a decrease in its concentration in the blood. The concentration of inorganic phosphorus, on the contrary, increased significantly, which is the result of the decay of high-energy compounds and depletion of energy reserves in dogs with pancreatitis.

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ЛІПІДНИЙ ПРОФІЛЬ КРОВІ ЯК ДІАГНОСТИЧНИЙ МАРКЕР ГОСТРОГО ПАНКРЕАТИТУ СОБАК

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Анотація. Гострий панкреатит належить до поширених незаразних патологій собак, несвоєчасна діагностика та терапія якого закінчується летально (27–58 % випадків). Одним з найпоширеніших діагностичних тестів гострого панкреатиту є визначення концентрації тригліцеридів та інших фракцій ліпідів крові. Метою досліджень було дослідити зміни вмісту фракцій ліпідів та інших біохімічних показників у собак за гострого панкреатиту. Для експерименту було сформовано дві групи собак по 10 особин в кожній. Контрольна група включала здорових тварин, дослідна – собак із гострим панкреатитом. Встановлено, що у собак з гострим панкреатитом концентрація тригліцеридів зростала на 67 % порівняно зі здоровими особинами. Концентрація холестерину і фосфоліпідів також збільшувалась на 23 і 9 % відповідно. Запальні процеси у підшлунковій залозі призводили до розвитку цитолітичних процесів у її ацинусах, а також гепатоцитах печінки, на що вказувала збільшена активність індикаторних ферментів АлАТ, АсАТ, ЛФ та білірубину. Також у хворих собак порушувалась білоксинтезувальна функція печінки: реєстрували зменшену частку альбумінів на фоні підвищеного загального білка сироватки крові. Гострий панкреатит призводить до зменшення синтезу інсуліну, що проявляється гіперглікемією – у хворих собак рівень глюкози вірогідно вдвічі перевищив показник здорових тварин. За панкреатиту порушення перетравлення та всмоктування поживних речовин корму обумовлювало інтенсивне використання організмом макроергів (зокрема, креатинфосфату) і збільшення креатиніну (у 3,8 рази). Водночас зростав катаболізм білків і накопичувались продукти їх проміжного та кінцевого обміну – аміак і сечовина (на 60 та 57 % відповідно), що є ознакою зменшення фільтраційної здатності нирок. Крім того, за гострого панкреатиту в межах фізіологічної норми концентрація Кальцію зменшувалась, а неорганічного фосфору – збільшувалась

Ключові слова: тригліцериди, холестерин, фосфоліпіди, індикаторні ферменти, підшлункова залоза



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ETHOLOGICAL METHODS FOR THE SELECTION OF YOUNG PIGS FOR HERD REPLACEMENT

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Abstract. Ethologists have identified many aspects of animal behaviour, and their research experience can be used in agricultural production for the selection of animals with necessary behavioural qualities. The purpose of the study was to find labour saving and effective methods for the selection of young pigs for herd replacement, including identification of their behavioural characteristics in the context of industrial pork production. The method for the selection of young animals based on the viability index of newborn piglets was compared with other method, which takes into account the independent attachment of piglets to the front three pairs of sow teats. It was found that the probability of independent attachment of a piglet to anterior teats has a positive and high correlation with its viability index, with a correlation coefficient of 0.95. Piglets that occupied the front three pairs of teats during the suckling period significantly ($P \leq 0.001$) exceeded the rest in weight at the 21st and at the 60th days by 22.7% and 5.4%, respectively. When assessing the behavioural reactions of piglets weaned from sows in an artificially created stress conditions, groups of piglets resistant and not resistant to psychological (emotional) stress were selected for subsequent observation. Moreover, it was found that among the sows obtained from stress-resistant piglets, the superiority in fertility during the first insemination and the total proportion of farrowing was 11.1 p.p., in terms of multiple fertility – 2.6 piglets ($P \leq 0.05$) or 33.3%, and in terms of the share of those transferred to the main herd – 27.8 p.p. in comparison with the group of unstable ones. Based on the obtained results, the use of an ethological method for selecting piglets for herd replacement was substantiated, taking into account the independent attachment to anterior teats and an express method for selecting piglets based on their resistance to psychological stress

Keywords: ethology, selection, herd replacements, piglets, viability, stress resistance



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INTRODUCTION

Modern ethologists have identified many aspects of behaviour in animals of various species, from insects to predators [1]. Laboratory rats, pigeons, red junglefowls, horses, and close human relatives – primates – were used as the main model species in the study of animal behaviour. [2; 3]. The scientific advances allow for a better understanding of general cognitive processes. This leads to the creation of more effective strategies for both wildlife management and directional selection among domestic species. Such an approach allows selecting individuals that meet specific human requirements based on their behaviour [1].

The experience accumulated by ethologists can also be used in the conditions of agricultural production. An increase in the amount of livestock production can be achieved with the proper understanding of the behavioural activity of bred animals, which allows selecting animals that meet specific requirements [4].

In the pig breeding of the Republic of Belarus, despite the difficult current situation resulting from the epizootic of African swine fever, there are objective prerequisites for increasing the pork production based on the use of improved highly productive genotypes [5]. One of the criteria for increasing the pork production at industrial complexes is to increase the efficiency of the use of broodstock. This will allow, by increasing the multiplicity and safety of young animals, to increase the level of production without exceedance of the number of sows in farms [6].

At a number of pig breeding complexes in the Republic of Belarus, as a result of the recent slippage due to the threat of ASF, a specific self-replacement system is used. When organising the broodstock reproduction, the necessary piglets are not purchased from breeding plants, but are selected from the number of pigs born in own herds, with subsequent rearing and introduction into the main herd. In such a situation, breeders of industrial complexes need methods that allow them to forecast the future viability and productivity of piglets selected for the replenishment of a herd.

Earlier, to assess the strength and vitality of the offspring born in sows, Russian scientists proposed the use of the viability index of newborn piglets (VINP). It is determined by the ratio of the live weight of each scored piglet at birth in grammes to the time it adopts a standing posture in seconds immediately after birth. Determination of VINP allows assessing the viability of piglets already in the first minutes of life. Also it allows identifying, by subsequent ranking, physiologically immature individuals, i.e., unsuitable for the replenishment of a herd [7]. However, due to its increased labour intensity, this technique is of little use for widespread practice, especially in large farms with a significant number of daily farrowings. And in the Republic of Belarus, industrial production of pork is carried out mainly at such farms.

It is known that each piglet, in order to systematically obtain food, conquers one of the nipples of the sow's teats in the struggle with its peers. The selected teat is constantly used by this piglet during the entire suckling period. As a rule, the largest and most viable piglets occupy the three front pairs of the milkiest teats, subsequently consuming more milk than their peers from the rear teats [8; 9]. Attempts to introduce weaker piglets to the anterior lobes of the mammary gland to prepare them for weaning in terms of live weight do not give the desired effect. The weak pigs are still pushed away from the teat by the strong ones [8]. Therefore, the fact that a piglet occupies a sow teat, which belongs to the three front pairs, can be used as a criterion for its selection for replenishment of a herd.

At the same time, a number of studies suggest that the viability and future productivity of young farm animals is influenced not only by the initial physical development and the rate of subsequent gain in live weight [10; 11]. After all, every animal has a certain type of higher nervous activity from birth, which determines the psychological (emotional) resistance of a given individual to the impact of stress factors, both technological and social, that arise throughout life [10; 12]. While mild stress is beneficial for survival, severe stress exposure dramatically increases the risk of physical and mental health problems [13]. The most important link in intraspecific communication is the mutual orientation of individuals to signals that are directly related to the main processes of life [14].

In the social life of pigs kept at pig breeding enterprises in groups, the rank position occupied by each specific individual in such a group, conditions for its further existence and, as a result, its productivity and longevity are a consequence of the manifestation of primary behavioural actions associated with life and manifested when interacting with a changing external environment. In turn, the direction and severity of such actions is based on the psychological (emotional) resistance of the individual to the effects of stress factors [12].

The activation of the stress response after exposure to psychological (emotional) stressors causes a whole cascade of physiological reactions in the animal, which may even be detrimental if repeated or chronic [15]. The increased fear experienced at the same time positively correlates with the depression of the general condition of the individual and a decrease in the manifestation of exploratory behaviour [2; 16].

A hypothesis was put forward linking the depletion of self-control resources and an increase in anxiety in stressed individuals with a decrease in blood glucose levels. However, it was not confirmed [17]. It has definitely been established that in anxious, emotionally stressed individuals, the exploratory reaction slows down in the presence of even a mild threat. Such a response is not observed in non-anxious individuals,

which can effectively act by disconnecting from the stress factor [18].

To reflect the natural connections between the identified elements of behaviour and the consequences of their manifestation, a classification of these elements must first be established [11]. In pigs, such significant and opposite behavioural elements are the passive defensive reaction. It is expressed in the individual's desire to run away and squeeze into the corner of the pen, turning back to the source of stress. The reaction might also include exploratory behaviour, expressed in the individual's desire to reduce the distance from the source of influence, to sniff it or touch it. Manifestation of one of the above behavioural reactions testifies to the strength or weakness of the nervous processes directly related to the communication of an individual in the group, resistance to the effects of technological stress factors, and hence to the health and productivity of the animal. This suggests the feasibility of the identification of psychological (emotional) resistance or non-resistance of piglets to stress, as a criterion for their subsequent selection for herd replacement.

The purpose of the study was to find labour saving and rather effective methods for the selection of young pigs for herd replacement, including identification of their behavioural characteristics in the context of industrial technology of pork production.

In accordance with the objective, the following tasks were set:

1. Scientifically substantiate the ethological method for the selection of piglets for herd replacement, taking into account their individual attachment to the three anterior pairs of sow's teats.

2. Scientifically substantiate the ethological method for the selection of piglets for herd replacement, taking into account their resistance to psychological (emotional) stress.

MATERIALS AND METHODS

The experimental part of the study was conducted in 2011-2013 before the onset of the African swine fever epizootic in the Republic of Belarus. The final processing with the analysis of the data obtained during the experiments was carried out in 2020. Three scientific and practical experiments were carried out in the following conditions: the pig farm in Sitze Communal Unitary Industrial Enterprise; the pig-breeding complex of JSC Dokshitskiy Rayagroservice of the Dokshitsy district of the Vitebsk region; the pig-breeding complex of JSC Agrokombinat Voskhod in the Mogilev district.

In the Sitze pig farm, the object of research were 163 pre-nursery pigs from 19 sows. The pigs were ranked based on the VINP index. When observing the process of their independent attachment to the teats, a relationship between the value of this indicator and the result of such attachment was revealed. The assessment of the viability of piglets was carried out according to the value

of VINP, which is determined after the birth of each piglet. Taking into account the value of this indicator, the piglets were conditionally divided into three groups: piglets with increased viability, where the VINP was 4.0 and higher (n=14); piglets with an average viability with the VINP from 3.0 to 3.9 (n=74); piglets with low viability with a VINP of 2.9 and below (n=75). To analyse the productivity of piglets, the dynamics of their live weight during the suckling period was estimated.

In the second experiment in the pig-breeding complex of JSC Dokshitskiy Rayagroservice, the influence of both the live weight in piglets at birth and their psychological resistance to stress on the growth rate of animals during the suckling period was assessed. The results obtained were analysed in three groups, into which the piglets were conditionally divided in accordance with their live weight at birth: small – weighing up to 1 kg (n=42); medium – weighing over 1 kg and up to 1.3 kg (n=82); large – weighing over 1.3 kg (n=68). In piglets, the dynamics of live weight was taken into account during the suckling period, and then, immediately after its completion. Resistance to psychological (emotional) stress was assessed using the ethological methodology developed at the Department of specialised animal farming of the Vitebsk State Academy of Veterinary Medicine. The technique consisted in assessing the behavioural response of each pig in an artificially created stress situation, taking into account the manifestation of either a passive-defensive reaction or exploratory behaviour by the individual. The source of stress was a red-coloured stick, one end of which was placed in a pen with a piglet nest some time after weaning them from a sow.

The third experiment was conducted in the pig-breeding complex of JSC Agrokombinat Voskhod. The pigs that were attached to the three front pairs of teats during the suckling period were identified for the replacement of a herd. At the end of the suckling period, testing for psychological (emotional) stress resistance was also carried out, according to the method described above. As a result, among the gilts selected for replacement, two groups were identified: resistant (n=36) and not resistant (n=32) to psychological stress. The health and productivity of animals of both groups was monitored during the period from weaning to transfer to the main broodstock. The study investigated the reasons for the withdrawal of animals in each group during the rearing period, as well as for the period from insemination to transfer to the main herd. At the first farrowing, the number of piglets born to sows was also taken into account.

The data obtained during all three experiments were biometrically processed using the MS Excel software.

RESULTS AND DISCUSSION

The results of studying the dynamics of live weight during the suckling period in individuals with different levels of viability are presented in the table 1.

Table 1. Growth dynamics of suckling piglets with different viability

Piglet viability	n	VINP	Average live weight at birth, kg	Average live weight at the 21 st day, kg	Average live weight at the 60 th day, kg
Increased	14	4.4±0.10	1.14±0.02***	5.2±0.17*	15.7±0.36*
Average	74	3.3±0.03	1.03±0.01*	4.6±0.07*	15.3±0.10*
Low	75	2.7±0.02	0.99±0.01	4.0±0.05	14.6±0.09

Note: Significant difference between the average indicators of animals with increased and average viability in comparison with the indicators of individuals with a low viability index – * $P \leq 0.05$; *** $P \leq 0.001$

When analysing the data in Table 1, it was found that piglets with an increased VINP value actually turned out to be physiologically more mature. Their average live weight at birth was 15.1% and 4.0% higher than those of their peers with average and low viability index. In the future, they were able to grow more intensively, which can also be seen in the table. The live weight of piglets with low viability and at the 21st day and at weaning was significantly ($P \leq 0.05$) lower than in individuals with a high and medium viability, respectively, by 28.8%-13.7% and 7.8%-4.6%.

In the course of observing the process of feeding piglets by sows, it was revealed that all individuals with increased viability were attached to the anterior teats of their mothers. Among piglets with medium and low levels of viability, 83.8% and 52.0%, respectively, were attached to the anterior teats. Analysis of the dynamics of the live weight of piglets during the suckling period also showed that the individuals that occupied the anterior teats had an average live weight of 4.7 kg at the 21st day, and 15.3 kg at the 60th day. They significantly ($P \leq 0.001$) outnumbered peers attached to the rear nipples in

weight at the 21st day – by 0.9 kg or 22.7%, and at the 60th day – by 0.8 kg or 5.4%.

During the analysis of the correlation between the viability index of newborn piglets and their live weight at weaning at the 60th day, it was found that, in general, for all the studied pigs, the coefficient of such correlation was 0.60. At the same time, for piglets sucking only the front 3 pairs of teats it was already 0.95, and for the ones sucking rear teats – 0.98. Consequently, it was found that the ability of a piglet to occupy the front, milkier teats, and to lead in live weight by the end of the suckling period is in a high positive relationship with its VINP.

It is much less labour-intensive to identify the attachment of piglets to certain teats (with subsequent tagging and selection) than to estimate the VINP indicator for each piglet being born, especially during mass farrowing in pig farms.

The findings obtained in the second experiment, when studying the dynamics of live weight during the suckling period in individuals with different viability and different response to psychological stress are presented in the Table 2.

Table 2. Growth dynamics of suckling piglets depending on their live weight and psychological stress resistance

Piglets by live weight at birth	Stress resistance	n	Average live weight of a piglet, kg			Absolute gain, kg	Average daily gain, g
			at birth	at the 21 st day	at the 30 th day		
Large	Resistant	32	1.46±0.01	5.7±0.05	7.5±0.07	6.1±0.07	202±1.6
	Not resistant	36	1.48±0.01	5.5±0.08	7.6±0.11	6.1±0.11	204±2.4
Average	Resistant	36	1.21±0.02	5.2±0.10	7.4±0.09	6.2±0.09	206±1.9
	Not resistant	46	1.20 ±0.02	4.9±0.08*	7.1±0.08*	5.9 ±0.09*	196±2.0*
Small	Resistant	18	1.00±0.01	5.2±0.25	7.1±0.26	6.1±0.26	204±5.7
	Not resistant	24	0.97±0.01	4.7±0.12*	6.7±0.08*	5.7±0.08*	190±1.7*

Note: Significant difference between the indicators of resistant and not resistant individuals within groups by weight at birth – * $P \leq 0.05$

When analysing the Table 2, it was found that during the suckling period, the growth rate of piglets with medium and low weight groups largely depends on their resistance to psychological stress. Thus, with practically the same live weight at birth in these groups, a significant ($P \leq 0.05$) decrease in the growth rate of not resistant piglets was established in comparison with

individuals that are resistant to stress. The difference in absolute growth was 4.8%-6.6%, and according to the average daily gain – 4.9%-6.9%. The absence of a negative effect of stress instability on subsequent growth rate in initially large piglets can be explained by the following: they immediately occupied better teats, dominating over smaller peers due to their live weight and

size, which ensured an increase in growth in the future.

In the course of the third experiment, based on the subsequent culling of piglets in each of the groups, it was found that the culling of stress-resistant animals was 25% during the rearing period. Furthermore, no culls was noted among stress-resistant animals during this period. 12.5% of non-stress-resistant piglets and

half as many of resistant piglets were discarded due to insemination failure and diseases during the gestation period. The reproductive qualities of the sows of first-litters with different resistance to psychological stress, which, over time, became the pigs selected for replacement, are presented in the Table 3.

Table 3. Reproductive qualities of the tested sows

Stress resistance	Selected pigs, animals	Inseminated, animals	Impregnated by first insemination, %	Farrowed sows, %		Piglets per farrowing, animals		Transferred to the main herd, animals
				by first insemination	total	total	alive	
Not resistant	32	24	66.7	87.5	83.3	9.8±0.53	7.8±0.94	16
Resistant	36	36	77.8	100.0	94.4	11.2±0.32	10.4±0.29*	28
Total	68	60	73.3	95.5	90.0	10.5±0.42	9.1±0.62	44

Note: Significant difference in relation to the mean value – * $P \leq 0.05$

When analysing Table 3, the superiority of animals resistant to psychological (emotional) stress was established over those not resistant: in terms of impregnation during the first insemination – by 11.1 p.p.; in the specific weight of animals farrowing from the first insemination – by 12.5 p.p.; and in terms of the total proportion of farrowed animals – by 11.1 p.p. When assessing the indicators of the prolificacy of first-litters, as the basis of their productivity (Table 3), it was found that this indicator in the group of stress-resistant sows was significantly higher by 2.6 piglets or 33.3% in comparison with the stress-resistant group. In terms of the number of stillborn piglets, stress-unstable sows exceeded stress-resistant ones by 2.5 times.

In general (Table 3), in the group of stress-resistant animals, compared to the group of non-resistant, the proportion of sows eventually transferred to the main herd was 27.8 p.p. higher.

In addition, a comparison of the average indicators of reproductive qualities for all stress-resistant sows indicated a pronounced tendency to their increase (Table 3). Thus, the first insemination rate and the proportion of farrowed sows among stress-resistant animals were 4.5 p.p. higher than the average values of the same indicators for all selected animals. Multiple pregnancies in stress-resistant sows were, respectively, higher by 1.3 piglets or by 14.3%; the number of weak piglets was lower by 16.7%; the yield of viable piglets was higher by 19%; the number of stillborn piglets was lower by 42.9%. The proportion of stress-resistant sows transferred to the main herd was higher than the total for all sows by 13.1 p.p.

Thus, attention to the resistance to psychological (emotional) stress when selecting young animals for herd replacement in the context of industrial pork production will reduce the cost of raising and maintaining

broodstock. This is done by reducing the weight of animals leaving, both during the rearing period and during the examination based on the results of the first farrowing. The proposed method will facilitate the rearing of viable piglets for sow farrowing at enterprises.

CONCLUSIONS

Analysis of the research findings allows for the following conclusions:

1. It has been established that all piglets with an increased viability index of newborn piglets (VINP) during the suckling period were independently attached to the anterior teats of their mothers. In the animals with medium and low viability, only 83.8% and 52.0% of animals were attached to the three front teats, respectively.

2. The probability of a piglet to attach to the front teats and to lead in live weight by the end of the suckling period is in a positive and significant relationship with its VINP with a correlation coefficient of 0.95. Piglets from the front three pairs of teats significantly ($P \leq 0.001$) exceeded the rest in weight at the 21st day and at the 60th day by 22.7% and 5.4%, respectively. Based on the findings, the ethological method for the selection of the most viable piglets for herd replacement was scientifically substantiated, taking into account their attachment to the anterior teats during the suckling period.

3. The average live weight of piglets at birth in medium and low weight groups is practically the same. However, a significant decrease in the average daily gain in live weight in stress-unstable animals in comparison with stress resistant individuals by 4.9%-6.9% ($P \leq 0.05$) is noted.

4. It was found that among animals resistant to psychological (emotional) stress: the superiority in fertility during the first insemination and in the total weight of farrowing animals was 11.1 p.p. In terms of

multiple births – 2.6 piglets ($P \leq 0.05$) or 33.3%, in comparison with stress-resistant animals. Multiple pregnancies in the group of stress-resistant sows were significantly ($P \leq 0.05$) higher by 2.6 piglets or by 33.3%. In terms of the number of stillborn piglets, stress-unstable sows exceeded the stress-resistant ones by 2.5 times. The proportion of stress-resistant sows transferred to the main herd was 27.8 p.p. higher than in the stress-unstable group.

Based on the analysis of the obtained results, an

ethological express method for selecting piglets for herd replacement was scientifically substantiated, taking into account their resistance to psychological (emotional) stress. The proposed method consists in assessing the behavioral reactions of animals in an artificially created stressful situation. The individuals manifesting exploratory behaviour are selected for herd replacement, and animals manifesting only a passive-defensive reaction are excluded from the selection process.

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ЕТОЛОГІЧНІ ПРИЙОМИ ВІДБОРУ МОЛОДНЯКУ СВИНЕЙ ДЛЯ РЕМОНТУ СТАДА

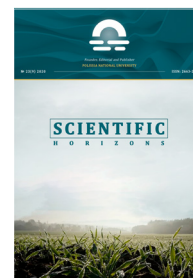
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Анотація. Етологами виявлено безліч аспектів поведінки тварин, і накопичений ними дослідний досвід може бути використаний у сільськогосподарському виробництві під час відбору особин з потрібними людині поведінковими якостями. Мета досліджень полягала в пошуку малотрудомістких та ефективних прийомів відбору молодняку свиней для ремонту стада з урахуванням виявлення їх поведінкових особливостей в умовах промислової технології виробництва свинини. Під час порівняння способу відбору молодняку за величиною індексу життєздатності новонароджених поросят з прийомом відбору, який враховує самозакріплення поросят

за трьома передніми парами сосків свиноматки, встановлено, що ймовірність самозакріплення поросяти за передніми трьома парами сосків свиноматки знаходиться в позитивній і високій кореляції з величиною його індексу життєздатності за коефіцієнта кореляції 0,95. Поросята, що займали передні три пари сосків протягом підсисного періоду достовірно ($P \leq 0,001$) перевершували інших по масі в 21 день і в 60 днів на 22,7 % і 5,4 % відповідно. За проведення оцінки поведінкових реакцій поросят, відібраних від свиноматок, у штучно створеній стресовій ситуації виділені для подальшого спостереження групи ремонтних свинок стійких і не стійких до психологічного (емоційного) стресу. Встановлено також, що серед свиноматок, отриманих із свинок стійких до стресу, перевага по заплідненості за першого запліднення і загальній питомій вазі опоросних становило 11,1 п.п., з багатопліддя – 2,6 гол. ($P \leq 0,05$) або 33,3 %, а за питомою вагою переведених в основне стадо – 27,8 п.п. у порівнянні з групою не стійкі. На підставі отриманих результатів обґрунтовано використання етологічного прийому відбору поросят для ремонту з урахуванням факту їх самозакріплення за передніми трьома парами сосків свиноматки й експрес-методу відбору поросят з урахуванням їх стійкості до психологічного стресу

Ключові слова: етологія, відбір, ремонтний молодняк, поросята, життєздатність, стійкість до стресів



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CLINICAL MANIFESTATION AND METHODS OF TREATMENT OF PODODERMATITIS IN DOGS

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Abstract. This paper provides data on the clinical signs of pododermatitis in dogs and also investigates effective treatment regimens. The urgency of the stated problem is due to the growing incidence of pododermatitis in dogs, its polyetiological nature, which requires a multifaceted approach to diagnostics and the introduction of effective treatments methods. Thereby, the purpose of the study was to investigate the clinical manifestations of skin diseases of the distal extremities in dogs and to determine the efficacy of complex therapy of pododermatitis. The studies were based on clinical research methods in dermatology, parasitological (skin scraping), bacteriological, and mycological (seeding on nutrient media with subsequent isolation of the pathogen) surveys. Based on the findings of the study, the absolute number of cases revealed lesions of 2 paws (53.3%), much less often – all 4 limbs (26.7%). It was found that mainly localisation of superficial skin lesions was found in 56.2% in the area of the interdigital space and 43.7% of cases – only on the plantar surface of the pastern (metatarsus), rarely – inflammation of the claw phalanx (31.2%). The main clinical signs of dermatitis of the distal extremities in dogs were erosive and ulcerative inflammation, alopecia, papules and pustules filled with purulent exudate, erythematous inflammation, haemorrhage, areas of lichenification. Studies on the treatment of dogs with pododermatitis caused by *Staphylococcus intermedius*, *Demodex canis* and *Malassezia pachydermatis* have shown the following: introduction of drugs Bravecto, Cefuroxime, Orungal, Apoquel and Derinat increased the efficacy of therapy in animals of the experimental group, as compared with the control (from 28.6% to 66.7%), reducing the duration of treatment to 21 days ($p < 0.01$) and extending the remission period to an average of 185 days ($p < 0.01$). The prospect of further research is the unification of clinical, morphological, and biochemical blood parameters as diagnostic criteria for pododermatitis in dogs

Keywords: pododermatitis, furunculosis, dogs, clinical signs, therapeutic efficacy



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INTRODUCTION

Diseases of the distal extremities in animals is a pressing issue in modern veterinary medicine. In Ukraine, productive farm animals were a traditional object for a detailed study of this group of pathologies [1; 2]. At the same time, there are currently research works in the world aimed at studying the inflammatory pathology of the distal extremities in dogs: R.M. Breathnach, K.P. Baker, P.J. Quinn, T.A. McGeady, C.M. Ahern, & B.R. Jones [3]; A.V. Bokarev [4]. However, insignificant attention has been paid to the study of the skin in this area. Notably, there are almost no special methods for studying diseases of the distal extremities in dogs. Most often, veterinarians use general diagnostic methods for this group of sick animals, with the appointment of classical measures for the treatment of dermatitis.

One of the important aspects of studying the problem of pododermatitis in dogs is the lack of research data on the pathogenesis of the disease. This leads to the lack of effective therapeutic and prophylactic regimes for this pathology. Often practicing veterinarians do not attribute pododermatitis to independent diseases, but consider them a link in dermatological diseases. This position leads to a number of dangerous medical errors: the use of monotherapy does not deliver a positive result; the sensitisation of dog's body with allergens complicates the disease progression; the treatment protocols do not provide a lasting clinical effect; sick animals are prescribed several courses of treatment without a positive result.

In contrast, in foreign countries, a comprehensive study of inflammatory pathology of the skin of the distal extremities in dogs is actively taking place. E. Bonsin'o, (2008) for many years conducted study on the clinical manifestations, pathogenesis, and treatment of dermatitis of the lower extremities in dogs. The scientist has found that drug treatment did not always ensure the recovery of sick animals and was the basis for further surgery [5]. Studies conducted by Peterson, Su (2000) have led to scientific interest in this pathology and highlighted the etiological factors of pododermatitis in dogs [6]. V.V. Velkov proposed original methods for the diagnosis and treatment of chronic pododermatitis in small animals. The proposed rehabilitation measures were based on an integrated approach using antibacterial, sensitising, and nonsteroidal drugs on the background of diet therapy and limb correction [7].

Foreign scientists are also conducting experiments to determine the most effective treatment regimens for dogs with pododermatitis, taking into account the etiological factor and the disease phase [8-9]. Pododermatitis is caused mostly by saprophytic microflora (bacterial and fungal) of the skin, which leads to increased pathological processes under conditions of reduced immune status. Since a significant number of skin diseases are accompanied by immunodeficiency, an important and mandatory component in the treatment

protocol are the means of general stimulant therapy. According to recent reports, administration of immunomodulators (Imudol, Katobevit, etc.) is recommended [10].

Given the urgency of this problem in veterinary medicine, the following should be noted:

1) practitioners pay insufficient attention to dermatitis of the lower extremities. However, in terms of pharmacological intervention, pododermatitis is much more difficult to treat than dermatitis of other localisation;

2) pododermatitis (even in simple form), induced by mechanical trauma, have a high tendency to transition to a chronic form;

3) most dermatitis of the distal extremities, which are registered at the primary reception, due to the long progression, lose contact with the initial factor and run as a polyetiological disease, not responding to monoethiotropic therapy [11-17].

The *purpose of the study* was to investigate the clinical manifestations of skin diseases of the distal extremities in dogs and to determine the effectiveness of complex therapy of pododermatitis in dogs.

MATERIALS AND METHODS

The study was conducted in the veterinary hospital in Feldman Ecopark (Kharkiv region, Dergachiv district) and the Department of Surgery Kalashnik of the Kharkiv State Zooveterinary Academy. Among all animals with a diagnosis of dermatitis admitted to the veterinary hospital in Feldman Ecopark during 2019-2020, 289 dogs were examined, including 116 with skin diseases of various localisations. In the structure of dermatological diseases included 16 dogs with dermatitis of the distal extremities.

The subjects for the study were dogs aged 5 to 17 years, outbred, of different sexes, with pathologies of the skin – interdigital abscess (duration of clinical symptoms ranged from 3 days to 8 months). Diagnostic studies were based on anamnestic data (age, condition, limb posture, comorbidities – elbow dysplasia, etc., response to treatment and propensity to relapse), clinical examination, and laboratory findings. Clinical examinations of animals were performed according to the generally accepted method (visual examination, palpation, diascopy), paying attention to the condition of the skin in the distal extremities [18]. Particular attention was paid to the presence of itching, its intensity, time of onset, nature of the exudate, local temperature, pain, localisation of skin rashes, alopecia, erythema, hyperpigmentation and lichenification in different parts of the body [19].

Diagnostic studies to detect canine scabies *Sarcoptes canis* and *Demodex canis* were performed by deep scraping of the skin from 5 affected areas until the appearance of blood. During the analysis of scrapings, the characteristic morphological features of mites of different species and their total number in the studied

material were taken into account [20]. To differentiate from dermatitis of fungal etiology, microscopy of hair and scales from the affected areas of the skin was carried out [21]. Bacteriological and mycological studies were conducted at the Institute of Dermatology and Venereology of the Academy of Medical Sciences of Ukraine (Kharkiv).

To study the effectiveness of various treatment regimens for pododermatitis in dogs caused by *Staphylococcus intermedius*, *Demodex canis* and *Malassezia pachydermatis*, two groups of animals were formed: experimental (n=9) and control (n=7). The disease was in an associative form. For the treatment of dogs of the control group the following drugs were used: Ivermek (manufacturer LLC Nita-Pharm, Russia, the active substance (AS) – ivermectin), at a dose of 0.3 mg/kg body weight (0.2 ml per 10 kg body weight) with an interval of 6 days (5 injections); Amitraz solution 2.5% (the drug was applied topically for 1 month, once every 3 days, multiplicity 5 times); Levomicol ointment (manufacturer Chervona Zirka, Kharkiv, AS – chloramphenicol – 7.5 mg, methyluracil – 40 mg) 2 times a day for 10 days; Nystatin (manufacturer Zdorovya pharmaceutical company, Kharkiv, AS – nystatin at a dose of 500,000 IU orally, once daily for 10 days); Allegra 180 mg (manufacturer Sanofi, France, AS – fexofenadine hydrochloride – 180 mg) was administered orally with food 1 pill once daily for 10 days; Sinulox (manufacturer Pfizer, USA, AS – amoxicillin trihydrate – 40 mg, clavulanic acid – 10 mg) was administered orally at a dose of 12.5 mg/kg body weight 2 times/day for 15 days. For the treatment of dogs in the experimental group the following drugs were used: Bravecto (manufacturer MSD Animal Health, Austria, AS – fluralaner, at a dose of 500 mg/kg body weight, given as a single dose); Novertin ointment (JSC Ukrzoovetprompostach, Ukraine, AS – aversectin C – 0.05 g) at the rate of 0.2 g/cm² once daily with an interval of 7 days, multiplicity – 3 times; Orungal (manufacturer Via S. Janssen, Italy, AS – itraconazole – 100 mg) at a dose of 10 mg/kg body weight, once daily for 10 days; Cefuroxime (manufacturer Sandoz, USA, AS – cefuroxime axetil – 500 mg) at a dose of 500 mg/kg body weight, 1 pill once daily for 7 days; Derinat (manufacturer Technomedservice, Russia, AS – sodium deoxyribonucleate) at a dose of 7.5 mg (0.5 ml) 1 injection with an interval of 72 hours, 5 injections in total. To facilitate the penetration of the drug through the skin of animals, keratolytic pet shampoo Keratolux was used (manufacturer Virbac, France, AS – salicylic acid, zinc gluconate, vitamin B6, piroctone olamine, fatty acids). To eliminate itching, Apoquel (manufactured by Zoetis, USA, AS – oclacitinib – 5.4 mg) was used orally at a dose of 0.4-0.6 mg per 1 kg of body weight of the animal 2 times a day for 21 days.

Evaluation of the effectiveness of therapeutic measures for pododermatitis in dogs was performed

according to clinical criteria. In particular, the dynamics of changes in the symptoms of the disease was determined; duration of treatment; the number of cured animals; the proportion of recurrences and their complications; remission period. Skin scrapings were examined every 3-4 weeks to determine tick and fungal agents. The duration of observations was two months, until 2 negative skin scrapings, negative bacteriological and mycological cultures were obtained.

RESULTS AND DISCUSSION

Analysing the results of studies, it was found that skin diseases of various etiologies are widespread. After examination of 289 dogs, dermatological pathologies were registered in 116 individuals, which is 40.13%. Pododermatitis in dogs from the total number of cases of skin diseases was diagnosed in 16 animals, which corresponds to 13.79%. Analysis of the etiological factors of the development of pododermatitis indicates the associative nature of dermatitis of the distal extremities in the examined sick dogs. Thus, the pathogen *Demodex canis* was found in (87.5%) patients, in 75% of animals – *Staphylococcus epidermidis* was isolated, and in 68.75% of dogs *Malassezia pachydermatis* was diagnosed.

Versatile macromorphological manifestations of pathological processes were revealed during external examination of distal extremities. Thus, 7 out of 16 dogs, which accounted for 43.7%, were diagnosed with general dermatitis along with pododermatitis. In most cases (9 dogs out of 16 – 56.2%) a local process was recorded, which was limited to the distal extremities and did not extend to the skin on other parts of the body.

As a result of the conducted examinations it was established that 2 paws (53.3%) were most often affected in dogs. There were frequent cases of pathology of all 4 extremities (26.7%), more sporadic cases of inflammation of one and three paws (12.5% and 6.2% – respectively). After external examination of the distal extremities in 16 dogs with pododermatitis, it was found that visual inflammation of superficial tissues was localised in:

1) in the form of inflammation, during which more tissues of the pastern (metatarsus) and fingers were affected – in 12 dogs (75%).

2) only in the interdigital space – in 9 dogs (56.2%);

3) only on the plantar surface of the pastern / metatarsus – in 7 dogs (43.7%);

4) only in the form of local inflammation of the claw phalanx, local inflammation of the claw folds and soft tissues, limited only to the phalanges of the fingers – in 5 dogs (31.2%);

5) only on the dorsal side of the pastern / metatarsus – in 2 dogs (12.5%).

Macromorphological visualisation of dermatitis of the distal extremities of dogs of different localisation is presented in Figures 1-3.



Figure 1. Inflammation of the dorsal side of the pastern



Figure 2. Inflammation of the plantar side of the pastern



Figure 3. Metatarsal panniculitis in dogs

Another important criterion for establishing a clinical diagnosis was the visualisation of the variability of tissue damage at the site of inflammation. Thus, the external signs of pododermatitis in dogs were: alopecia,

patches, erythema, haemorrhage, papules, vesicles, pustules, erosion, ulcers, necrosis, scars, lichenification and mixed type of damage. The findings are presented in the Table 1.

Table 1. Clinical signs of dermatitis of the distal extremities in dogs, %

Indicator	Erythema and haemorrhage	Alopecia and patches	Pustule / bulla	Papule / vesicle	Erosion and ulcers	Lichenification and scars	Mixed type	n (number of dogs)
Total	1	3	1	1	4	1	5	16
Total, %	6.25	18.75	6.25	6.25	25	6.25	31.25	100

In the vast majority of examined dogs (31.25%), a mixed type of damage was recorded in the area of inflammation of the distal extremities – simultaneous damage to superficial and deep tissues of varying intensity. Erosive ulcerative dermatitis ranked second in the

frequency of visual diagnosis (25%). Skin lesions of the distal extremities in the form of monomorphological variants in dogs were less common. In 18.75% of cases, the general signs of pododermatitis were characterised by alopecia and patches, in which epidermal disorders

were not observed. In other animals (6.25%) pododermatitis manifested as pustular, bullous, and papular rash with a haemorrhagic and purulent exudate, erythema and haemorrhage, and was characterised by fibrosis and lichenification. Thus, the main clinical signs of dermatitis of the distal extremities in dogs were erosive-ulcerative inflammation and alopecia. The scientific literature presents quite similar methods of therapy, which do not differ in variety. Treatment regimens were determined depending on the form of disease progression and the etiological factor. Treatment strategy involved the effect of drugs on the tissues, organs and systems of the dog's body, directly related to the pathogenesis of a disease [22].

Taking into account the etiological factors and pathogenesis of a disease, a clinical trial of two treatment regimens for pododermatitis in dogs caused by *Staphylococcus intermedius*, *Demodex canis* and *Malassezia pachydermatis* was developed and clinically tested. To study the effectiveness of different therapeutic regimens for pododermatitis in dogs, two groups of animals were formed (control and experimental), 7 and 9 patients, respectively.

The animals of the control group were treated with Ivermectin and a 2.5% Amitraz solution as an acaricidal preparation, Sinulox in combination with Levomikol was prescribed for antibacterial therapy, antifungal therapy was represented by Nystatin, as an antihistamine – Allegra.

Treatment of patients in the experimental group was carried out using the latest drugs. An insecto-acaricidal agent – Bravecto, to which there is no resistance among ticks and is safe for the body of animals, with the active substance Fluralaner, which blocks GABA-dependent and glutamate-dependent arthropod receptors. Fungicidal agent – Orungal, with the active substance itraconazole, which suppresses the synthesis of ergosterol and has a wide antifungal spectrum. Antibacterial agent – Cefuroxime, which belongs to the 2nd generation cephalosporin. In addition, drugs of general action were used: Apoquel, which refers to selective inhibitors of Janus kinase (JAK), Derinat – an immunomodulatory agent that activates the immune response to bacterial and fungal antigens, as well as a local keratolytic agent – Keratolux.

Analysis of the efficacy of treatment measures for pododermatitis in dogs caused by *Staphylococcus intermedius*, *Demodex canis* and *Malassezia pachydermatis* allowed establishing the following patterns (Table 2). The use of drugs Bravecto, Cefuroxime, Orungal, Apoquel compared with a combination of drugs Ivermectin, Levomikol, 2.5% solution of Amitraz, Allegra, Sinulox allowed increasing the proportion of dogs with complete healing by 2.3 times (from 28.7% to 66.7%), decreasing unsatisfactory treatment outcomes by 5.1 times (from 60.1% to 11.1%), and reducing the disease duration by 1.6 times ($p < 0.01$) with a prolongation of the remission period by 2 times ($p < 0.01$).

Table 2. Efficacy of treatment for associative pododermatitis in dogs

Indicator	Control		Experimental	
	amount	%	amount	%
Total amount of sick animals	7	100	9	100
Recovery	2	28.7	6	66.7
Improvements (positive dynamics)	1	11.2	2	22.2
Unaltered	4	60.1	1	11.1
Duration of treatment, days	35±3		21±3**	
Period of remission, days	90±2		185±4**	

Note: ** – $p < 0.01$

Based on the obtained results, it was found that the most common dermatitis of the distal extremities in dogs is caused by several etiological factors, including pathogens *Demodex canis*, *Malassezia pachydermatis* and *Staphylococcus epidermidis*. Studies have identified various macromorphological variants of pathological processes of pododermatitis in dogs. They are characterised by different depth and site of inflammation and the main clinical signs, which were represented by erosive-ulcerative inflammation and alopecia. The complex regimen developed taking into account the etiological factors and pathogenesis of the disease allows increasing the efficacy of treatment and improve the long-term prognosis. Therefore, this treatment regimen can be recommended

for the introduction in veterinary practice.

The obtained results on the complex treatment of pododermatitis in dogs can be traced by other researchers. Thus, it was found that in the chronicity of the disease it is expedient to use systemic glucocorticoids, 0.1% tacrolimus topical, and cyclosporine [23].

It was also found that the efficacy of treatment with antimicrobials after preliminary tests to determine the sensitivity of microorganisms was 98.6%, which indicates the elimination of the etiological factor. For the treatment of pododermatitis of bacterial etiology, it was useful to topically apply a solution of dimethyl sulfoxide in combination with enrofloxacin (10 mg/ml) and steroids (0.1 mg/ml). In chronic cases of *Malassezia*

pododermatitis in dogs, the pulse therapy was prescribed. Systemic therapy included oral administration of ketonazole at a dose of 5-10 mg/kg once daily (two consecutive days for three weeks). For topical therapy, shampoos containing 2% miconazole and 2% chlorhexidine solution (twice a week) were used, as well as lotions containing terbinafine, nystatin, and clotrimazole [24].

Many studies have been conducted using various etiotropic drugs for pododermatitis in dogs, indicating the high efficacy of the proposed treatment protocols. Researchers point out that for demodicosis it is necessary to carry out acaricide treatment using macrocyclic lactones, drugs from the isoxazoline class [25]. Other studies suggest the effectiveness of Amitraz at a concentration of 0.125% to 1.25% daily [26]. Scientists argue that for pododermatitis, accompanied by a secondary bacterial infection, it is necessary to use local and systemic antibiotic therapy. The latter should be continued for 1-2 weeks; for local treatments, shampoos with chlorhexidine (3-4%) and benzyl peroxide are used. Remarkably, this treatment regimen allowed controlling the main symptoms: itching and erythematous inflammation of the skin. But the study shows that after 2 months of treatment, recurrences of the disease were recorded in 2 animals. [27].

CONCLUSIONS

Pododermatitis of dogs in the structure of skin diseases accounted for 13.79% of all cases and had different macromorphological clinical variability. In dermatitis of the distal extremities in dogs, the main clinical symptoms were erosive-ulcerative and erythematous inflammation of the interdigital space, lichenification, fibrosis, ulcers, haemorrhage, alopecia areata, the presence of popular and pustular rashes with a haemorrhagic and purulent exudate. In most cases (75%), inflammation of the tissues was localised in the pastern (metatarsus) and fingers of dogs.

The associative nature of dermatitis of the distal extremities in the examined sick dogs was established. Thus, the pathogen *Demodex canis* was detected in (87.5%) patients, 68.75% of dogs were diagnosed with *Malassezia pachydermatis*, and 75% of experimental animals were diagnosed with *Staphylococcus epidermidis* (62.5%). The use of drugs Bravecto, Cefuroxime, Orungal, Apoquel compared with a combination of Ivermek, Levomicol, 2.5% Amitraz solution, Allegra, and Sinulox increased the proportion of animals with complete healing by 2.3 times (from 28.6% to 66.7%), reduced unsatisfactory results by 5.1 times (from 57.1 to 11.1%), as well as reduced the duration of treatment period by 1.6 times ($p < 0.01$) with extending the remission period by 2 times ($p < 0.01$).

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КЛІНІЧНИЙ ПРОЯВ І СПОСОБИ ЛІКУВАННЯ ПОДОДЕРМАТИТІВ У СОБАК

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Анотація. У представлений статті наведені дані щодо клінічних ознак за перебігу пододерматитів у собак, а також досліджені ефективні схеми їх лікування. Актуальність проблеми зумовлена зростанням випадків захворювання на пододерматити у собак, їх поліетіологічним характером, що потребує різнобічного підходу за проведення діагностичних тестів і впровадження ефективних способів лікування. У зв'язку з цим метою дослідження було вивчити клінічний прояв захворювань шкіри дистального відділу кінцівок у собак і визначити ефективність заходів комплексної терапії пододерматитів. Дослідження проводились на підставі клінічних методів дослідження у дерматології, паразитологічних (зіскрібків шкіри) бактеріологічних і мікологічних (висіви на поживні середовища із подальшим виділенням збудника). За результатами досліджень встановлено, що в абсолютній кількості випадків виявляли ураження 2-х лап (53,3 %), значно рідше всіх 4 кінцівок (26,7 %). Було з'ясовано, що в основному локалізація поверхневих уражень шкіри виявлялась у 56,2 % в області міжпальцевого своду та 43,7 % випадків – лише із підошовної сторони п'ясті (плюсни); рідше запалення зони кігтьової фаланги (31,2 %). Основними клінічними ознаками дерматиту дистального відділу кінцівок у собак були ерозійно-виразкове запалення та алопеції, папули та пустули, заповнені гнійним ексудатом, еритемне запалення, геморагії, ділянки ліхенізації. Під час досліджень щодо лікування собак, хворих на пододерматит, спричиненого *Staphylococcus intermedius*, *Demodex canis* та *Malassezia pachydermatis* було встановлено, що включення до комплексної схеми лікарських засобів «Бравекто», «Цефуроксим», «Орунгал», «Апоквель» та «Деринат» підвищило ефективність терапії у тварин дослідної групи, як порівняти із контролем (з 28,6 до 66,7 %) на тлі скорочення тривалості курсу лікування до 21 доби ($p < 0,01$) та подовження періоду ремісії в середньому до 185 днів ($p < 0,01$). Перспективою подальших досліджень є уніфікація клініко-морфологічних і біохімічних показників крові, як діагностичних критеріїв за пододерматиту в собак

Ключові слова: пододемодекоз, фурункулез, собаки, клінічні ознаки, терапевтична ефективність

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REGULARITIES AND TRENDS OF THE OF THE LIVESTOCK INDUSTRY CURRENT STATE IN THE ZHYTOMYR REGION

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Abstract. An important condition for the provision of the country's food security is the production of sufficient quantities of food ensuring its proper quality. The current state of development of the livestock industry, as the main supplier of the population with meat, milk and other products both in Ukraine and at the regional level does not meet its potential capabilities. The purpose of the study was to investigate the trends and patterns of the current state of the livestock industry at the regional level and to find the main ways of its development. The study used general scientific and economic-statistical methods, namely: series of dynamics, analysis and synthesis, comparison. Analysis of the current trends in the livestock industry at the regional level as well as some of its indicators in general for Ukraine was carried out. Changes and dynamics of the average annual available number of livestock and poultry by groups of animals are revealed. It was found that the positive changes in the number of animals led to an increase in meat production, including lamb and goat, and poultry. However, this did not increase the production of beef, pork, milk and honey. The structure of meat production does not fully correspond to the natural and economic area of the animal husbandry. The influence of changes in the dynamics of the level of productivity of farm animals on the gross output of products, especially in the branches of pig breeding, sheep breeding, beekeeping, is estimated. According to the results of the research, the level of production of the main types of livestock products per capita has increased, but does not yet fully meet the physiological norms of consumption of these products. Feed evaluation in animal husbandry allowed measuring the efficiency of their use in terms of nutrients per 1 conventional head and unit of production by its types. An assessment of the economic efficiency of the industry is carried out according to the main indicators that summarise it. In the structure of production costs, the largest part is occupied by direct material costs. It was found that only the production of milk and chicken eggs was profitable. The study suggests the main approaches to the development of the livestock industry in the future

Keywords: market transformation, strategic orientation, trends in the livestock industry development, productivity



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INTRODUCTION

The market transformation of Ukraine's agriculture, its radical restructuring and purposeful state agrarian policy are aimed at ensuring that the agri-food sector provides economic growth for the national economy, raising social living standards, sustainable development and improving environmental security. Recently, the positive changes have been observed only in poultry and beekeeping industries [1], which do not solve the problem of balanced, systemic development of agriculture in the long term. Therefore, comprehensive scientific and innovative support of the economic stabilisation to achieve the strategic goals of radical agrarian transformations acquires special importance in the sectoral dimension.

Among the branches of agricultural production, animal husbandry plays a unique role of catalyst for the success of market transformations; it is a model embodiment of the paradigm of interaction of economic, social and ecological systems. On the one hand, the industry is relatively risky, technologically complex, resource- and labour-intensive, dependent on external conditions, demanding the qualifications and human qualities of its employees. However, on the other hand, animal husbandry has historically been a traditional branch of agriculture in Ukraine. It is an important source of income for peasants, an inviolable component of rural life, a means of strengthening the rural community, and a source of indispensable and essential food. Thus, the prospects of animal husbandry in Ukraine must correspond to its natural and economic potential, historical traditions, social role and ecological purpose.

The development animal husbandry in Ukraine is inextricably linked with the objectively necessary renewal and modernisation of the industry, which requires the following; creation and widespread introduction of new, highly productive animal breeds; resource-saving and environmentally friendly technologies for keeping and feeding livestock and poultry; automated and computerised processes; the use of the latest biotechnological and physicochemical methods and processes aimed at improving product quality [2; 3].

The innovative vector for the development of an effective organisational and economic management mechanism in the livestock industry provides fundamental changes in intersectoral and sectoral economic relations. This implies the strengthening of state regulation and the use of such economic levers as pricing, lending, taxation, insurance, improving property relations, introducing a risk management system and modern marketing technologies, stimulating support for the development of agricultural cooperation and vertical integration [4-6].

There is an urgent need to develop and implement an adequate policy focused on the safe interaction of livestock and the environment at the national and regional levels. Such a policy should prevent overburdening the industry on ecosystems, land and water

resources in the context of intensifying its development. Numerous studies of Ukrainian and foreign scientists were aimed at the current state of development of the livestock industry, taking into account its specifics, productivity, diversity of global, industry, regional, technological and organisational features. In particular, Ukrainian scientists have studied the directions for the development of the agricultural sector of the economy, taking into account the investment support of the livestock industry in Ukraine [7-9]. The leading role in the development of the livestock industry in the near future is assigned to state regulation of its economy [10-13]. Ways to intensify modernisation shifts aimed at the revival of animal husbandry are, first of all, their socio-economic component [14-17]. Further development of the livestock industry in the future is impossible without an empirical study of the influence of the main factors of its productivity in general and by animal species in particular [18-20].

Realising the potential of the livestock sector in climate change mitigation requires the promotion of research and development of new effective mechanisms for the introduction, dissemination and transfer of technologies to limit greenhouse gas emissions. This includes better mechanisms for monitoring, accounting and control of emissions in livestock production [10; 21; 22]. The reinforcement of the strategic orientation of Ukrainian livestock industry and intensification of its development to the level of compliance with the existing capabilities and the subsequent transition to competitive development is highlighted in this study. The above is aimed primarily at ensuring food security both in the country and at the regional level in particular.

The *purpose* of the study is to assess the productivity of livestock farming, its efficiency and the main reasons for its change with the further development of the industry in the long term, taking into account a set of factors. The key tasks include: analysis of the dynamics of the average annual number of livestock and poultry; the volume of livestock production; the level of livestock production per capita; level of animal feeding; analysis of the structure of the production cost of livestock products, and level of its profitability.

MATERIALS AND METHODS

In the process of organising and conducting research on the patterns and trends of the current state of the livestock industry in Zhytomyr region, the following general and special economic methods were widely used: economic analysis, which was implemented through a set of research techniques that constitute this method. The most important element of the methodology of economic analysis were techniques and methods of analysis, which were used at different stages for: primary processing of collected information, study of the state and patterns of development of the livestock industry,

determining the impact of factors on business results. A separate subsystem of general (synthetic) and analytical indicators was developed for each research task, based on the principle of their sufficiency for the corresponding depth of analytical research. At the same time, the relationships between indicators, algorithms for their calculation and levels of values were established.

Indicators of extensive and intensive development and changes, natural and cost, absolute and relative, were distinguished throughout the analysis. The set of indicators was determined by the nature of the study of causal relationships. During the study of economic efficiency of livestock production, qualitative and quantitative methods of economic analysis (analysis, synthesis, induction, deduction, average and relative values, time series, graphical techniques, etc.) were used to determine the size, scale, trends, and dynamics of development of the livestock industry [23].

At the first stage of the study, current trends in the state of development of the livestock industry were investigated. Using the time series and their indicators, the average annual livestock and poultry population, its absolute and relative deviation for the last three years were determined. Since changes in livestock and poultry directly affect the volume of production, it was considered necessary to study changes in the dynamics of production by type; including meat (in slaughter weight) of cattle, pork, lamb and goat, rabbit, poultry, milk, wool, chicken eggs, honey. It was expedient to study the structure of meat production of all kinds during the analysed period. In addition to the impact of changes in livestock and poultry on production volumes, a significant determining factor was the level of its productivity. The analysis of the latter was carried out through a system of indicators, namely: the average annual milk yield

per cow, the average annual shearing of wool from one sheep, the yield of offspring per 100 females by livestock, honey per 1 bee colony. The assessment of the state of the livestock industry was carried out through the level of production of meat (in slaughter weight), milk, eggs per person in the dynamics. The influence of changes in the level of cattle nutrition on the payback of feed products was studied using scientific methods of induction and deduction in general and by the main types of livestock products.

To increase the sustainable development of the livestock industry, the economic efficiency of its production is important. Among the main performance indicators is the structure of production costs, which was determined by the following cost items: direct material costs, including feed; other products; fuels and lubricants; fuel and electricity; spare parts, materials for repair; salary expenses; other direct costs, including contributions to social activities; amortisation; overhead costs, including services of third parties. The summarising indicator of livestock production in agricultural enterprises was estimated by types of products: cattle for meat, pigs for meat, sheep and goats for meat, poultry for meat, milk, and chicken eggs.

The information base of the analytical study was the statistical reporting of business entities of various business categories.

RESULTS AND DISCUSSION

Assessment of the state of livestock production

Current trends in the development of the livestock industry in the Zhytomyr region are defined primarily by the presence of livestock and poultry in farms of all business categories. The dynamics of the available livestock and poultry are given in Table 1.

Table 1. Dynamics of average annual number of livestock and poultry in the farms of Zhytomyr region, thousand animal units

Groups of animals	Years			2016 to 2018	
	2016	2017	2018	+, -	%
Bovine cattle	184.1	183.0	189.4	5.3	102.9
• in particular Dairy cows	109.3	109.4	111.5	2.2	105.3
Pigs	137.0	118.2	146.6	9.6	107.0
Sheep and goats	27.0	23.9	27.5	0.5	101.9
Poultry of all types (adult and young), including fattening chickens	6961.1	7398.5	7491.7	530.6	107.6
Number of bee families	191.6	193.4	193.9	2.3	101.2

Source: calculated by the author based on [24]

The data in Table 1 show that, in general, there was a slight increase in the total number of animals during the analysed period. Thus, the number of animal units in 2018 amounted to 189.4 thousand units, which

is 5.3 thousand more, or 2.9%, compared to 2016. The number of dairy cows increased by 2.2 thousand units, or 5.3%; pigs – by 9.6 thousand units, or 7.0%; poultry – by 530.6 thousand units, or 7.6%. An increase in the

number of bee colonies was 2.3 thousand, or 1.2%, and at the end of 2018 there were 193.9 thousand bee colonies. Positive changes in the number of livestock and poultry were reflected in the livestock production (Table 2).

As can be seen from Table 2, the production of meat in the slaughter weight in general in the farms of Zhytomyr region increased in 2018 by 1.3 thousand tonnes, or 2.4%, as compared to 2016. At the same time, during the analysed period there was a decrease in production of pork by 1000 tonnes, beef and veal by 300 tonnes. In the farms of the region in 2018 there was

a significant decrease in milk production and amounts to 553.3 thousand tonnes, which was 13.3 thousand tonnes less than in 2016 amounted to 97.7% of the base year. Positive trends have taken place in the field of poultry farming. Thus, the increase in the production of chicken eggs in 2018 was 33.9 million units, or 5.1%, as compared to 2016. Despite a significant increase in the number of bee colonies (1.3 thousand), honey production during the period of study decreased by 240 tonnes. The structure of meat production of all species for the analysed period is shown in Fig. 1.

Table 2. Dynamics of livestock production in agricultural enterprises of Zhytomyr region

Groups of animals	Years			2016 to 2018	
	2016	2017	2018	+,-	%
Meat (slaughter weight), total, ths t.	53.3	53.3	54.6	1.3	102.4
• beef (in particular veal)	15.6	15.8	15.3	-0.3	98.1
• pork	26.0	24.2	25.0	-1.0	96.2
• lamb and goat meat	0.3	0.5	0.5	0.2	166.7
• rabbit meat	0.9	1.1	1.3	0.4	144.5
• poultry	8.7	9.7	10.2	1.5	177.3
Milk, ths. t.	566.6	547.7	553.3	-13.3	97.7
Wool, t.	27	28	27	-	100.0
Chicken eggs (mln. pcs.)	661.9	688.1	695.8	33.9	105.1
Honey, t.	8074	7952	7834	-240	97.0

Source: calculated by the author based on [24]

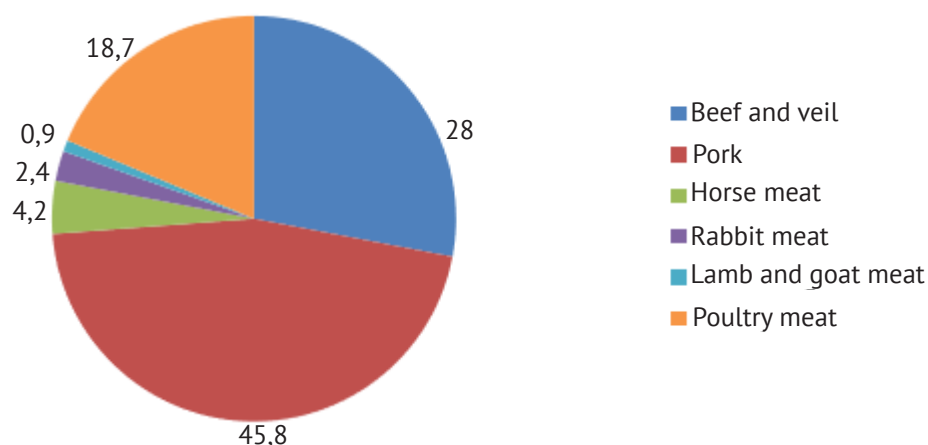


Figure 1. Structure of meat production by types in 2018, %

Source: calculated by the author based on [24]

The largest share in the structure of meat production in 2018 was pork – 45.8%, and beef and veal – 28.0%, poultry – 18.7%, horse meat – 4.2%, rabbit meat – 2.4%, lamb and goat meat – 0.9%. That is, the structure of meat production does not fully correspond to the natural and economic area of the livestock industry. The development of the livestock industry should be typical

for this region, first of all. The change in livestock production is largely influenced by changes in livestock and poultry productivity (Table 3). According to the results of the study of the dynamics of productivity of farm animals, as one of the factors of production intensity, the level of productivity by groups of animals has increased slightly, but far from the potential capabilities. Thus, in

2018, the average annual milk yield per cow increased by 20 kg., compared to 2016 and was 5087 kg., which is 0.4%. A significant decline in productivity occurred in the

pig industry. In 2018, the yield of offspring per 100 sows was 1046 piglets, which is 520 units, or 66.8%, less than in 2016.

Table 3. Dynamics of productivity of farm animals

Productivity indicators	Years			2016 to 2018	
	2016	2017	2018	+, -	%
Average annual milk yield per cow, kg.	5067	4977	5087	20	100.4
Average annual shearing of wool from one sheep, kg.	1.8	1.9	1.7	0.1	94.5
Offspring yield, per 100 females, units ¹ :					
• calves	70	67	76	6	108.6
• piglets (from main sows)	1566	668	1046	-520.0	66.8
• lambs and goats (from ewes)	81	104	77	-4.0	95.1
Received honey per 1 bee colony, kg.	42.1	40.5	40.4	-1.7	96.0

Source: calculated by the author based on [24]

Note: 1 – in enterprises

During the analysed period there was a decline in productivity of sheep and beekeeping. The level of development of the livestock industry is largely

characterised by such indicators as the production of the enterprises per capita (Table 4).

Table 4. Production of livestock products per capita in agricultural enterprises of Zhytomyr region, kg.

Type of production	Years			2016 to 2018	
	2016	2017	2018	+, -	%
Meat (in slaughter weight)	42.8	43.1	44.5	1.7	104.0
Milk	455.5	443.2	451.4	-4.1	99.1
Eggs	532	557	568	36	106.8

Source: calculated by the author based on [24]

According to the findings of the study, in 2018, as compared to 2016, the level of production of the main types of livestock products increased. Thus, the production of meat of all kinds in the slaughter weight in 2018 per capita was 44.5 kg., which is 4% more than in 2016. Milk – 451.4 kg., or 0.9% less, eggs – 568, or 6.8% more, respectively. At the same time, the achieved level of production does not yet fully meet the physiological norms of consumption of livestock products. Consumption of all types of meat has been almost halved, only the production of milk and eggs exceeds the minimum and rational norms, which is positive.

The keystone for the development of the livestock industry is the level of provision of livestock and poultry with high-quality and nutrient-balanced feed. The analysis of feed consumption in animal husbandry in agricultural enterprises of Zhytomyr region is presented in Table 5. According to Table 5, consumption of feed per capita tended to increase during the studied period. Thus, in 2018, feed costs amounted to 36.97 centners against 35.92 cwt. of feed units, 2.9% higher than in 2016. Judging by these indicators, it can be concluded that the level of livestock and poultry nutrition at the present stage does not meet necessary requirements.

Table 5. Consumption of feed at the animal husbandry in agricultural enterprises of Zhytomyr region

Indicators	Years			2016 to 2018	
	2016	2017	2018	+, -	%
Feed costs per conventional animal unit, cwt., f.u.	35.92	33.10	36.97	1.05	102.9
Concentrated feed consumption, ths. t., f.u.	122.5	115.9	162.3	39.8	132.5
Feed consumption, total, ths. t., f.u.	269.1	243.9	254.1	-15.0	94.4

Source: calculated by the author based on [24]

In total, the feed consumption throughout the study period decreased by 15 thousand tonnes of feed units and amount to 254.1 thousand tonnes in 2018, against 269.1 ths. t., or a decrease of 5.6%. However, there is a significant increase in the consumption of concentrated feed. In 2018, its consumption amounted to 162.5 thousand tonnes, or 32.5% more than in 2016.

This significant increase in concentrated feed consumption is due to an increase in the share in the structure of pork production – 45.8%.

One of the main indicators of the efficiency of livestock production and rational use of feed is its consumption in terms of feed units per unit of the corresponding industry product (Table 6).

Table 6. Dynamics of feed consumption for the production of 1 centner of products in the enterprises of the Zhytomyr region, cwt, f.u.

Type of production	Years			2016 to 2018	
	2016	2017	2018	+, -	%
Gain in beef,	16.1	15.05	14.87	-1.23	92.4
• using concentrated feed	4.89	5.11	7.09	3.01	161.6
Gain in pork,	4.36	4.45	4.28	-0.08	89.2
• using concentrated feed	4.21	4.09	3.55	-0.66	84.3
Milk,	1.14	1.03	0.98	-0.16	8.6
• using concentrated feed	0.39	0.39	0.58	0.19	148.7

Source: calculated by the author based on [24]

The level of feed consumption in 2018 for the production of beef decreased by 1.23 centners of feed units; the increase in pork – by 0.08 cwt. f.u.; milk – by 0.16 cwt. f.u., or respectively, by 7.6%, 10.8%, 14.1% against 2016. At the same time, there is a significant increase in the consumption of concentrated feed in the production of beef and milk, which is 61.6% and 48.7%, respectively. This gives grounds to state the use of feeds that are not balanced in nutrients, in particular

digestible protein and microelements.

Efficiency of livestock production

To increase the sustainable development of the livestock industry, the economic efficiency of its products, both main and secondary, is of great importance. One of the main performance indicators of livestock production efficiency is its prime cost. Analysis of the structure of production costs is presented in Table 7.

Table 7. The structure of the livestock production costs at the enterprises of Zhytomyr region

Indicators	Years				Deviation, (+,-)	
	2017		2018		mln. UAH %	
	mln. UAH	%	mln. UAH	%		
<i>Direct material costs</i>	751.4	65.2	833.9	65.9	82.5	0.7
• in particular feed	599.9	52.0	665.1	52.6	65.2	0.6
• of which purchased	97.9	8.5	209.7	16.6	111.8	8.1
• other products	7.7	0.7	7.3	0.6	-0.4	-0.1
• fuels and lubricants	47.1	4.1	57.3	4.5	10.2	0.4
• fuel and energy	1.1	0.1	1.4	0.1	0.3	-
• electricity	26.7	2.3	32.9	2.6	6.2	0.3
• spare parts, materials for repair	44.4	3.8	41.1	3.2	-3.3	-0.6
• salary expenses	128.3	11.1	142.0	11.2	13.7	0.1
• other direct costs	106.0	9.2	135.5	10.7	29.5	1.5
• in particular contributions to social activities	28.4	2.5	31.7	2.5	3.3	-

Continuation of table 7

Indicators	Years				Deviation, (+,-)	
	2017		2018		mln. UAH	%
	mln. UAH	%	mln. UAH	%		
• depreciation	48.0	4.2	61.6	4.9	13.6	0.7
<i>Total expenditures</i>	167.7	14.5	154.0	12.2	-13.7	-2.3
• of which services of third parties	81.8	7.1	26.2	2.1	-55.6	-5.0
<i>Total production costs</i>	1153.4	100.0	1265.4	100	112.0	X

Source: calculated by the author based on [24]

Enterprises of all categories do not always use progressive forms of organising the procurement and storage of high-quality feed by sex and age groups of livestock and poultry. It is especially inappropriate to use modern technologies for preparing feed for feeding during a calendar year. Analysis of the structure of the production cost of livestock production in 2018 shows that production costs in the industry increased by UAH 112.0 million, or 9.7%, as compared to 2017. In the structure of production cost the largest share is occupied by direct material costs, 65.9%, among them feed – 52.6%, of which purchased – 16.6%. Labour costs account for

11.2%, other direct costs – 10.7%, overhead costs – 12.2%.

Changes in the structure of production costs show that during the analysed period, direct material costs have increased by 0.7%, including feed by 0.6%, of which purchased by 8.1%, other direct costs increased by 1.5%. Costs were reduced by such items as overhead costs – by 2.3%; spare parts, materials for repair – by 0.6%. The summarising indicator of economic efficiency of livestock production is the achieved level of profitability (loss ratio). The dynamics of the level of profitability of the main types of livestock products are given in the Table 8.

Table 8. Dynamics of the level of livestock production profitability in agricultural enterprises of Zhytomyr region, %

Types of products	Years				
	2014	2015	2016	2017	2018
Cattle for meat	-40.0	-18.8	-29.1	32.6	-25.4
Pigs for meat	-2.2	18.2	-0.4	12.1	-4.2
Sheep and goats for meat	-34.9	-48.5	-48.5	-77.9	-65.1
Poultry for meat	-19.6	-2.5	-10.3	-16.6	-7.3
Milk	17.8	12.4	12.0	24.2	13.7
Chicken eggs	16.7	27.4	30.6	0.5	22.1

Source: calculated by the author based on [20]

This table shows that in 2018 only the production of milk and chicken eggs was profitable, the level of profitability of which was 13.7% and 22.1% respectively. The loss rate of beef was 25.4%, pork – 4.2%, lamb and goat meat – 65.1%, and poultry – 7.3%. At the same time, in 2017, the production of beef and pork was profitable, with a profitability rate of 32.6% and 12.1% respectively.

The study of patterns and trends of the current state of the livestock industry in Ukraine indicates its deterioration. Thus, as of January 2020, the number of cattle in Ukraine was 3.4 million, which is 5.7% less than on the same date in 2019. "The dairy herd was 1.82 million animals in total, which is 5% less (96.9 thousand) than in 2018. In particular, the number of cattle in

agricultural enterprises in 2019 decreased to 1.05 million animal units (-7.5% compared to 2018), in particular the number of dairy cattle decreased to 388 thousand animal units, which is 6.4 % less than in 2018" [1]. A similar situation has developed in households, where in 2019 the number of cattle decreased by 4.7% compared to 2018 and was 2.09 million, of which cows – 1.39 million, or 4.6% (6.5 thousand units) less than in 2018 [20].

The above negative trends and patterns of the livestock industry are inherent in the farms of Zhytomyr region. Thus, as of September 1, 2019, at the farms of all categories the number of cattle decreased by 5.6%, including cows – by 4.5%, sheep and goats – by 2.3%, poultry – by 14, 2%. The number of sheep and goats kept at enterprises decreased by 18%, poultry – by 14.2%,

cattle – by 1.6%, including cows – by 4.3%. At the same time, the number of pigs increased by 16.7%. The number of pigs in households increased by 7.0%, sheep and goats – by 0.8%, poultry – by 0.4%. On the other hand, the number of cattle decreased by 7.2%, including cows – by 4.6% [20].

The results of the above study suggest that the state of the livestock industry in Ukraine in general and in Zhytomyr region in particular, has reached a critical point, which in turn threatens the food security of the country.

CONCLUSIONS

1. Positive changes for the analysed period in the dynamics of livestock and poultry were reflected in the volume of livestock production. The production of meat in the slaughter weight in general in the farms of Zhytomyr region in 2018 increased by 1.3 thousand tonnes,

or 2.4%, as compared to 2016. At the same time, there was a decrease in production volumes by 1000 tonnes, beef by 300 tonnes, and milk by 13.3 thousand tonnes.

2. The decrease in the production of certain types of livestock products was significantly influenced by the decrease in the level of livestock productivity in the following industries: sheep – by 5.5%, pig – by 33.2%, due to a decrease in the level of feeding.

3. Only the production of milk and chicken eggs was profitable in 2018, the level of profitability of which was 13.7% and 22.1% respectively. The profitability of beef was 25.4%, pork – 4.2%, and sheep and goat meat – 65.1%.

4. One of the reserves to increase the livestock production, increase the productivity of livestock and poultry is the rational use of feed, balanced in their nutrition and compliance with feeding standards by species, sex and age groups of livestock and poultry.

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ЗАКОНОМІРНОСТІ ТА ТЕНДЕНЦІЇ СУЧАСНОГО СТАНУ ГАЛУЗІ ТВАРИННИЦТВА В ЖИТОМИРСЬКІЙ ОБЛАСТІ

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Анотація. Важливою умовою забезпечення продовольчої безпеки країни є виробництво достатньої кількості продуктів харчування та забезпечення належної їх якості. Сучасний стан розвитку галузі тваринництва, як основного постачальника у забезпеченні населення м'ясом, молоком та іншими продуктами як в Україні, так і на регіональному рівні не відповідає її потенційним можливостям. Метою дослідження є вивчення тенденцій і закономірностей сучасного стану галузі тваринництва на рівні регіону та пошук основних шляхів її розвитку. Методами і прийомами дослідження стали загальнонаукові та економіко-статистичні методи, а саме: ряди динаміки, аналізу та синтезу, порівняння. Здійснено оцінку сучасних тенденцій розвитку галузі тваринництва на регіональному рівні, а також окремих її показників загалом в Україні. Виявлено зміни та їх тенденції динаміки наявного середньорічного поголів'я худоби і птиці за групами тварин. Встановлено, що позитивні зміни в поголів'ї тварин обумовили збільшення обсягів виробництва м'яса, зокрема баранини та козлятини, птиці. Однак, це не сприяло підвищенню обсягів виробництва м'яса великої рогатої худоби, свинини, молока, меду. Структура виробництва м'яса не повною мірою відповідає природно-економічній зоні ведення галузі тваринництва. Оцінено вплив зміни динаміки рівня продуктивності сільськогосподарських тварин на валовий вихід продукції, особливо в галузях свинарства, вівчарства, бджільництва. За результатами дослідження виявлено, що рівень виробництва основних видів продукції тваринництва з розрахунку на одну особу підвищився, але ще не повною мірою відповідає фізіологічним нормам споживання даної продукції. Оцінка кормів у тваринництві дала можливість визначити рівень ефективності їх використання за поживними речовинами в перерахунку на 1 умовну голову та одиницю продукції за її видами. Здійснено оцінку економічної ефективності галузі за основними узагальнюючими її показниками. У структурі виробничої собівартості найбільшу частину займають прямі матеріальні витрати. Встановлено, що рентабельним було лише виробництво молока, яєць курячих. У статті запропоновано основні шляхи розвитку галузі тваринництва на перспективу

Ключові слова: ринкова трансформація, стратегічна орієнтація, тенденції розвитку галузі тваринництва, продуктивність



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EFFICIENCY OF APPLICATION OF DIFFERENT FORMS OF SUPERABSORBENTS IN CROPS OF BASIL

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Abstract. The main factors limiting the productivity of vegetables are the arid climate and uneven rainfall, but the use of absorbents can solve this problem. The purpose of the study was to investigate the influence of absorbents on the productivity of basil. This study used field and laboratory measurements, statistical, computational and analytical methods. The study revealed that absorbent in a form of gel positively influenced the increase of the leaf area index (+7.26% in Badioryi cultivar, +8.20% in the Rutan cultivar – leaf area, +34.55% in the Badioryi cultivar, 37.43% in the Rutan cultivar – leaf area index). Absorbents contributed to a slight decrease of sugar content (-0.86-2.68% in the Badioryi cultivar, -1.48–2.35% in the Rutan cultivar) and content (-8.8-13.2%) and yield of the essential oil (-19.6-39.5) in both cultivars. The activity of APX, CAT, SOD, tended to decrease in all variants, regardless of the form of the absorbent: APX (-12.8-35.1%), CAT (-10.9-22.0%), SOD (-11.9-17.0%). Results of the study have shown that the increase in the activity of antioxidant enzymes in control variants of basil varieties indicates their drought resistance. It has been substantiated that higher yield was observed in the variant with gel absorbent. Thus, the yield of the Badioryi and Rutan cultivars exceeded the control by 52.67 and 50.05%, respectively. In general, the productivity of basil has increased with the use of superabsorbent polymers. This practice can be recommended to agricultural producers who grow vegetables, in particular, basil in areas of unstable or insufficient moisture. Nevertheless, it is not desirable to use absorbents on industrial crops (to obtain essential oil), since with an increase in moisture and an increase in yield, it significantly decreases content and yield of essential oil

Keywords: antioxidant activity, *Ocimum basilicum*, chlorophyll, yield



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INTRODUCTION

The forest-steppe of Ukraine belongs to the zone of unstable moisture, therefore, ensuring optimal soil moisture throughout the growing season is a crucial issue in the technology of growing any crop and basil in particular. Optimisation of soil water regime and preservation of moisture reserves are urgent problems of agrocenoses. The current climate change towards warming with the contrasting change of excessively humid periods to hot days requires appropriate adjustments in the fertility management process.

Absorbents play an important role in agricultural production [1]. Over the last decade, hydrogels have been widely used to improve water supply to plants, due to their high water-retaining properties, the use of absorbents can be an effective means to increase the efficiency of both water and fertilisers [2; 3]. Studies indicate a good ability of absorbents to reduce water stress of plants and provide high productivity, which enhances growth and yield [4; 5].

In Ukraine, a small number of scientists study the influence of various forms of absorbents on the productivity of vegetable plants, in particular cucumbers [6], celery root [7] and petioles [8], garden spinach [9]. However, foreign scientists have achieved significant success in this area in the following crops: black pepper (peas) [10], which improved physiological processes that affect quality indicators. Soybeans [11] and potatoes [12], where plant growth and development and yields significantly improved. Cotton [13], where seed germination and root system development increased

significantly and soil changes from the use of hydrogels showed that the introduction of absorbents into the soil delayed water evaporation, thus making water available to plants for a longer period. Greenhouse experiments showed that despite a significant sharp decrease in water supply (50%) to the soil, plant productivity was higher with the introduction of absorbents [14]. Other scientists stated that the introduction of absorbents increased soil moisture (regardless of type) by 14% and improved digestibility of macronutrients by plants [15; 16].

Therefore, the primary purpose of this study was to evaluate the effect of various forms of superabsorbents on plant growth, chlorophyll content, activity of antioxidant enzymes and productivity of basil.

MATERIALS AND METHODS

Studies of the influence of different forms of superabsorbent were conducted in 2019-2020 in the experimental field of the Department of Vegetable Growing of Uman National University of Horticulture (Right-Bank Forest-Steppe of Ukraine) according to generally accepted methods [17-19]. The soil of the experimental plot is podzolic heavy loam chernozem with a humus horizon (humus content about 2.2%) 40-45 cm thick; pH (salt) -6.0-6.2. The arable layer contains 64 mg/kg of soil of easily hydrolysed nitrogen (according to Cornfield); 102 mg/kg – mobile phosphorus (according to Chirikov); 123 mg/kg – exchangeable potassium (according to Chirikov) (Table 1).

Table 1. Physico-chemical parameters of podzolic heavy loam chernozem

Indicator	Actual content
Organic matter (humus), %	2.2
pH	6.0-6.2
P ₂ O ₅ , mg/kg	102
K ₂ O, mg/kg	123
NO ₃ , mg/kg	64

Planting was carried out according to the scheme of 50×30 cm. The total area of the experimental plot was 400 m², the accounting area was 10 m². The study was carried out according to the two-factor experiment method with a randomised placement of variants in four replications. The two-factor experiment consisted in the use of Maxi Marin superabsorbent in the form of gel and granules.

Methods of application. During transplantation, the absorbent in the form of a gel was used, thoroughly mixing 2 g of hydrogel / 1 L of water. The solution was allowed to stand for half an hour until prepared. The roots of the plant were immersed in the solution and then transplanted into the field. Absorbent in the form of granules – 5 kg/ha, introduced before planting seedlings,

locally in the furrows (according to the manufacturer's recommendations), the absorbent was applied to a depth of 20-25 cm.

Biometric research. The length and width of the leaves, the area of the leaf blade and the total area of the leaves per plant were measured on the 60th day after planting. The height of the plant, the number of leaves per plant, and the area of the leaf blade was determined by the calculation (linear) method, using the parameters of the length and width of the leaf by the equation (1):

$$S_n = 0.74 \times ab \quad (1)$$

where: S_n – area of one leaf, cm²; a – the widest part of the leaf, cm; b – leaf length, cm; 0.74 – leaf configuration coefficient.

Plant material. Badioryi and Rutan cultivars of basil (*Ocimum basilicum* L.).

The content of assimilating pigments was determined by the spectrophotometric method of A. Ermakova [20].

Determination of the activity of antioxidant enzymes was carried out using a SF-2000 spectrophotometer. The activity of superoxide dismutase (SOD), catalase (CAT), ascorbate peroxidase (APO) was analysed. For enzyme extraction, the leaves, pre-frozen in liquid nitrogen, were homogenised in 50 mmol potassium phosphate buffer (pH 7.2) containing 0.1 mmol ethylenediaminetetraacetic acid (EDTA), 0.1% phenylmethylsulfonyl fluoride and 2% polyvinylpyrrolidone. The homogenate was centrifuged at 15,000 g for 15 minutes.

The total activity of SOD (superoxide dismutase) was determined by the ability of the enzyme to inhibit photochemical reduction of nitrosine tetrazolium to formazan according to the method [21; 22]. The reaction medium (2 ml) contained 0.1 MK, Na-phosphate buffer (pH 7.8), 9.3 mmol L-methionine, 152.3 µm nitrosonium tetrazolium, 1.1 µM Trilon B, 2.4% Triton X-100 and 100 µl of enzymatic preparation. The reaction was started by adding 50 µl of 111.3 µM riboflavin solution and performed in light (illumination of photosynthetic active radiation 180 µmol/m²•s) for 30 min. The dark control was the complete reaction medium incubated in the dark, and the light control was the complete reaction medium incubated in light without the addition of the enzymatic extract, using 100 µl of 0.1 MK, Na-phosphate buffer (pH 7.8). The reaction was stopped by placing the samples in the dark. The optical density was determined at 560 nm on a spectrophotometer. The activity of SOD was expressed in the RU/mg protein.

The activity of CAT (catalase) in the supernatant was determined by enzymatic decomposition of H₂O₂ at 240 nm [23; 24]. The reaction medium contained 2 ml of 0.1 MK, Na-phosphate buffer (pH 7.0), 50 µl of 19.4 mmol H₂O₂. 60 µl of enzymatic preparation was added to the resulting mixture and the dynamics of changes in optical

density were recorded with a spectrophotometer for 1 min. CAT activity was expressed in µmol H₂O₂/min /1 mg protein.

The activity of APO (ascorbate peroxidase) was determined by the Asada method [25]. The reaction mixture contained 50 mmol potassium phosphate buffer (pH 7.2), 0.1 mmol EDTA, 1 mmol ascorbate and supernatant. The reaction was initiated by the addition of 0.1 mmol H₂O₂. The decrease in ascorbate content was recorded on a SF-2000 spectrophotometer (Russia) at 290 nm (ε=2.88 mS/cm).

Dry matter (%). The average dry weight (g) of the leaves was measured by drying 10 randomly selected leaves in an oven with forced circulation of hot air at 70°C to obtain a constant mass. The percentage of dry matter of the leaves was estimated by taking the ratio of dry weight to fresh weight of selected leaves and multiplying it by 100.

The analysis of vitamin C was determined by the iodometric method of Murray in accordance with DSTU 4958:2008 [26].

Soil moisture was determined by thermostatic weight method according to equation (2):

$$M, \% = (A - B) / (B - C) \times 100, \quad (2)$$

where *A* – weight of box with wet soil, g; *B* – weight of box with dry soil, g; *C* – mass of the empty box, g.

Weather conditions in the years of research. According to the Uman meteorological station, hydrometeorological conditions in 2019 were characterised by slightly less precipitation compared to the average long-term indicators. The amount of precipitation during this period in 2020 was much higher than in 2019. Most of it fell in June, which allowed the plants to form better leaf mass. The air temperature in 2019-2020 at the time of planting was slightly higher than perennial, which had a positive effect on the development of basil plants (Table 2).

Statistical analysis. Statistical analysis was carried out using Microsoft Office Excel software, version 2016 (Microsoft Corp., USA). The results were calculated at significance levels of 0.01 and 0.05.

Table 2. Weather conditions during the growing season of basil in 2019 and 2020

Month	Precipitation, mm			Temperature, °C		
	2019	2020	Average value	2019	2020	Average value
May	35.6	101.0	55	17.0	12.5	14.6
June	69.8	70.4	87	23.4	20.9	17.6
July	33.8	21.4	87	20.0	21.6	19.0
August	19.2	17.1	59	20.7	21.2	18.2
September	30.6	27.4	43	15.6	17.8	13.6

RESULTS AND DISCUSSION

Since the main root mass of basil plants is in the arable soil layer 0-30 cm, the productivity of this crop

largely depends on the moisture content. In 2020, productive moisture reserves accumulated during the

winter-spring period were higher than in 2019 due to heavy rainfall in May. The dynamics of the productive moisture reserves in the root zone is presented in Figure 1.

The superabsorbent in the form of a gel helped to increase the productive moisture reserves. On average over two years, the application of the gel increased this indicator relative to control by 27-29% in May; 25-37% in June; 28-29% in July. When the granules were applied, the soil moisture values were significantly lower compared to the gel variants. There was also a significant

inter-varietal difference in moisture reserves. The soil in the variants with the Badioryi cultivar was characterised by large moisture reserves, which indicates its lower need for water and. Therefore, it can be assumed that this cultivar has a higher drought resistance.

Similar results were shown in studies with winter wheat and different hydrogel rates and in studies with soybeans and winter wheat, where productive moisture reserves increased significantly compared to control [27; 28].

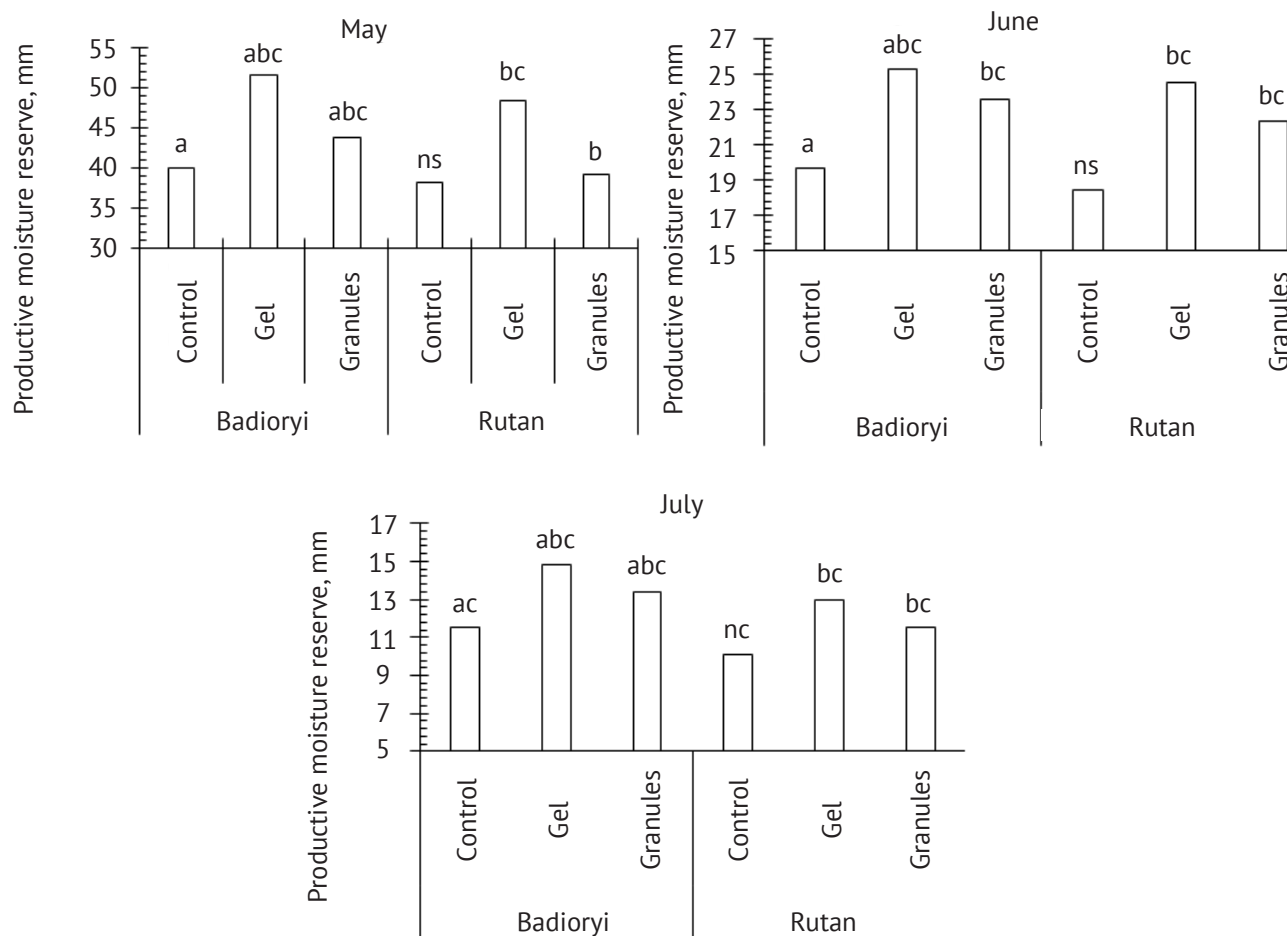


Figure 1. Dynamics of the productive moisture reserve (mm) in the root zone (in the soil layer 0-30 cm) of basil plants depending on the form of the superabsorbent (2019-2020)

Note: a – A; b – B; c – A×B the difference is significant and ns – insignificant at the level $p \leq 0.05$

The results of statistical processing	May	June	July
LSD _{0.05} A	1.51	0.57	0.29
B	1.85	0.70	0.35
A×B	2.62	0.99	0.50

Note: a – A; b – B; c – A×B the difference is significant and ns – insignificant at the level $p \leq 0.05$

Plant growth and leaf area development. The absorbent in the form of a gel contributed to a significant increase in the height of plants of both Badioryi and Rutan cultivars (+10.71% and +8.45% relative to control). The use of the absorbent in the form of a gel had a positive

effect on the increase in the diameter of the bush of basil plants of these two studied varieties (+16.14% and +14.10% relative to control). Absorbent in the form of a gel contributed to a significant increase in the number of leaves on the plants of Badioryi and Rutan

cultivars (+8.76 and +5.96% relative to control) (Table 3). The use of absorbent in the form of a gel contributed to a significant increase in the number of leaves on the plant (+8.76% in the Badioryi cultivar and +5.96% in the Rutan cultivar). The absorbent in the form of granules was less effective and caused a slight increase, +3.59 and +1.58%, respectively) of this indicator in both cultivars. The height of the plant and the number of leaves were increased due to the high moisture content in the soil, which contributed to increased cell activity, causing an increase in plant height and the number of leaves per plant. The obtained results are consistent with the

results on cucumber crops [29].

Calculation of the area of basil leaves indicated that it significantly increases with the use of the absorbent in the form of gel (+7.26% in the Badioryi cultivar, +8.20% in the Rutan cultivar).

Biochemical indicators. In the control variants, the dry matter content of the Badioryi and Rutan cultivars was higher in 2020 by 9.05% and 9.42%. The use of absorbents in the cultivation technology helps to increase yields, but at the same time slightly reduces the dry matter content, regardless of the form of the absorbent (Table 4).

Table 3. Plant growth and leaf area of basil plants depending on the form of the superabsorbent (2019-2020)

Cultivar (Factor A)	Superabsorbent (Factor B)	Plant height, cm	Plant diameter, cm	Number of leaves on the plant, pcs	Number of leaves, pcs	Leaf area, cm ²
Badioryi	Control	40.68 ^{bc}	37.08 ^{ns}	10.01 ^a	185.06 ^{ns}	25.24 ^{ab}
	Gel	45.04 ^{ns}	43.06 ^{bc}	10.53 ^c	201.27 ^{ns}	31.00 ^{ab}
	Granules	42.43 ^{ns}	40.51 ^{ns}	10.41 ^{ns}	192.28 ^{ns}	27.40 ^{ab}
Rutan	Control	40.90 ^{ns}	37.48 ^{ns}	6.73 ^{ns}	186.04 ^{ns}	17.37 ^{ns}
	Gel	44.35 ^{bc}	42.76 ^b	7.73 ^b	197.13 ^{ns}	22.34 ^b
	Granules	42.09 ^{ns}	40.35 ^{ns}	7.64 ^{bc}	188.98 ^{ns}	19.54 ^b
LSD _{0.05} A		1.12	1.40	0.24	5.54	0.52
B		1.38	1.71	0.30	6.78	0.64
A×B		1.95	2.43	0.42	9.59	0.90
CV%		4.2	6.3	18.8	3.3	21.3

Note: a – A; b – B; c – A×B the difference is significant and ns – insignificant at the level $p \leq 0.05$

Table 4. Biochemical indicators of basil plants depending on the form of superabsorbent (2019-2020)

Cultivar (Factor A)	Superabsorbent (Factor B)	Sugars, mg/100 g	Dry matter, %	Ascorbic acid, mg/100 g	Essential oil, %	Yield of essential oil, kg/ha
Badioryi	Control	9.10 ^{ns}	8.88 ^{ns}	13.17 ^b	1.09 ^{ns}	7.02 ^{ac}
	Gel	9.02 ^{ns}	8.71 ^{ns}	10.51 ^{ns}	0.99 ^b	4.25 ^a
	Granules	8.86 ^{ns}	8.76 ^{ns}	12.26 ^b	1.01 ^b	5.39 ^{abc}
Rutan	Control	18.66 ^a	9.23 ^{ns}	15.76 ^{abc}	1.51 ^{abc}	6.52 ^c
	Gel	18.38 ^a	8.98 ^{ns}	12.65 ^a	1.31 ^{abc}	3.94 ^{ns}
	Granules	18.22 ^a	9.07 ^{ns}	14.41 ^{ab}	1.35 ^{abc}	5.24 ^{bc}
LSD _{0.01} A		0.51	0.36	0.60	0.05	0.14
B		0.63	0.44	0.74	0.06	0.18
A×B		0.89	0.62	1.03	0.09	0.25
CV%		37.7	2.2	13.8	17.4	22.5

Note: a – A; b – B; c – A×B the difference is significant and ns – insignificant at the level $p \leq 0.05$

When using the absorbent in the form of a gel in the Badioryi and Rutan cultivars, the dry matter content was the lowest (-1.61% and -1.99% in 2019 and -2.10% and -3.40% in 2020). The use of absorbents contributed to a slight reduction in sugar content, but the difference between the varieties on average for two years of growing plants was very significant: Badioryi cultivar – 8.86-9.10 mg/100 g wwt, Rutan cultivar – 18.22-18.66 mg/100 g wwt. The content of ascorbic acid in the Badioryi and Rutan cultivars, regardless of the form of the absorbent, decreased significantly during both years (-6.76%-20.30% and -8.04%-19.28% in 2019, -7.10%-19.86% and -9.05%-20.21% in 2020, respectively), in all variants of the experiment. But the use of the absorbent in the form of granules contributed to its largest and less significant reduction in content.

The absorbent in the form of a gel significantly reduced the content and yield of essential oil in both cultivars. The use of the absorbent in the form of granules contributed to a less significant decrease in concentration, which contributed to a significant reduction (-23.2%-39.5% and -19.6%-39.6% of the Badioryi and Rutan cultivars) of the yield of essential oil per unit area. There is an assumption that under stress the number of oil-forming glands increases due to a decrease in leaf area, which leads to increased accumulation of essential oil. There are no similar data using superabsorbents, but there are studies on the effect of irrigation, which indicate a decrease in the content of essential oil in other crops at optimal

and excessive humidity [29], *Ocimum* spp. [30], *Salvia officinalis* [30].

Activity of antioxidant enzymes and pigment complex of leaves. The activity of APO, CAT, SOD, as a rule, decreased in all variants, regardless of the form of the absorbent. The studied cultivars had significantly lower activity of APO and SOD (-12.84%-24.13% APO and 11.85%-11.97% SOD – in the Badioryi cultivar – 21.15%-35.12% APO and 16.01%-16.99% SOD – in the Rutan cultivar). But the activity of KAT had a slight decrease in this indicator for both cultivars in all variants of the experiment (-10.89-18.43% – in the variety Badioryi and 13.11-21.95% in the variety Rutan). The obtained results indicate that the highest physiological activity is shown by SOD. The activity of the antioxidant complex is much higher both for control and for other options.

Results of the study have shown that the increase in the activity of antioxidant enzymes in control variants of basil varieties indicates their drought resistance. The use of absorbents increased the amount of chlorophyll a+b, but with the use of the absorbent in the form of a gel, the increase was most significant for control (+21.31% in the Badioryi cultivar, 22.51% in the Rutan cultivar). The absorbent in the form of granules also contributed to a significant increase in the concentration of chlorophyll a+b by an average of 12.45% in the Badioryi cultivar and 10.29% in the Rutan cultivar. The inter-varietal difference in this indicator was insignificant: the Badioryi cultivar accumulated 1.43%-1.74%, the Rutan cultivar – 1.43-1.75 mg/g wwt. (Table 5).

Table 5. The activity of antioxidant enzymes in the leaves and the chlorophyll content in basil plants, depending on the form of superabsorbent (2019-2020)

Cultivar (Factor A)	Superabsorbent (Factor B)	APO	CAT	SOD	Chlorophyll content, mg/g wwt		
		RU/mg protein			a	b	Σ a + b
Badioryi	Control	0.23	0.40	74.75	1.05	0.38	1.43
	Gel	0.17	0.32	65.90	1.29	0.45	1.74
	Granules	0.20	0.35	65.80	1.23	0.38	1.61
Rutan	Control	0.15	0.33	67.75	0.99	0.43	1.43
	Gel	0.10	0.26	56.23	1.23	0.52	1.75
	Granules	0.12	0.29	56.90	1.09	0.48	1.57
	LSD _{0.01} A	0.007	0.013	2.506	0.05	0.046	0.053
	B	0.010	0.016	3.069	0.06	0.056	0.070
	A×B	0.013	0.022	4.341	0.09	0.079	0.093
	CV%	30.1	15.1	10.9	10.3	12.3	8.9

Note: a – A; b – B; c – A×B the difference is significant and ns – insignificant at the level $p \leq 0.05$

Mass and yield of plants. The findings indicated a significant effect of absorbents on the change in plant weight of basil, regardless of the form of the absorbent in all variants of the experiment. The use of

the absorbent in the form of a gel was more effective for the Badioryi and Rutan cultivars during both years of cultivation (+27.46 and +30.45 g in 2019 and +19.97 and +7.99 g in 2020). Absorbent in the form of granules

also contributed to a significant increase in this indicator in both varieties (+15.98 and +18.97 g in 2019 and +9.98 and +5.09 g in 2020 relative to control).

Yield is the most important indicator of the effectiveness of cultivation technology. The use of Maxi Marin absorbent in the form of granules significantly increased the yield of basil of both varieties (+2.46 and +2.55 tonnes in 2019 and +2.89 and +2.4 tonnes in 2020 relative to control). The use of the absorbent in the form of a gel was more effective. Higher yields were observed when using the absorbent in the form of a gel. Thus, the yield of Badioryi and Rutan cultivars was at the level of 16.11 and 10.93 t/ha, which exceeded the control by 5.56 and 3.64 t/ha.

The use of superabsorbent polymer improves plant growth. For example, the total amount of raw cucumber biomass (*Cucumis sativus* L.) and fruit biomass increased by 840 and 494 g per plant, respectively [31]. Another study with different varieties of potatoes (*Solanum tuberosum* L.) found an increase in tuber yield using superabsorbents locally in the furrows to a depth of 25 cm [32]. A similar result was found when applying 60 and 90 kg/ha of superabsorbents to a depth of 20 cm, which increased the yield of potatoes by 38.2% and 50.5% relative to the control [33]. Although the use of superabsorbents can improve plant growth, the depth of its application can significantly affect its effectiveness (Fig. 2).

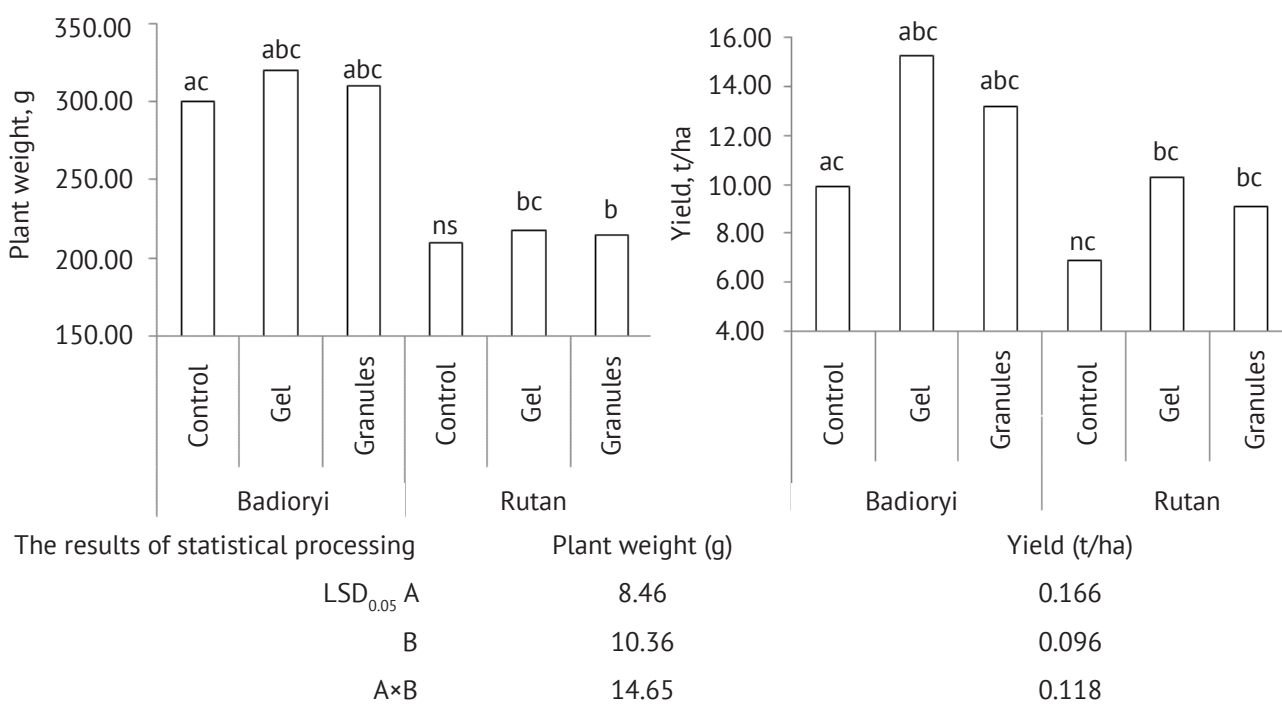


Figure 2. Plant weight (g) and yield (t/ha) of basil varieties depending on the form of superabsorbent on average over two years

Note: a – A; b – B; c – A×B the difference is significant and ns – insignificant at the level $p \leq 0.05$

In conditions of insufficient humidity, superabsorbents have a greater impact on plant productivity [34; 35]. The dry matter of sorghum (*Sorghum bicolor* L. Moench) increased only when there was a lack of water in the sandy loamy soil [34]. In a three-year study, the use of superabsorbents increased the yield of beans (*Phaseolus vulgaris* L.) grown on superabsorbents [36].

CONCLUSIONS

The findings showed that an increase in the activity of antioxidant enzymes (catalase, superoxide dismutase and ascorbate peroxidase) in varieties of basil indicates their resistance to drought, and this is accompanied by an increase in chlorophyll content. Therefore, the use of

superabsorbent, which has the ability to absorb significant amounts of water, improves growth and physiological reactions of plants and can help plants in conditions of water shortage. On the other hand, with improvement of water regime, the concentration of sugar, ascorbic acid, essential oil decreases.

The productivity of basil plants is increased with the use of superabsorbent polymers. Higher growth and yield were observed with the introduction of the absorbent in the form of a gel compared with the control. This practice can be recommended to agricultural producers who grow vegetables, including basil, in areas of unstable or insufficient moisture.

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ЕФЕКТИВНІСТЬ ЗАСТОСУВАННЯ РІЗНИХ ФОРМ СУПЕРАБСОРБЕНТІВ У ПОСІВАХ ВАСИЛЬКІВ СПРАВЖНІХ

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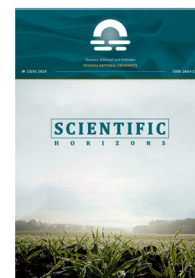
Анотація. Основними чинниками, що обмежують продуктивність овочів, є посушливість клімату та нерівномірність надходження опадів, тому застосування абсорбентів може вирішити цю проблему. Метою досліджень було вивчення впливу суперабсорбуючих матеріалів на продуктивність васильків справжніх. Для досліджень використовували польові, лабораторні, статистичні і розрахунково-аналітичні методи. Площа листка та показник листового індексу також істотно збільшується за застосування абсорбенту у формі гелю (+7,26 % у сорту Бадьорій, +8,20 % у сорту Рутан – площа листка, +34,55 % у сорту Бадьорій, 37,43 % у сорту Рутан – листовий індекс). Абсорбенти сприяли неістотному зменшенню вмісту цукрів (-0,86–2,68 % у сорту Бадьорій, -1,48–2,35 % у сорту Рутан) та вмісту (-8,8–13,2 %) і виходу ефірної олії з гектару (-19,6–39,5) в обох сортах. Відзначалася динаміка зниження активності антиоксидантних ферментів АПО, КАТ, СОД у всіх варіантах експерименту, незалежно від форми абсорбенту. АПО (-12,8–35,1 %), КАТ (-10,9–22,0 %), СОД (-11,9–17,0 %). Результати цього дослідження показали, що підвищення активності антиоксидантних ферментів у контрольних варіантах сортів базилика вказує на їх посухостійкість. Обґрунтовано, що більшу урожайність відзначали у варіанті з внесенням абсорбенту у формі гелю. Так, урожайність сортів Бадьорій і Рутан переважала контроль на 52,67 та 50,05 % відповідно. Загалом, продуктивність базилика підвищується із застосуванням суперабсорбуючих полімерів. Дану практику можна рекомендувати сільськогосподарським виробникам, які вирощують овочі, зокрема, васильки справжні, у районах з нестабільною або недостатньою кількістю опадів, але не бажано використовувати абсорбенти на технічних посівах (для отримання ефірної олії), оскільки з підвищенням вологості та збільшенням врожайності істотно знижується вміст і вихід ефірної олії

Ключові слова: антиоксидантна активність, васильки справжні, хлорофіл, урожайність

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AGROECOLOGICAL STABILITY OF CULTIVARS OF SPARSELY DISTRIBUTED LEGUMES IN THE CONTEXT OF CLIMATE CHANGE

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Abstract. A prerequisite for increasing the area of sparsely distributed leguminous crops lies in the analysis of their cultivars according to agroecological indicators. Therefore, the purpose was to develop the State Register of plant cultivars suitable for distribution in Ukraine for 2021 and Official descriptions of plant cultivars and indicators of economic suitability, highlighted in the information and reference system "Sort" (cultivar) regarding the assessment of agroecological resistance of cultivars of sparsely distributed legumes. The highest potential seed yield, according to the State Register of plant cultivars of Ukraine, is attributed to horse bean cultivars Tiffani and Fanfare, lentil cultivars YeS Maksymum, Blondi and SNIM 18, chickpea cultivars Goksu, Aras, Zehavit, YeS Alunt and a cultivar of grass pea Ivolha. The highest resistance to diseases is attributed to the cultivars of horse beans Birgit, Apollo, and Stella, cultivars of lentils Blondi, Khryzolit, SNIM 18, Harri, Linza, cultivars of chickpeas Odysei, Zodiak, Rodin, Oven, Stepovyi velet, and all cultivars of grass pea. The most resistant to pests are horse beans Sirius and Fanfare, lentil cultivars Harri, Blondi, Khryzolit, SNIM 18, cultivars of chickpea Dostatok, Zodiak, Lara, Yaryna, YeS Alunt, Rodin, Stepovyi velet, Kozeroh and Odysei. The most drought-resistant is the cultivar of grass pea Ivolha, as well as most cultivars of horse beans, except Sirius and Fanfare, lentil cultivars, except YeS Maksymum, Antonina, and Harri, chickpeas, except Zehavit and Budzhak cultivars. Analysis of agroecological resistance of cultivars of sparsely distributed leguminous plants and their potential seed yield showed that to a large extent, high productivity is ensured by resistance to adverse agroecological factors: the influence of diseases, pests, and drought. The practical value of the study is to recommend the production of cultivars of sparsely distributed legumes with the highest indicators of resistance to diseases, pests, and drought with the highest potential yield

Keywords: horse beans, lentils, chickpea, grass pea, cultivar, drought resistance, yield



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INTRODUCTION

Leguminous crops are valuable in the food, fodder, and agroecological significance of agricultural plants in Ukraine. However, their acreage is very low. In general, in Ukraine, the acreage under leguminous crops in 2019 amounted to 566.0 thousand hectares, which is approximately 2% of the structure of the sown area and is a very low indicator [1]. Of the total area of leguminous crops in Ukraine, over 84% belongs to peas and soybeans. These two crops are the main ones among legumes. At the same time, under conditions of the climate change, the potential of other legumes, such as chickpeas, lentils, grass peas, beans, etc. is not fully utilised, which can provide higher yields in extreme weather conditions at a lower cost.

The determining factor in the expansion of acreage under sparsely distributed leguminous crops is the correct selection of cultivars, taking into account modern environmental conditions. One of the main indicators in the selection of leguminous varieties for certain soil and climatic conditions is their potential yield and manufacturability of cultivation [2]. The main indicators of the manufacturability of leguminous crops are the resistance of plants to lodging, shedding of beans, the suitability of plants for direct combining, the height of attachment of lower beans, and the height of plants. It is also necessary to consider the maturation time of cultivars, their reaction to weather and soil conditions [3]. Climate change in recent years has led to the fact that some varieties of legumes have become severely suppressed by drought, and this has affected their resistance to diseases, pests, and most importantly – their productivity [4]. Therefore, the ecological indicators of the suitability of leguminous cultivars should include their drought resistance, as well as resistance to the most common diseases and pests.

The fulfilment of the genetic potential of leguminous crops requires not only optimisation of environmental factors, but also an appropriate cultivation technology adapted to a specific cultivar [5]. The issue of optimal selection of leguminous cultivars for growing in certain ecological conditions is covered in the studies of V. F. Kaminskyi [6], H. Hing, H. Jiang, K. Zhou, N. Hing [7], H. Zhao, H. Cao, P. Ming-Zhen, I. Song [8], R.A. Guntynsky [9], M.A. Vishnyakova [10], N.E. Novikova [11], O.L. Kirilesko [12] and others.

Modern cultivars of leguminous crops are capable of realising approximately 50% of their productive potential [13]. One of the main reasons for this is an incorrectly selected cultivar for specific ecological growing conditions [14]. Therefore, the *purpose* and *objective* of the study is to analyse the current assortment of sparsely distributed leguminous crops included in the State Register of plant cultivars suitable for cultivation in Ukraine in terms of their potential productivity and resistance to drought, pests, and diseases.

MATERIALS AND METHODS

The assessment of agroecological stability of leguminous crops was carried out by processing the State Register of plant cultivars suitable for distribution in Ukraine for 2021 [15] and official descriptions of plant cultivars and indicators of economic suitability, submitted in the official bulletins “Protection of rights to plant cultivars”, which are placed in the information and reference system “Sort” [16-26]. The authors of the study analysed materials on such leguminous crops, which, according to official data of the State Statistics Service of Ukraine, have the smallest acreage in 2019: horse beans (*Vicia faba* L.), lentils (*Lens culinaris* Medik.), chickpea (*Cicer arietinum* L.) and grass pea (*Lathyrus sativus* L.).

Cultivars of leguminous plant species according to the state qualification examination for determining indicators of suitability for distribution in Ukraine, among other things, are evaluated by grain yield, resistance (tolerance) to diseases, pest damage, adverse meteorological conditions, and other indicators. The parameters of agroecological resistance covered in official documents are the ratio of plants to the effects of pests, diseases, and droughts. Quantitatively, stability is determined on a relative nine-point scale (1-9 points), where 9 points correspond to the highest stability, and 1 point corresponds to the lowest stability. Therewith, the following gradation of cultivars is used by points: 9 points – the cultivar is excellent; 7 points – the cultivar is good; 5 points – the cultivar is satisfactory; 3 points – the cultivar is bad; 1 point – the cultivar is very bad [27]. Potential levels of seed yield of the studied leguminous crops were also analysed. The studied indicators were compared with each other using mathematical and statistical correlation and regression analysis.

These indicators of sparsely distributed leguminous crops were established based on the methodology of conducting an expert examination of plant varieties of the group of grains, cereals, and legumes for suitability for distribution in Ukraine. All experiments are carried out on plots of 10-25 m² in size with four-fold repetition [27]. Identification of the resistance of leguminous crops to the main pests is carried out according to the following parameters: bruchid – a month after harvesting according to the percentage of damaged grains; pod borer – before harvesting according to the percentage of damaged grains; bean aphid – with a noticeable population on plants as a percentage; pea leaf weevil – with noticeable damage to plant seedlings as a percentage [27].

Determination of plant resistance to diseases is carried out according to the following methods: bacteriosis – during the filling of the main mass of beans and before harvesting according to the percentage of the affected surface; fusariosis – 10 days after germination according to the percentage of affected plants; ascochytois – during the filling of the main mass of beans and before harvesting according to the percentage

of damage to leaves, stems, and beans; stripe disease – before harvesting according to the percentage of affected plants; bacterial wilting, root rot – in the phase of full flowering according to the percentage of affected plants [27]. Assessment of the resistance of cultivars to adverse meteorological conditions, in particular drought, is carried out in accordance with general guidelines. During the growing season, leguminous cultivars are visually evaluated for drought resistance. To determine the yield of plants, they are collected separately or by direct combining [27].

RESULTS AND DISCUSSION

As of 2021, the State Register of plant cultivars suitable for distribution in Ukraine includes 10 cultivars of horse beans (*Vicia faba* L.) [15]. The main diseases of horse beans are bacteriosis (*Bacterium phaseoli* E.F.Sm), fusariosis

(*Fusarium oxysporum* Sch.), ascochytois (*Ascochyta viciae* Libert.) and stripe disease (*Bacterium lathyri* (Mann. et Taub.) Burgw.). The most common pests of horse beans are the bruchid (*Bruchus rufimanus* Boh.), the pod borer (*Etiella zinckenella* Tr.), the stem borer (*Lixus algirus* L.).

Resistance to major diseases in horse bean cultivars is 5.3-7.8 points. Birhit cultivar has the highest resistance to a complex of diseases – 7.8 points, Apollo and Stella cultivars – 7.5 points each. The least resistant to diseases is the Fanfare cultivar – 5.3 points. For the Bakhus cultivar, there is no information on its resistance to diseases (Table 1). The most resistant to pests are the cultivars of horse beans Sirius – 7 points and Fanfare – 6.3 points. The most vulnerable to pests are the cultivars Apollo, Stella, Birhit – all with a resistance score of 5. At the same time, there is no information on pest resistance of Vivat, Bakhus and Peremozhets' cultivars.

Table 1. Indicators of agroecological resistance of horse bean cultivars according to the State Register of plant cultivars of Ukraine

Cultivar	Resistance to diseases, points	Pest resistance, points	Drought resistance, points	Grain yield, t/ha
Aleksiiia	6.0	6.0	7.0	4.5
Apollo	7.5	5.0	7.0	5.2
Vivat	6.0	no data available	no data available	4.5
Stella	7.5	5.0	7.0	5.3
Sirius	7.0	7.0	5.0	4.2
Fanfare	5.3	6.3	6.0	5.7
Birhit	7.8	5.0	7.0	5.0
Bakhus	no data available	no data available	no data available	no data available
Tiffani	6.3	6.0	7.0	5.9
Peremozhets'	7.0	no data available	7.0	no data available

Source: [16; 17; 19; 23-25]

Drought resistance of all cultivars of horse beans is in the range of 5-7 points. Most cultivars have a drought tolerance score of 7, only the Sirius cultivar has 5 points, and the Fanfare cultivar has 6 points. There is no information on the drought resistance of Vivat and Bakhus cultivars. The potential yield of horse bean seeds is in the range of 4.2-5.9 t/ha. The highest yield is attributed to the Tiffani cultivar – 5.9 t/ha and Fanfare – 5.7 t/ha. The lowest yield is attributed to Sirius – 4.2 t/ha, Vivat and Alexia – 4.5 t/ha each. There is no information on the yield of horse bean cultivars Bakhus and Peremozhets'.

An average positive correlation was established between the drought resistance score of plants and the yield of horse bean seeds ($r = 0.432$). A graphical representation of the correlation and regression relationship between the yield of horse bean seeds and the drought resistance score of plants, as well as the regression equation and the approximation confidence value (R^2) between the studied values are presented in Fig. 1.

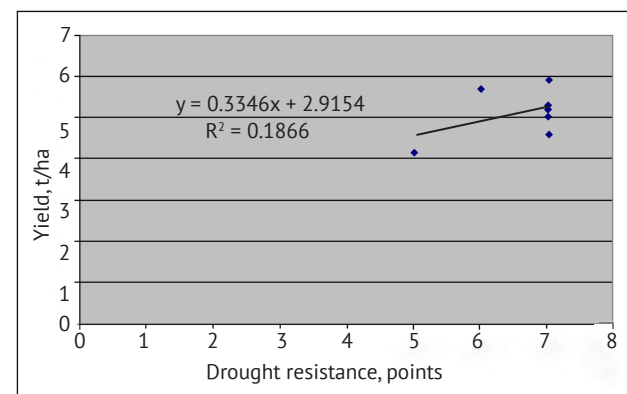


Figure 1. Correlation and regression relationship between drought resistance score (X) and seed yield (y) of horse beans

Source: [16; 17; 19; 23-25]

For 2021, the State Register of plant cultivars suitable for distribution in Ukraine includes 9 cultivars of lentils (*Lens culinaris* Medik.) [15]. The main diseases of food lentils are ascochytirosis (*Ascochyta ervicola* Syd.), fusariosis (*Fusarium oxysporum* Schlecht.), bacterial wilt (*Corynebacterium insidiosum* (Mc Cull.) Jons.). The most common pests of lentils are bean aphids (*Aphis*

fabae Scopoli.) and pea leaf weevil (*Sitona lineatus* L.). The highest resistance to diseases is attributed to the following cultivars of lentils: Blondi, Khryzolit, SNIM 18 – 8 points each, Harri – 7.7, Linza – 7.5 points. The least resistant to diseases are the following varieties: YeS Maksymum – 6.3 points, Antonina – 6.7 points (Table 2).

Table 2. Indicators of agroecological resistance of lentil cultivars according to the State Register of plant cultivars of Ukraine

Cultivar	Resistance to diseases, points	Pest resistance, points	Drought resistance, points	Grain yield, t/ha
YeS Maksymum	6.3	7.0	7.0	2.81
Blondi	8.0	8.0	8.0	2.60
Khryzolit	8.0	8.0	8.0	2.00
Svitanok	7.0	no data available	8.2	2.04
Antonina	6.7	6.0	7.0	2.10
Darynka	7.0	6.0	8.0	2.14
Linza	7.5	no data available	no data available	1.74
SNIM 18	8.0	8.0	8.0	2.60
Harri	7.7	9.0	7.0	2.30

Source: [18-22]

The highest pest resistance is attributed to the Harry cultivar – 9 points, Blondi, Khryzolit, SNIM 18 – all 8 points each. The most vulnerable to pests are the cultivars Antonina and Darynka – 6 points each. There are no data on pest resistance of the Svitanok and Linza cultivars. Most cultivars of lentils have a high drought resistance – 8.0-8.2 points. Less drought-resistant are the YeS Maksymum, Antonina, and Harri cultivars, which have a drought resistance score of 7. The highest potential yield of lentil seeds is attributed to the YeS Maksymum cultivars – 2.81 t/ha, Blondi and SNIM 18 – 2.60 t/ha each, and the least productive is the Linza cultivar – 1.74 t/ha.

As of 2021, the State Register of plant cultivars suitable for distribution in Ukraine includes 19 varieties

of chickpeas (*Cicer arietinum* L.) [15]. The main pest of chickpeas is the bruchid (*Bruchus rufimanus* Boh.), and diseases – ascochytirosis (*Ascochyta ervicola* Syd.) and root rot (*Bipolaris sorokiniana* Shoem). The highest resistance to diseases among the cultivars of chickpeas is attributed to Odysei – 8.7 points, Zodiak, Rodin, Oven, Stepovyi velet – all 8.5 points each. The least resistant to diseases are the cultivars Zehavit – 5.5 points, Goksu and Budzhak – 6 points each. Data on disease resistance of Triumf and Pehas varieties are not available (Table 3). Chickpea cultivars YeS Alunt and Oven have increased resistance to pests – 9 points each. The most vulnerable to pests are Aras, Zehavit, and Goksu cultivars – 5 points each. There is no information on pest resistance of Triumf, Pehas, Fahot, Odysei and Budzhak cultivars.

Table 3. Indicators of agroecological resistance of lentil cultivars according to the State Register of plant cultivars of Ukraine

Cultivar	Resistance to diseases, points	Pest resistance, points	Drought resistance, points	Grain yield, t/ha
Triumf	no data available	no data available	8.0	1.69
Aras	7.5	5.0	8.0	4.00
Dostatok	7.0	8.0	9.0	2.00
Zodiak	8.5	8.0	9.0	2.80
Lara	7.0	7.0	9.0	3.40
Yaryna	8.0	8.0	9.0	1.80
Pehas	no data available	no data available	no data available	1.89
YeS Alunt	8.0	9.0	9.0	3.89

Continuation of table 3

Rodin	8.5	7.0	9.0	2.80
Zehavit	5.5	5.0	5.0	3.90
Eve	7.5	7.0	8.0	3.20
Oven	8.5	9.0	8.0	2.00
Fahot	7.1	no data available	8.7	2.64
Stepovyi velet	8.5	8.0	9.0	1.80
Goksu	6.0	5.0	7.0	4.10
Kira	7.0	7.0	8.0	3.30
Kozeroh	8.0	8.0	9.0	2.70
Odysei	8.7	no data available	9.0	2.25
Budzhak	6.0	no data available	5.0	2.00

Source: [19; 21; 23-26]

Most cultivars of chickpeas have the highest drought resistance, with a score of 9. These are Dostatok, Zodiak, Lara, Yaryna, YeS Alunt, Rodin, Stepovyi velet, Kozeroh and Odysei. The lowest drought resistance is attributed to the cultivars Zehavit and Budzhak – 5 points each. There is no information on the drought resistance of the Pehas cultivar. The highest potential seed yield is attributed to chickpea cultivars Goksu – 4.10 t/ha, Aras – 4.00 t/ha, Zehavit – 3.90 t/ha, YeS Alunt – 3.89 t/ha. The lowest yield is observed in the cultivars Triumf – 1.69 t/ha, Yaryna and Stepovyi velet – 1.80 t/ha each and Pehas – 1.89 t/ha.

An average negative correlation was established

between the score of resistance of chickpea plants to diseases and seed yield ($r = -0.429$), and a strong negative correlation was found between the score of resistance of chickpea plants to pests and seed yield ($r = -0.674$). This indicates that during the creation of breeding cultivars of chickpeas, cultivars with high potential seed productivity are described by reduced resistance to diseases and pests. As of 2021, two cultivars of the grass pea (*Lathyrus sativus* L.) were introduced in the State Register of plant cultivars of Ukraine. The Ivolha cultivar has a higher seed yield – 3.69 t/ha and higher drought resistance – 9 points than the Spodivanka cultivar (Table 4).

Table 4. Indicators of agroecological resistance of grass pea cultivars according to the State Register of plant cultivars of Ukraine

Cultivar	Resistance to diseases, points	Pest resistance, points	Drought resistance, points	Grain yield, t/ha
Ivolha	8.0	no data available	9.0	3.69
Spodivanka	8.0	no data available	5.0	3.10

Source: [16]

Analysis of agroecological resistance of cultivars of sparsely distributed leguminous plants and their potential seed yield showed that to a large extent, high productivity is ensured by resistance to adverse agroecological factors. It is established that the increased yield of horse beans of the Fanfare cultivar is combined with its high resistance to pests, and Tiffani cultivar – with drought resistance; considerable productivity of lentil cultivars Blondi and SNIM 18 is combined with increased resistance to diseases, pests and drought; all high-yielding cultivars of chickpeas – Goksu, Aras, Zehavit, YeS Alunt are marked by an increased score of drought resistance, and the YeS Alunt cultivar also has a high score of resistance to pests; the productivity of the grass pea cultivar Ivolha is combined with drought and disease resistance.

At the same time, the Fanfare horse bean cultivar,

despite its high productivity, has a low score of drought resistance and resistance to diseases; the YeS Maksymum lentil cultivar combines high seed yield with low drought resistance and a low score of disease resistance; the high-performance chickpea cultivar Zehavit is marked by low scores of resistance to diseases, pests and drought, the Goksu cultivar – by low resistance to diseases and pests, the Aras cultivar – by low resistance to pests.

Comparison of the studied types of leguminous crops according to the value of the disease resistance score indicated that the most resistant to them are chickpea cultivars with the highest score of 8.7, lentils and grass pea had a resistance score of 8, and horse beans – 7.8 points. The most resistant to pest damage among the studied leguminous crops are some cultivars of food lentils and chickpeas with the highest score

of 9. At the same time, horse bean cultivars had the lowest pest resistance score of 7. The highest drought resistance among the studied types of leguminous crops was attributed to cultivars of chickpeas and grass peas – 9 points each, lentils – 8.2 points, and horse beans – 7 points. Horse bean cultivars have the highest potential for seed productivity among the studied leguminous crops – 5.9 t/ha. The maximum yield of chickpea seeds reaches 4.1 t/ha, grass peas – 3.7 t/ha, and lentils – only 2.8 t/ha.

CONCLUSIONS

According to the State Register of plant cultivars of Ukraine, the highest potential seed yield is attributed to horse bean cultivars Tiffani and Fanfare, lentil cultivars YeS Maksimum, Blondi and SNIM 18, chickpea cultivars Goksu, Aras, Zehavit, YeS Alunt and a cultivar of grass pea Ivolha. Among the cultivars of horse beans, the most resistant to diseases such as bacteriosis,

fusariosis, ascochyosis and stripe disease are Birhit, Apollo, and Stella, lentil cultivars Blondi, Khryzolit, SNIM 18, Harri, Linza are resistant to ascochyosis, fusariosis and bacterial wilt, among the cultivars of chickpeas resistant to ascochyosis and root rot are Odysei, Zodiak, Rodin, Oven, Stepovyi velet, all cultivars of grass pea have increased resistance to its diseases.

The most resistant cultivars of horse beans to pests such as bruchid, pod borer and stem borer are Sirius and Fanfare, lentil cultivars Harri, Blondi, Khryzolit, SNIM 18 are resistant to damage by bean aphids and pea leaf weevils, chickpea cultivars Dostatok, Zodiak, Lara, Yaryna, YeS Alunt, Rodin, Stepovyi velet, Kozeroh and Odysei have increased resistance to bruchids. The most drought-resistant is the cultivar of grass pea Ivolha, as well as all cultivars of horse beans, except Sirius and Fanfare, all lentil cultivars, except YeS Maksimum, Antonina, and Harri, and all cultivars of chickpea, except Zehavit and Budzhak.

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АГРОЕКОЛОГІЧНА СТІЙКІСТЬ СОРТІВ МАЛОПОШИРЕНИХ ЗЕРНОБОБОВИХ КУЛЬТУР В УМОВАХ ЗМІНИ КЛІМАТУ

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Анотація. Передумовою збільшення площ малопоширених зернобобових культур є аналіз їх сортів за агроєкологічними показниками. Тому метою було опрацювання Державного реєстру сортів рослин, придатних для поширення в Україні на 2021 рік та Офіційних описів сортів рослин і показників господарської придатності, висвітлених в Інформаційно-довідковій системі «Сорт» щодо оцінки агроєкологічної стійкості сортів малопоширених зернобобових культур. Найвищою потенційною урожайністю насіння, за даними Державного реєстру сортів рослин України, відзначаються сорти бобів кінських Тіффані та Фанфаре, сорти сочевиці харчової ЄС Максимум, Блонді та СНІМ 18, сорти нуту звичайного Гоксу, Арас, Зехавіт, ЄС Алунт і сорт чини посівної Іволга. Найвищою стійкістю до хвороб характеризуються сорти бобів кінських Біргіт, Аполло та Стелла, сорти сочевиці харчової Блонді, Хризоліт, СНІМ 18, Гаррі, Лінза, сорти нуту звичайного Одисей, Зодіак, Родін, Овен, Степовий велет та усі сорти чини посівної. Найбільш стійкими до шкідників є сорти бобів кінських Сіріус та Фанфаре, сорти сочевиці харчової Гаррі, Блонді, Хризоліт, СНІМ 18, сорти нуту звичайного Достаток, Зодіак, Лара, Ярина, ЄС Алунт, Родін, Степовий велет, Козерог та Одисей. Найбільш посухостійким є сорт чини посівної Іволга, а також більшість сортів бобів кінських, крім Сіріусу та Фанфаре, сортів сочевиці харчової, крім ЄС Максимум, Антоніні та Гаррі, нуту звичайного, крім сортів Зехавіт і Буджак. Аналіз агроєкологічної стійкості сортів малопоширених зернобобових рослин та їхньої потенційної урожайності насіння показав, що значною мірою висока продуктивність забезпечується стійкістю до несприятливих агроєкологічних чинників: впливу хвороб, шкідників і посухи. Практична цінність досліджень полягає у рекомендації виробництву сортів малопоширених зернобобових культур із найвищими показниками стійкості до впливу хвороб, шкідників і посухи з найбільшою потенційною урожайністю

Ключові слова: боби кінські, сочевиця харчова, нут звичайний, чина посівна, сорт, посухостійкість, урожайність



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SPECIES COMPOSITION OF HARMFUL ENTOMOCOMPLEX IN PEACH ORCHARDS OF SOUTHERN UKRAINE

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Abstract. Studies of the dynamics of changes in the species composition of pests in fruit orchards in the context of climate change became especially relevant. Monitoring of phytophagous insects in gardens with the isolation of dominant species is a key component for building an effective system of protection of perennial plantings. The study was conducted in 2018-2020 on the basis of the Melitopol Experimental Station of Horticulture named after M.F. Sidorenko IS NAAS. The purpose of the study was to establish the species composition of phytophages and the level of their colonisation of peach orchards to optimise measures to protect this crop from pest damage. Conducting route and detailed surveys in different phases of tree development (swelling of buds, pink bud, flowering, end of flowering, forming, growth and ripening of fruits) showed that the entomocenosis of peach orchards consisted of 15 species of phytophagous insects belonging to 4 orders, 10 families, and 2 species of mites. The species composition and level of pest colonisation of peach orchards changed under the influence of weather conditions and protection measures. *Lepidoptera* insects were represented by 7 species of pests, among which the main carpophages were *Gnathocampa molesta* Busck., to a lesser extent *Anarsia lineatella*. The attack density of these pests each year was at a high and medium level, respectively. Throughout all the years of study most harmful of insects from the order Coleoptera was polyphagous *Epicometis hirta*. The main Homoptera pest in 2018 was *Quadraspidiotus perniciosus* Comst., while the prevalence of other catfacing insects was weak. During the vegetation periods of 2019-2020 the development of insects such as aphids and increase in the colonisation of leaves by mites, *Thrips fuscipennis* Haliche and *Typhlocyba rosae* L. was recorded in peach orchards

Keywords: pest colonisation, monitoring, peach orchards, phytophages



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INTRODUCTION

Horticulture is an important branch of the agro-industrial complex of Ukraine, which meets the needs of the population in fruits that contain a complex of important macro- and microelements, as well as vitamins [1]. The range of crops and their varieties depends on the climatic conditions of the region and local agricultural traditions [2]. In the structure of orchards in the South of Ukraine, stone fruit crops dominate. Among them, one of the early fruiting is the peach. This plant is characterised by high taste and its fruits contain approximately 13% of various vitamins and 10.7% of acids [3]. According to statistics in the southern regions, the area of peach orchards as of 2018 was more than 2.9 thousand hectares, but compared to 2000, it decreased almost twice [4].

Species and quantitative composition of pests in orchards is not stable and depends on the age of the gardens, species, and varietal composition [5]. The development of the entomocomplex of perennial plantings begins from the moment the garden is laid and continues throughout the entire period of its cultivation under the influence of biotic and abiotic factors introduced with the planting material and by migration from nearby territories [6]. Significant changes in the biodiversity of entomoacarifauna also occur under the action of pesticides [7; 8]. Analysis of the species composition of pests in the fruit crop agrocenoses indicates the presence of both polyphagous and specialised species. In some phytophages there are periodic increase their numbers and such species such as *Laspeyresia* are constantly harming plantings [9; 10].

A number of authors [11; 12] have determined that the main part of the biomass of phytophagous insects in orchards is from order *Lepidoptera*. Among them, the *Grapholitha molesta* is the most harmful in peach orchards [13-15]. The spread of pests such as *Anarsia lineatella* is observed in outbreaks mostly in older plantings [7; 15]. However, in some countries this phytophagous is the dominant species, as compared with other members of this order [16-19]. According to the observations of N.M. Karpun and O.V. Mikhailova [20] in peach orchards in the humid subtropics of Russia there are about 18 species of pests, while more than 43.7% of harmful species are polyphagous.

The studies by S.P. Iovleva [15] found that in the foothills of the Crimea in peach orchards of different ages there are 30 species of pests and 1 species of mites. In plantings of 3-4 years of age the species diversity is three times smaller. Dominant representatives of a number of isopods are species of the family *Aphididae*, in particular green and striped peach aphids (*Myzodes persicae* and *Brachycaudus persicae*). A number of beetles include 13 species, of which 9 belong to the family *Curculionidae*. The authors noted the strong colonisation of peach orchards by lepidopteran pests, namely the *Grapholitha molesta* and *Anarsia lineatella*. During 2015-2017, it was found

that in the territory of the Crimea the peach orchards were dominated by 3 species of aphids, as well as *Grapholitha molesta*, *Anarsia lineatella*, and *Epicometis hirta* [21].

According to a number of authors [14], in the South of Ukraine during 2012-2013, the constant species in the peach agrocenoses were *Grapholitha molesta*, *Anarsia lineatella*, *Myzodes persicae*, and *Tetranychus crataegi* Hirst. The colonisation of trees with *Epicometis hirta*, *Sciaphobus squalidus* and other phytophagous species is observed not every year. According to the study in 2018-2019, it was found that the main pests of peach were *Grapholitha molesta* and *Quadraspidiotus pemiciosus* [22].

R. Andreev and P. Vasilev note that in Bulgaria the most common pests on peaches are the *Grapholitha molesta* and *Anarsia lineatella*. In addition to these phytophages, 8 species of aphids have been recorded, while only 3 of them are dominant and of economic importance [23]. In peach orchards in Brazil, the most common pests are fruit flies of the family *Tephritidae*, the larvae of which will cause large yield losses [24].

Changes in the main meteorological parameters of the climate in today's conditions lead to changes in the structure of the complex of pests [25; 26]. In this regard, the constant monitoring of fruit plantings to obtain information on the species composition of pests, their distribution, levels of damage with the release of dominant phytophages is the basis for making decisions on the applicability of protective measures. Extermination of all pests without exception is always incomparably more expensive than just keeping their numbers below the level of the economic threshold of harm [12].

In view of the above, the purpose of the study was to establish the species composition of phytophagous insects and the level of pest colonisation of peach orchards to optimise measures to protect this crop from pest damage.

MATERIALS AND METHODS

Field and laboratory studies on the species composition of peach pests were conducted in 2018-2020 at the "Naukova" Melitopol Experimental Station of Horticulture named after M.F. Sidorenko IS NAAS. Peach orchards of 2004-2007 years of planting were represented by varieties: Iiyunskyi rannii, Melitopolskyi iasnyi, Charivnyk, Zlatodar, Vireneia, Redhaven, Spokusa, Zolotystyi, Mriya, Yuvileynyi Sidorenka. The scheme of planting trees – 5x4 m, stock – rootstock 1. The soil of the experimental site – heavy loam southern chernozem, soil retention system – black fallow.

Detection of peach pests was carried out by conducting routine and detailed surveys of peach plantings in accordance with the phases of the host plant: swelling of buds, pink bud, flowering, end of flowering, forming, growth and ripening of fruits. The

number of sample trees was at least 8 of each variety. Determination of the species composition and pest colonisation of peach plantations was carried out using various methods, in particular: visual estimation of pests or damage to leaves, shoots, shaking, the use of pheromone traps. Thus, the estimation of the pest colonisation of peach plantings by weevils started during the bud bursting phase. It was carried out by shaking different sides of the crown of the four branches of each sample tree. *Diaspididae* and *Lecaniidae* were counted during a thorough examination of bark on the trunks, main branches, and shoots. For this, shoots 10 cm long and small parts of the bark with colonies of scale insects (if present on main branches) 3 cm long and 2 cm wide were cut off. The presence of *Tortricidae* was determined by examining 100 inflorescences and leaves on trees. The species composition of mites and the level of their presence were recorded on the leaves of trees, plucking them from all tiers of the tree in the amount of 10 pcs. The colonisation of trees with catfacing insects (aphids, leafhoppers) was carried out by inspecting the leaves and shoots 0.5 m long (two shoots on each side of the crown) [27]. Pheromone traps at the rate of 1 trap per 0.5 ha were used to record lepidopteran pests [28].

The collected material was analysed in the laboratory using MBS-10 binocular microscope. Insect species were established using atlases and identifiers of pests based on plant damage [29; 30]. According to the data on the number of pests, the level of pest colonisation of plantings was determined for each sample.

Weather conditions during the study differed in temperature and moisture content. However, a common feature for weather conditions were increased air temperatures compared with long-term averages. In

2018, the average monthly air temperature during the growing season (April-September) was in the range of +13.4°C...+25.9°C; in 2019 it was +11.4°C +25.3°C; in 2020 +9.4°C...+24.9°C, which is 0.5-4.8°C higher than long-term values. During the spring and summer months, there was 227.2-270.4 mm of precipitation. The uneven distribution of rainfall was observed, which led to a significant deficit of moisture and a decrease in the relative humidity below 50%.

RESULTS AND DISCUSSION

Phytopathological monitoring conducted in peach orchards during 2018-2020 revealed that the species composition of the entomocomplex is dominated by representatives of the class *Insecta*. The share of which in 2018 and 2020 was 91.7 and 93.3%, from the class *Arachnida* – 8.3 and 6.7%, respectively. In 2019, the share of phytophagous insects decreased slightly to 87.5%, while the share of mites increased to 12.5%.

Throughout the study, the order *Lepidoptera* was widespread and the most numerous in terms of species diversity, which in 2018 accounted for 63.6% of the total number of insect pests (Fig. 1). In 2019-2020, the share of representatives of this order decreased and amounted to 46.7%, which is due to the expansion of the species composition of phytophages in other orders. The orders *Coleoptera* and *Homoptera* in 2018 had 2 species of insects each with a total share of 18.2%. In 2019 and 2020 – 3 and 4 species, which amounted to 20.0% and 26.7% of the total detected phytophages. In addition, in 2019-2020 the taxonomic structure of the harmful entomocomplex of peach included one species from the order Thysanoptera with a share of 6.6%.

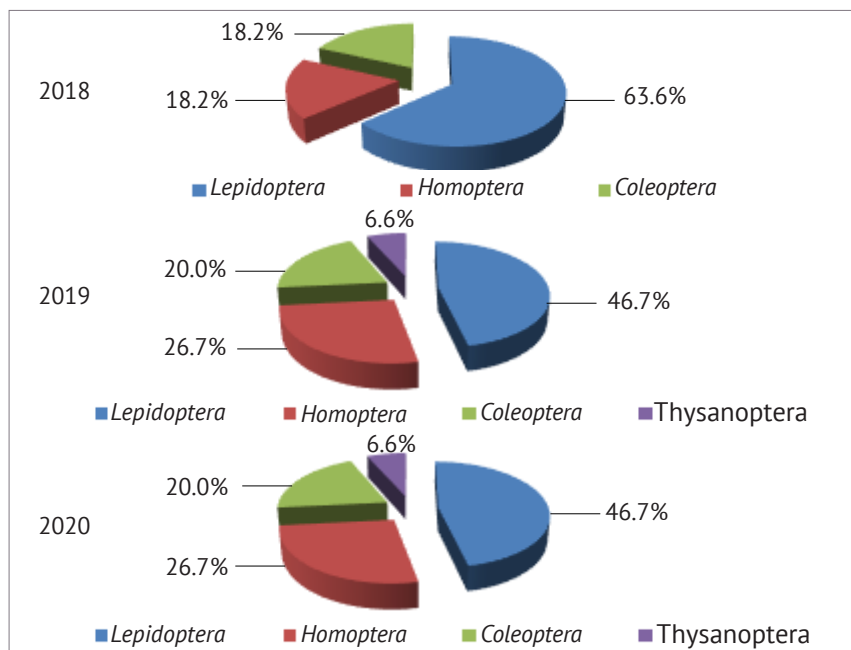


Figure 1. Taxonomic structure of the harmful entomocomplex of peach plantings (Naukova Experimental Station, 2018-2020)

In the conditions of the Southern Steppe of Ukraine in the peach agrocenoses, 15 insect pests belonging to 4 orders, 10 families, and 2 species of mites were recorded (Table 1).

Table 1. Species composition of the harmful entomocomplex in peach plantings in the South of Ukraine (Naukova Experimental Station, 2018-2020)

Phytophage	Pest colonisation		
	2018	2019	2020
Class <i>Insecta</i>			
Order <i>Lepidoptera</i>			
Family <i>Tortricidae</i>			
<i>Archips rosana</i> L.	+	+	+
<i>Archips podana</i> Scop.	+	+	+
<i>Grapholitha molesta</i> Busck.	+++	+++	+++
<i>Laspeyresia pomonella</i> L.	+	+	+
<i>Grapholitha funebrana</i> Tr.	+	+	+
Family <i>Gelechiidae</i>			
<i>Anarsia lineatella</i> Zell.	++	++	++
Family <i>Lithocolletidae</i>			
<i>Lithocolletis cerasicolella</i> H.S.	+	-	-
Order <i>Homoptera</i>			
Suborder <i>Aphidinea</i>			
Family <i>Aphididae</i>			
<i>Myzodes persicae</i> Sulz.	-	++	++
<i>Hyalopterus pruni</i> Geoffr.	-	+	++
Suborder <i>Coccoidea</i>			
Family <i>Diaspididae</i>			
<i>Quadraspidiotus perniciosus</i> Comst.	++	++	++
Suborder <i>Auchenorrhyncha</i>			
Family <i>Cicadellidae</i>			
<i>Typhlocyba rosae</i> L.	+	++	++
Order <i>Coleoptera</i>			
Family <i>Scarabaeidae</i>			
<i>Epicometis hirta</i> Poda.	+	++	++
Family <i>Curculionidae</i>			
<i>Sciaphobus squalidus</i> Gyll.	+	+	+
Family <i>Buprestidae</i>			
<i>Capnodis cariosa</i> Pall.	-	+	+
Order <i>Thysanoptera</i>			
Family <i>Tripidae</i>			
<i>Thrips fuscipennis</i> Haliche	-	++	++
Class <i>Arachnida</i>			
Order <i>Acarina</i>			
<i>Tetranychus viennensis</i> Zacher.	+	++	-
<i>Tetranychus urticae</i> Koch.	-	++	++

Note: + – low pest colonisation; ++ – average pest colonisation; +++ – strong pest colonisation; – species is absent

It was found that in peach plantings the species composition of pests changed over the years under the influence of weather conditions, varietal characteristics of the crop, protection measures.

The complex of pests from the order *Coleoptera* included 3 species from three families *Scarabaeidae*, *Curculionidae*, *Buprestidae*. Among them, the greatest damage was caused by the polyphagous *Epicometis hirta*, the imago of which feeds intensively on flowers during the flowering of fruit trees and leads to significant crop losses [12]. During the flowering of peach trees in 2018 (15-17.04-24.04) under dry weather conditions and average daily air temperature +10.6°C ... +15.8°C, a weak population of pest beetles was established. In 2019, during the flowering of peach trees (17-18.04-26-27.04), the average daily air temperature was +7.4°C...+18.1°C (maximum – +25.6°C), while the density of *Epicometis hirta* was higher than 2018. The level of pest infestation in the flowering phase of trees in 2020 (09-10.04-21-22.04) was lower than in 2019, due to the freezing of reproductive buds and low intensity of flowering trees. In addition to *Epicometis hirta* in the early spring period, a weak colonisation of trees with *Sciaphobus squalidus* was recorded, during the summer – with *Chrysobothris affinis*.

Among the pests of the order *Homoptera* there is a dangerous quarantine phytophage – *Quadraspidiotus pemiciosus*. The degree pest colonisation during the three years of study was at the average level. In the South of Ukraine, the pest colonisation of peach orchards with *Quadraspidiotus pemiciosus* fluctuates significantly [18]. It was found that peach plantings were dominated by two species of aphids, the intensive reproduction of which is observed from late May to mid-summer. At the same time, in 2018, the development of catfacing phytophages from the suborder Aphidinea was not recorded on any of the studied varieties. However, in 2019 the pest colonisation of gardens with *Anarsia lineatella* was at an average level, *Tetranychus urticae* Koch. – at a weak level, in 2020 – at an average level of both species.

In the peach agrocenoses, *Typhlocyba rosae* L. was a permanent species belonging to the order *Homoptera*. Reproduction of this pest in 2018 was observed during August at a weak level, which was due to the high average daily air temperature +23.0°C...+28.9°C and a significant deficit of moisture. In the following 2019 and 2020, the appearance of *Typhlocyba rosae* L. was recorded in peach plantations in late May-June and August, with the average degree of pest colonisation.

During the summer period, the development of representatives of the class *Arachnida*, including two species of mites, was observed. It was found that during 2018 and 2019, on different varieties of peach, respectively, a weak and medium contamination of leaves with motile stages of mite (*Tetranychus viennensis* Zacher) was recorded. The reproduction of

the common spider mite was detected in 2019 and 2020 at an average level.

In 2019 and 2020, in addition to the above species of catfacing insects, the average pest colonisation of peach leaves with *Thysanoptera* was recorded. It was found that in the peach agrocenoses, 7 pests from the order *Lepidoptera* were recorded, belonging to 3 families, the most numerous of which is the family *Tortricidae*. During the years of study there was a low degree of colonisation of peach orchards by two types of tortrix (*Archips rosana* L. and *Archips podana* Scop.). In 2018, there was a weak colonisation of trees by a member of the family *Lithocolletidae* – *Lithocolletis cerasicolella* H.S. In subsequent years, observations of peach leaves damaged by the insects were not observed.

Males of 4 species of lepidopterous phytophages were caught on pheromone traps in peach orchards. The most common and most dangerous of these insects was *Grapholitha molesta*. Depending on weather conditions, the flight of insects lasted from mid-April to late September. The four peaks of phytophagous flight corresponds to the development of four generations. At the same time, the colonisation of peach orchards by *Grapholitha molesta* was at a high level in all years of study. In the conditions of the South of Ukraine in peach orchards the *Grapholitha molesta* belonging to the family *Gelechiidae* also has indirect distribution [12]. The development of two complete generations and partially the third has been established. During the years of observation, the flight of *Grapholitha molesta* began in the 10th-20th day of May and lasted until the 20th-30th day of September. At the same time the pest colonisation of the species was at the average level.

CONCLUSIONS

In the peach agrocenoses, the species composition of insect pests in the Southern Steppe of Ukraine includes 15 phytophagous insects belonging to 4 orders, 10 families, as well as 2 species of mites. The level of pest infestation changed during the years of observations under the influence of weather and climatic conditions, and protective measures. The most numerous species in terms of species diversity was *Lepidoptera* – 46.7–63.6% of the total composition of phytophagous insects. Among which the constant and most harmful fruit-damaging species was *Grapholitha molesta* Busck., to a lesser extent – *Anarsia lineatella*. In the spring, *Epicometis hirta* was the most dangerous among insects from other orders. During the summer, there was a low and medium colonisation of peach plantations by catfacing insects (*Quadraspidiotus perniciosus*, *Myzodes persicae*, *Hyaloplerus pruni*, *Tetranychus viennensis* and *Tetranychus urticae*, *Typhlocyba rosae*), the total harmfulness of which was reflected in the weakening of trees productivity due to damage to vegetative organs.

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ВИДОВИЙ СКЛАД ШКІДЛИВОГО ЕНТОМОКОМПЛЕКСУ У НАСАДЖЕННЯХ ПЕРСИКА ПІВДНЯ УКРАЇНИ

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Анотація. Дослідження динаміки змін видового складу шкідників у плодкових насадженнях в умовах змін клімату набувають особливої актуальності. Моніторинг фітофагів у садах з виокремленням домінуючих видів є основною складовою для побудови ефективної системи захисту багаторічних насаджень. Метою досліджень, що проводились протягом 2018–2020 рр. на базі Мелітопольської дослідної станції садівництва імені М.Ф. Сидоренка ІС НААН, було встановлення видового складу фітофагів і рівня заселеності ними у насадженнях персика для оптимізації заходів захисту даної культури від пошкодження шкідниками. Проведення маршрутних і детальних обстежень у різні фази розвитку дерев (набрякання бруньок, рожевий бутон, цвітіння, кінець цвітіння, формування, ріст і дозрівання плодів) дало змогу визначити, що ентомоакароценоз персикових насаджень складався з 15 видів комах-фітофагів, що належать до 4 рядів і 10 родин та 2 видів кліщів. Видовий склад і рівень заселеності насаджень персика шкідниками змінювався під впливом погодних умов, проведених заходів із захисту. Ряд лускокрилих був представлений 7 видами шкідників, серед яких основними карпофагами є східна плодожерка, меншою мірою фруктова смугаста міль. Інтенсивність заселення насаджень персика даними шкідниками кожного року знаходилась на високому та середньому рівні відповідно. Протягом усіх років досліджень з ряду твердокрилих найбільшу шкідливість завдавав багатодіний фітофаг оленка волохата. Основним шкідником з ряду рівнокрилих у 2018 р. виявилася каліфорнійська щитівка, а заселеність іншими сисними фітофагами була на слабкому рівні. Протягом вегетаційних періодів 2019 та 2020 рр. у насадженнях персика зафіксовано розвиток сисних фітофагів з підряду попелиць і підвищення рівня заселення листків персика кліщами, трипсом розановим і цикадкою розановою

Ключові слова: заселеність, моніторинг, насадження персика, фітофаги



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FEATURES OF FORECASTING OF LEAF-EATING INSECTS DISTRIBUTION IN THE FORESTS OF ZHYTOMYR POLISSIA

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Abstract. Foliage damage by leaf-eating insects during mass reproduction causes deterioration of the sanitary state of forest and a decrease in its increment. Timely detection of pest foci allows reducing the cost of their elimination and preventing negative consequences for stands. The purpose of this study was to identify the species composition of leaf-eating insects on the territory of State Enterprise Zhytomyrske Forestry and the subcompartments with the greatest threat of foci development of the dominant species – *Tortrix viridana*, taking into account forest site conditions and stand structure. During the feeding period, the species composition of leaf-eating insects was identified, and after the end of oviposition, the density of *Tortrix viridana* egg masses was assessed on tree branches selected in subcompartments with different forest site conditions, age, the relative crop density, and proportion of oak in the stand composition. The database of forest inventory (Ukrderzhlisproekt) and the score assessment of the preferences of stands for foci development were used. Eleven species of leaf-eating insects from order *Lepidoptera* were identified, including 9 species from the family *Tortricidae*, of which *Tortrix viridana* dominated. The highest egg mass density of this pest was assessed in fresh dubrava conditions (D_2), in pure oak plantations aged 40-80 years with a low relative crop density. The average score of stand preference for *Tortrix viridana* was assessed by forest site conditions (2.93 and 2.88 for seed plantations and coppice forest, respectively), age (3.65), the relative density of stocking (2.6), and oak participation (3.3) in the State Enterprise Zhytomyrske Forestry. The list of subcompartments with a very high and high threat of an outbreak of *Tortrix viridana* has been established. A survey in these subcompartments would allow timely detection of pest population increase and prevent its development

Keywords: common oak, green oak leaf-roller, plot preference, forest site type, relative density of stocking, forest age



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INTRODUCTION

Common oak (*Quercus robur* L.) is distributed on about 27% of the forest fund of the State Forest Resources Agency of Ukraine, or 62% of the area of hardwood plantations [1]. In particular in Zhytomyr Oblast the share of oak plantations is about 14% [2]. Hundreds of species of insects feed on the leaves of oak trees, but only some of them are capable to increase their numbers hundreds of times every few years and completely devour the crowns of trees [3; 4]. These insects include mainly members of the order *Lepidoptera*, including the families *Tortricidae*, *Geometridae*, *Lymantriidae* and some others. Damage to 25% of the leaves has little effect on the condition and growth of plantings. At the same time, during outbreaks of mass reproduction, some trees can be completely eaten by larvae of leaf-eating insects 2-3 years in a row. This negatively affects the sanitary state of the forest and its increment [5-9], increases the susceptibility of trees to colonisation with stem pests [10] and pathogens [11].

To reduce the time and money spent on identifying foci of mass reproduction of leaf-eating insects and the timely application (if necessary) of forest protection measures, it is very important to know in which plantations the threat of foci development is greatest, and to monitor it [12-14]. The prevalence of leaf-eating insects depends on the availability of food (trees of a certain species), favourable microclimatic conditions for the existence of both leaf-eating insects and entomophages, which regulate the number of these pests [15; 16].

The availability of attractive food for leaf-eating insects depends on the type of forest site types and the species composition, which is determined by silvicultural and forestry measures. Microclimatic conditions (lighting, temperature, humidity) are formed by a certain combination of relative crop density, age, composition of plantations. Microclimatic conditions are significantly affected by a sharp increase in lighting and heating due to changes in land categories of neighboring areas after fire, wind, economic measures, [15; 17]. Usually leaf-eating insects are attracted by illuminated and warm areas of plantations [18-24], and for entomophages – more shaded, with a variety of flowering plants [3; 19; 25]. For polyphagous insects, the species composition is less important than for monophages [4; 20; 26; 27], which is, in particular, the green oak-roller moth *Tortrix viridana* Linnaeus, 1758 (*Lepidoptera: Tortricidae*).

These data on the distribution of foci of leaf-eating and needle-eating insects in forest stands and research materials allowed V.L. Meshkova [19] to score the indicators on each species in terms of the risk of development of foci of mass reproduction of the most common pests. Accordingly, using the forest management database for each species, the type of forest site types, age, participation of oak in the composition, and relative density of plantations are evaluated by a score. This approach allows estimating

the threat of outbreaks of certain pests in specific forest districts and forestry enterprises. This helps to establish a list of species and the area of plantations with very high and high risks of foci development [15]. The aforementioned approach is implemented in different regions of Ukraine, mainly for needle-eating insects in pine forests [18; 28]. In particular, with the use of digitised planting plans and appropriate software, the assessment of the threat of coniferous pests has been improved, taking into account changes in the land category of neighboring subcompartments [17].

At the same time, in deciduous plantations, the approach was tested in the Left-Bank Forest-Steppe [19]. According to studies of previous years [29], since the beginning of the 21st century there have been two outbreaks of mass reproduction of leaf-eating insects in the Zhytomyr Oblast, in 2002-2008 and 2010-2018. Moreover, in the forest fund of Zhytomyrske Forestry the maximum area of these insects during the last outbreak in 2013 reached 522 hectares. The following year it decreased almost twice, and since 2018 the populations of leaf-eating insects are depressed.

Thus, despite many studies of leaf-eating insects, the possibilities of using existing approaches to assess the threat of the spread of these pests in the forests of Zhytomyr Polissya remain unclear.

The *purpose* of the study was to identify the species composition of leaf-eating insects in the forests of Zhytomyrske Forestry SE and the subcompartments with the greatest threat of foci development of the most dominant species – green oak leaf-roller, taking into account forest site conditions and stand structure.

MATERIALS AND METHODS

The study was conducted in 2000 in the forest fund of State Enterprise Zhytomyrske Forestry. Given the publications [4; 19; 29] on the predominance among leaf-eating insects of species whose larvae feed in the spring – during the development of oak leaves, plantations were examined during the feeding period of the larvae. The surveys were carried out primarily in oak plantations, where the foci of mass reproduction of leaf-eating insects during the last outbreak were registered, as well as other plantations. Plantations were selected during the analysis of the Ukrderzhlisproekt database to cover the variety of types of forest growing conditions, age, relative density, and participation of common oak in the composition of forest stands.

Surveys of plantations were carried out along running lines [15]. As a part of the spring survey, in each subcompartment, 5 branches of oak were cut with a secateurs on a pole, and the number of growth shoots and caterpillars were estimated. Caterpillars were determined using identification guides [3; 30; 31], some individuals were fed leaves to form pupa and imago. The nomenclature of insect names was coordinated

with Fauna Europea [32]. The population density of caterpillars of each species was estimated as the number of individuals per 100 growth shoots. Since most species were very rare, these data were used only to determine the dominant species – green oak leaf-roller (*Tortrix viridana*).

After the flight of green oak leaf butterflies and their laying of eggs (from the second half of summer and autumn), the survey of plantations was conducted for the second time. During this examination, the egg mass density of this pest was determined [15]. For this purpose, 3 boughs at least 2 m long were selected from different parts of the crowns. The growth of the last year, secondary branches and shoots were cut off from each branch and only the central part was left. The number of eggs of *Tortrix viridana* on a segment of a bough 1 m long was counted. According to the obtained data on the egg mass density per 1 m of branch, the distribution of this pest in plantations was estimated depending on type of forest conditions, age, relative stand composition.

Forest site types were identified according to the edaphic grid of Alekseev-Pogrebnyak, which is built on the coordinates of trophic and humidity habitats [33]. Levels of threat of development of foci of *Tortrix viridana* were determined using the data of VO Ukrderzhlisproekt on the forest fund of Zhytomyrske Forestry. Using MS Excel filters, species in which the common oak is the main forest-forming species were selected. The area of plantations was calculated separately for each forest site type, for 10-year age classes of forest stands (≤ 20 years, 21-30, 31-40, 41-50, 51-60, 61-70, 71-80 and > 80 years), for relative density intervals (≤ 0.4 ; 0.5; 0.6; 0.7 and ≥ 0.8) and for plantations with different parts of oak in the composition (≤ 2 units, 3-5, 6, 7-8 and ≥ 9 units). Each indicator was scored according to the method proposed by V.L. Meshkova [19] and the corresponding areas and their shares were calculated from the total area of oak plantations in the forest fund of Zhytomyrske Forestry.

Statistical analysis of the data consisted in determining the average values of the *Tortrix viridana* egg mass density, standard error and their comparison using

the Student's t test [34]. The calculations were carried out using MS Excel software package.

RESULTS AND DISCUSSION

The findings of the survey of deciduous plantations of State Enterprise Zhytomyrske Forestry in the spring of 2020 indicate that damage caused by leaf-eating insects did not exceed 20%. During the examination, 11 species of leaf-eating insects from two families of the order *Lepidoptera* were identified. From the family *Tortricidae*, 9 species have been identified: *Tortrix viridana* Linnaeus, 1758 – green oak leaf-roller; *Pandemis cerasana* (Hübner, 1786) – barred fruit-tree tortrix; *Ptycholoma lecheana* (Linnaeus, 1758) – Leche's twist moth; *Archips podana* (Scopoli, 1763) – large fruit-tree tortrix; *Archips xylosteana* (Linnaeus, 1758) – variegated golden tortrix; *Archips crataegana* (Hübner, 1799) – brown oak tortrix; *Archips rosana* (Linnaeus, 1758) – rose tortrix; *Adoxophyes orana* (Fischer v. Röslerstamm, 1834) – summer fruit tortrix; *Aleimma loeflingiana* (Linnaeus, 1758) – yellow oak button. From the family *Geometridae*, 2 species were found: *Operophtera brumata* (Linnaeus, 1758) – winter moth; *Erannis defoliaria* (Clerck, 1759) – mottled umber. Most of the identified species are polyphagous and only *Tortrix viridana* L. is a monophage, which feeds only on the leaves of common oak. Caterpillars of this species were the most common – their average density was 0.7 ± 0.12 specimens per 100 growth shoots, while the density of other species did not exceed 0.1 ± 0.03 specimens per 100 growth shoots. The results of counting the caterpillars of leaf-eating insects during their feeding confirmed the expediency of counting the egg deposition of *Tortrix viridana* to determine the most attractive plantations for the pest outbreak.

The results of accounting for the egg deposition of *Tortrix viridana* carried out in the second half of 2000 revealed the peculiarities of their distribution by forest site type, age, crop density, and share of oak in the forest composition. Among the surveyed forest stands, the presence of egg depositions of *Tortrix viridana* was found only in three forest site types (FST) – fresh sudubrava (C_2), moist sudubrava (C_3) and fresh dubrava (D_2) (Fig. 1).

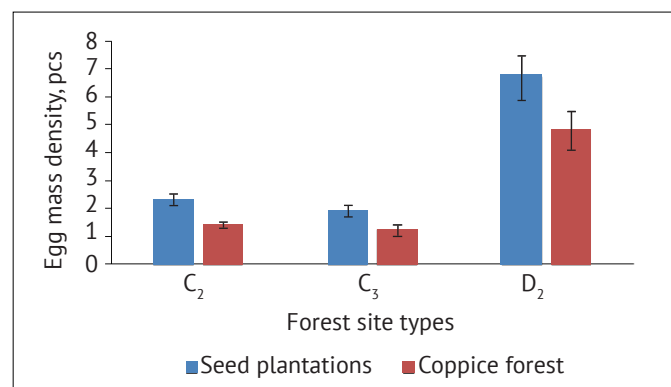


Figure 1. Distribution of egg mass density (\pm standard error) of *Tortrix viridana* depending on the forest site type: C_2 – fresh sudubrava; C_3 – moist sudubrava; D_2 – fresh dubrava

The egg mass density of *Tortrix viridana* in coppice stands of fresh dubrava was significantly higher than in coppice stands of fresh sudubrava ($t_{\text{fact.}} = 5.3$; $t_{0.01} = 2.73$) and moist sudubrava ($t_{\text{fact.}} = 5.8$; $t_{0.01} = 2.73$). The egg mass density in seed plantations of fresh dubrava was significantly higher than in seed plantations of fresh sudubrava ($t_{\text{fact.}} = 4.8$; $t_{0.01} = 2.76$) and moist sudubrava ($t_{\text{fact.}} = 4.9$; $t_{0.01} = 2.76$). The differences in the egg mass density between fresh and moist forest sites are not significant in both coppice stands ($t_{\text{fact.}} = 1.4$; $t_{0.05} = 2.02$) and in high forest ($t_{\text{fact.}} = 0.9$; $t_{0.05} = 2.02$). In all forest site types, the egg mass density of *Tortrix viridana* was higher in coppice than in high forest. The differences are significant only in moist sudubrava: in fresh dubrava ($t_{\text{fact.}} = 1.8$; $t_{0.05} = 2.02$), in fresh sudubrava ($t_{\text{fact.}} = 1.8$; $t_{0.05} = 2.02$) and in moist sudubrava ($t_{\text{fact.}} = 4.0$; $t_{0.05} = 2.02$).

Analysis of the distribution of the area of oak plantations in the forest fund of Zhytomyrske Forestry SE

by forest site types (Table 1) shows the predominance of seed plantations. According to the forest site types, both seed and coppice oak plantations predominate in fresh sudubrava, moist sudubrava and fresh dubrava. In fresh dubrava, where the highest egg density of *Tortrix viridana* was found, only 7.88% and 0.54% of high and coppice oak plantations, respectively, are represented.

The calculation of area of oak plantations with a different level of threat of *Tortrix viridana* outbreak, given the forest site type and the origin of stands (seed and coppice), shows that at the largest area (71.1 and 89.7% of seed and coppice stands, respectively) the risk of pest outbreaks is average (score "3" [19]) (Table 2). The share of the area with a very high risk of *Tortrix viridana* outbreak in seed and coppice stands is 7.9 and 0.5%, respectively. The average weighted score of attractiveness for *Tortrix viridana* of forest site types of seed oak plantations – 2.93, and coppice forest – 2.88.

Table 1. Distribution of the oak plantations area in Zhytomyrske Forestry SE by forest site types (FST)

Forest site types (FST)	Area, ha		Share, %	
	seed plantations	coppice forest	seed plantations	coppice forest
B ₂ – fresh subor	118.8	5.5	0.82	3.28
B ₃ – moist subor	106.0	0.7	0.73	0.42
C ₂ – fresh sudubrava	3192.9	30.6	22.01	18.24
C ₃ – moist sudubrava	7120.2	119.9	49.09	71.45
C ₄ – wet sudubrava	2.4	–	0.02	0.00
D ₂ – fresh dubrava	1143.6	0.9	7.88	0.54
D ₃ – moist dubrava	2821.0	10.2	19.45	6.08
D ₄ – wet dubrava	0.9	–	0.01	0.00
Total	14505.8	167.8	100.00	100.00

Note: Estimated on the basis of VO Ukrderzhlisproekt database as of January 1, 2019

Table 2. Distribution of stand area in different FST by attractiveness for *Tortrix viridana*

Indicators	Threat of foci development, points*			
	0 – absent and 1 low	2 – low	3 – average	5 – very high
FST	C ₄ , D ₄ , B ₂ –B ₃	D ₃	C ₂ –C ₃	D ₂
<i>oak seed plantations</i>				
Area	228.1	2821	10313.1	1143.6
Share, %	1.5	19.5	71.1	7.9
<i>oak coppice forest</i>				
Area	6.2	10.2	150.5	0.9
Share, %	3.7	6.1	89.7	0.5

Note: * – points according to [19]

Analysis of egg mass density of *Tortrix viridana* by age of stands shows that the pest inhabits the stands at the age of 20 years, and only after 80 years the number of individuals decreases (Fig. 2).

A significant increase in the egg mass density of *Tortrix viridana* was observed in the age range of 31-40 years compared with the interval of 21-30 years ($t_{\text{fact.}} = 2.9$; $t_{0.01} = 2.71$) and in the age range of 41-50 years compared with interval of 31-40 years ($t_{\text{fact.}} = 4.7$; $t_{0.01} = 2.71$).

A significant decrease in this indicator occurred at the age of over 80 years ($t_{\text{fact.}} = 6.2$; $t_{0.01} = 2.71$). Changes in the indicator within ten-year age intervals from 41 to 80 years are not significant ($t_{\text{fact.}} = 0.7-1.3$; $t_{0.05} = 2.02$).

The obtained data on the egg mass density of *Tortrix viridana* by age of stands do not differ from the literature [19]. Therefore, the distribution of the area of plantations by different ages was calculated according to the risk of pest outbreak (Table 3).

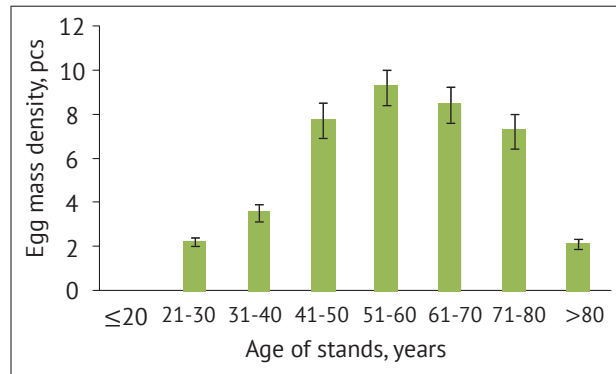


Figure 2. Distribution of egg mass density (\pm standard error) of *Tortrix viridana* depending on age of stands

Table 3. Distribution of the area of plantations by different ages according to their attractiveness for *Tortrix viridana*

Indicators	Threat of foci development, points*			
	0 – absent	2 – low	3 – average	5 – very high
Age, years	≤20	21-30 >80	31-40	41-80
Area	325.6	5877.2	283.1	8187.7
Share, %	2.2	40.1	1.9	55.8

Note: * – points according to [19]

According to the scoring of the attractiveness of oak stands by age, stands under 20 years of age are unsuitable for the development of *Tortrix viridana*. The area of such plantations is only 2.2%. Plantations with a low risk of *Tortrix viridana* outbreak – aged 21-30 years and over 80 years – account for 40.1% of the area.

Plantations with an average threat of *Tortrix viridana* outbreak (aged 31-40 years) grow on the area of 283.1 ha (1.9%). The most attractive for the pest outbreak are stands aged 41-80 years, occupying an area of 8187.7 ha (55.8% of the area of oak plantations) (Table 3). The average weighted score of attractiveness

for *Tortrix viridana* by the age of oak stands of the forest fund of Zhytomyrske Forestry is 3.65.

Analysis of the distribution of egg mass density of *Tortrix viridana* by the relative crop density (Fig. 3) shows a decrease in the pest population as the relative crop density increases. Differences in the egg mass density are significant between areas with relative crop density up to 0.4 and 0.5 ($t_{\text{fact.}} = 2.8$; $t_{0.01} = 2.71$), 0.6 and 0.7 ($t_{\text{fact.}} = 6.5$; $t_{0.01} = 2.71$), 0.7 and 0.8 ($t_{\text{fact.}} = 6.0$; $t_{0.01} = 2.71$) and are not significant between sites with relative crop density of 0.5 and 0.6 ($t_{\text{fact.}} = 1.3$; $t_{0.05} = 2.02$).

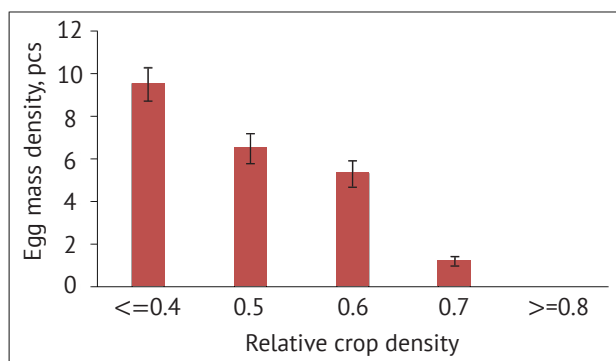


Figure 3. Distribution of egg mass density (\pm standard error) of *Tortrix viridana* depending on relative crop density

Distribution in plantings of phytophagous insects, in particular leaf-eating [4, 18], is largely determined by the relative crop density. The illumination of areas, rates and intensity of freezing, thawing, heating and cooling of soil, heating and cooling of air, ratio of terms and rates of development of trees, and composition of phytophagous and entomophagous insects depend on this indicator [19]. That is why the foci of mass reproduction of phytophages are most common in stands with lower relative crop density, as well as near suddenly illuminated areas as a result of windbreaks, fires, felling, construction, etc. [17].

Analysis of forest management data shows that among the oak plantations of Zhytomyrske Forestry, stands with a relative density of 0.7 (6648.6 ha, or 45.3%) prevail. Such plantations have a high risk of *Tortrix viridana* outbreak (Table. 4).

The area with less relative crop density, in which the risk of outbreak of leaf-eating insects is very high, is 15.8% of the area of oak plantations. In high-density stands (with a relative crop density of 0.8-1.0) there is no threat of pest outbreak. The average weighted score of attractiveness for *Tortrix viridana* in terms of the relative crop density of oak plantations of the forest fund of Zhytomyrske Forestry is 2.6.

As is well known [26; 35; 36], the resistance of plantations to insect damage is higher with greater biodiversity. According to V.L. Meshkova [19], plantations lose their attractiveness for *Tortrix viridana* even with the share of oak less than 7 units. According to the authors' study, the egg mass density of *Tortrix viridana* in the Zhytomyrske Forestry increased as the share of oak in the stands increased (Fig. 4).

Table 4. Distribution of area by the attractiveness of stands of different crop density for *Tortrix viridana*

Indicators	Threat of foci development, points*		
	0 – absent	4 – high	5 – very high
Age, years	≥0.8	0.7	≤0.6
Area	5710.7	6648.6	2314.3
Share, %	38.9	45.3	15.8

Note: * – points according to [19]

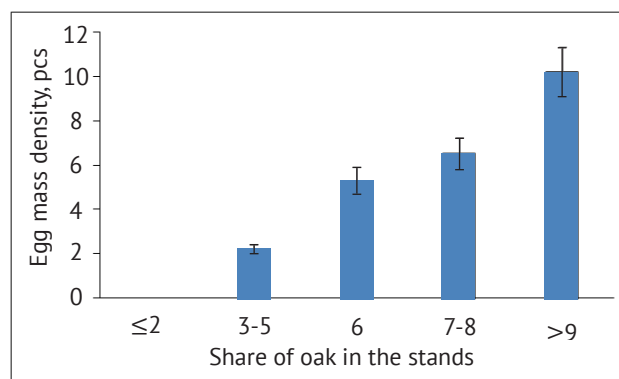


Figure 4. Distribution of egg mass density (\pm standard error) of *Tortrix viridana* depending on the share of oak in the stands

Differences in the egg mass density are significant between areas with a consistent increase in the share of oak in the composition from 3 to 6 ($t_{\text{fact.}} = 4.9$; $t_{0.01} = 2.71$), from 7 to 9 ($t_{\text{fact.}} = 2.8$; $t_{0.01} = 2.71$) and are not significant between sections with relative crop density of 6 and 7 ($t_{\text{fact.}} = 1.3$; $t_{0.05} = 2.02$).

The analysis of forest management data shows

that with the participation of oak in the composition of the oak plantations of the Zhytomyrske Forestry, stands with low threat of foci development prevail (Table 5). At the same time, plantations with an oak share of 7-8 (high threat) and 9-10 units (very high threat) are quite widely represented.

Table 5. Distribution of area of stands with different share of oak plantations on the attractiveness for *Tortrix viridana*

Indicators	Threat of foci development, points*				
	0 – absent	2 – low	3 – average	4 – high	5 – very high
Share of oak in the composition, units	≤ 2	3-5	6	7-8	≥9
Area	55.9	5463.8	2323.4	3848.7	2981.8
Share, %	0.4	37.3	15.8	26.2	20.3

Note: * – points according to [19]

The weighted average score of attractiveness for *Tortrix viridana* by the share of oak in the plantations of the forest fund of Zhytomyrske Forestry is 3.3.

The obtained data allow using forest management materials to determine the areas of forest where the pest outbreak is most probable, to calculate the area of potential foci, and to take the necessary measures to protect the forest in a timely manner.

Taking into account the forest site type, age, relative crop density and composition (see Tables 2-5), then, judging by the forest management database, in Zhytomyrske Forestry, the greatest risk of *Tortrix viridana* exists only in two divisions: Berezivske forestry, quarter 72 compartment 6 (1.3 ha) and Korabelne forestry quarter 61 compartment 1 (1 ha). Both plantations are located in FST D₂, have planting-stock age of 73 years, a relative crop density of 0.6 and 9 and 10 units of oak in the composition.

Taking into account areas with a very high and high risk of *Tortrix viridana*, adding compartments with a relative density of 0.7 and the share of oak in the composition of 7 and 8 units (see Tables 4, 5), the area of such plantations is 75 Ha.

Thus, oak plantations of Zhytomyrske Forestry are generally resistant to outbreaks of green oak leaf-roller and associated species of leaf-eating insects. At the same time, it is recommended to monitor the condition

of plantations in areas with the highest risk of mass reproduction outbreaks.

CONCLUSIONS

1. Eleven species of leaf-eating insects from the order *Lepidoptera*, including 9 from the family *Tortricidae*, were found in the oak plantations of the State Enterprise Zhytomyrske Forestry. Among the insects, the green oak leaf-roller (*Tortrix viridana* L.) dominated.

2. The highest egg mass density of *Tortrix viridana* was determined in fresh dubrava (D₂), in plantations aged 50 to 80 years. The egg mass density increased as the share of oak in the plantations increased and the relative crop density decreased.

3. The attractiveness of oak plantations for *Tortrix viridana* by forest site type is 2.93 and 2.88 for seed and coppice stands, respectively, by age of stand – 3.65, the relative crop density and participation of oak in the composition – 2.6 and 3.3 points. That is, the risk of outbreaks is average.

4. The combination of the most favourable conditions for the mass reproduction of *Tortrix viridana*, such as forest site type, age of stand, relative crop density, and composition of plantations is determined only in two compartments with a total area of 2.3 hectares, and the area of high and very high risk is 75 hectares.

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ОСОБЛИВОСТІ ПРОГНОЗУВАННЯ ПОШИРЕННЯ КОМАХ-ЛИСТОГРИЗІВ У ЛІСАХ ЖИТОМИРСЬКОГО ПОЛІССЯ

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Анотація. Пошкодження листя комахами-листогризами під час масових розмножень спричиняє погіршення санітарного стану насаджень і зменшення їхнього приросту. Вчасне виявлення осередків шкідників дає змогу зменшити витрати на їхню ліквідацію та запобігти негативним наслідкам для насаджень. Метою досліджень було визначити видовий склад комах-листогризів у лісах ДП «Житомирське ЛГ» та ділянки з найбільшою загрозою формування осередків домінантного виду – зеленої дубової листовійки з урахуванням лісорослинних умов і структури насаджень. У період живлення комах-листогризів визначали їхній видовий склад, а після завершення відкладання яєць оцінювали щільність кладок яєць зеленої дубової листовійки на гілках дерев, відібраних у насадженнях із різними типом лісорослинних умов, віком, відносною повнотою та часткою дуба у складі. Під час аналізу використано базу даних ВО «Укрдержліспроект» і бальову оцінку принадності насаджень для формування осередків. Виявлено 11 видів комах-листогризів із ряду лускокрилих (*Lepidoptera*), зокрема 9 – з родини листовійки (*Tortricidae*), з яких домінувала зелена дубова листовійка *Tortrix viridana*. Найбільшу щільність її кладок яєць визначено у свіжій діброві (D₂), у чистих низькоповнотних насадженнях віком 40–80 років. Розраховано середній бал принадності насаджень ДП «Житомирське ЛГ» для цього шкідника за типом лісорослинних умов (2,93 та 2,88 для насінневих і порослевих деревостані відповідно), віком (3,65), відносною повнотою (2,6) та участю дуба у складі (3,3). Встановлено перелік ділянок і площу насаджень із дуже високою та високою загрозою формування осередків масового розмноження зеленої дубової листовійки. Проведення нагляду на цих ділянках дасть змогу вчасно виявити зростання чисельності шкідника та вжити заходів запобігання його розвитку

Ключові слова: дуб звичайний, зелена дубова листовійка, принадність насаджень, тип лісорослинних умов, повнота насаджень, вік насаджень



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ANALYSIS OF SPECIES DIVERSITY OF FORESTS ON THE TERRITORY OF KHARKIVSKA OBLAST

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Abstract. The paper presents the findings of a study of species diversity of forests in the Kharkivska Oblast. The study was conducted on the territory of ten forestry enterprises and the State Enterprise Kharkiv Forest Research Station and the Homilsha Woods National Nature Park on an area of 282.3 thousand ha (area is subordinated to the State Forest Resources Agency of Ukraine). The purpose of the study was to analyse the species diversity and typological structure of forests in the Kharkivska Oblast. The study of species diversity was carried out based on analysis of the subcompartment database of the VO Ukrderzhlisproekt. The plantations were classified by the trophotope on the territory of the research facility in accordance with the main methodological provisions of the Ukrainian forestry and forest typology. A diagrammatic map of forests and dominant species (common oak and Scots pine) was compiled using the MapInfo Professional 12.5 software package and a vector map of 12 forestries in the Kharkivska Oblast. It has been established that 56 species of trees grow in the Kharkivska Oblast. Among these tree species, the predominant ones are common oak (53.4%) and Scots pine (32.7%). The distribution of plantations by trophotope is characterised by certain features. For example, dubrava conditions prevail in the stands (65.6% of the total area covered by forest vegetation), subor forests are 3.5 times less represented, and sudubravas and pine forests are the least common. Among the forest types, the most common are fresh maple-linden dubravas (43.7%) and fresh oak-pine subors (18.9%). The practical significance of the study is that the analysis of species diversity and typological structure of forests must be taken into account during the planning, organisation, and conduct of forestry activities in the Kharkivska Oblast

Keywords: common oak, Scots pine, tree species, forest site types, trophotope, state enterprise, national nature park



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INTRODUCTION

The species diversity of forests is declining under the influence of human economic activity and climate change. This impact is global and irreversible [1]. There is a significant probability of changes in the most common species (Scots pine and common oak) of Ukraine, which in turn will lead to the transformation or even destruction of forest natural ecosystems that exist today [2]. If some decisive action is not taken now, further adaptation to climate change will require significant efforts and financial costs [3].

Forests for their intended purpose and location perform mainly water-conserving [4], protective [5], health-improving [6], aesthetic [7], educational and other functions [8]. Forests have sanitary and recreational value, cause a positive effect on climate, soil conditions, and water resources [9], reduce the effects of water [10] and wind erosion [11; 12], and is also a source of forest resources [13]. The formation and distribution of forest depends on the geomorphological structure, soil conditions, terrain and climatic features. All these factors must be taken into account during the planning, organisation, and management of forestry activities [14].

A significant number of papers, both by Ukrainian [15-17] and foreign [18-20] scientists, are devoted to the study of the species and typological structure of forests. In Ukraine, studies of the typological diversity of forests were mainly conducted within natural areas: Polissya, Forest-Steppe and Steppe. Regarding the study of species diversity of forests in the Kharkivska Oblast, recently such studies have been almost non-existent [21; 22]. The scientific novelty of the findings lies in the fact that the species and typological structure (by forest site types, trophotopes, and forest types) of forest plantations in Kharkivska Oblast was analysed for the first time, including diagrammatic maps of predominant species (Scots pine and common oak). The *purpose* of the study was to identify the features of the species diversity of forests in the Kharkivska Oblast.

To achieve the stated goal, the following research objectives were set:

- to analyse the distribution of plantations by tree species and forest types;
- to compile a map of forests and predominant species (Scots pine and common oak);
- to determine the number of tree species, forest site types, and trophotopes on the territory of forestry enterprises in Kharkivska Oblast.

MATERIALS AND METHODS

Species diversity of forests of state forestry enterprises located in the Kharkivska Oblast, which are subordinated to the State Forest Resources Agency of Ukraine, was determined based on the forest inventory materials as of 01.01.2016. The subcompartment databases of Ukrderzhlisproekt were converted using the NewUn-PackOHOTA software package, which was developed at the URIFFM named after G.M. Vysotsky [23].

Study was conducted in several stages. At the first stage, materials of forest inventory of ten state-owned enterprises (SE Balakliyske forestry, SE Blyzniukivske forestry, SE Vovchanske forestry, SE Hutyanske forestry, SE Zhovtneve forestry, SE Zmiivske forestry, SE Izyumske forestry, SE Krasnogradske forestry, SE Kupyanske forestry, SE Chuguevo-Babchanske forestry), Kharkiv Forest Research Station, and Homilsha Woods National Nature Park were put together and analysed (Fig. 1). These materials (databases) were grouped by certain indicators. The filtering of information was carried out in the following sequence: tree species, forest site types, trophotopes, and forest types. The analysis of these data was performed using appropriate computer software (*Microsoft Excel 2010*), as well as geoinformation technologies (*MapInfo Professional 12.5. Beta*). The silvicultural and typological analysis of forests was carried out in accordance with the main methodological provisions of the forestry and ecological (Ukrainian) consensus group of forest typology [24].

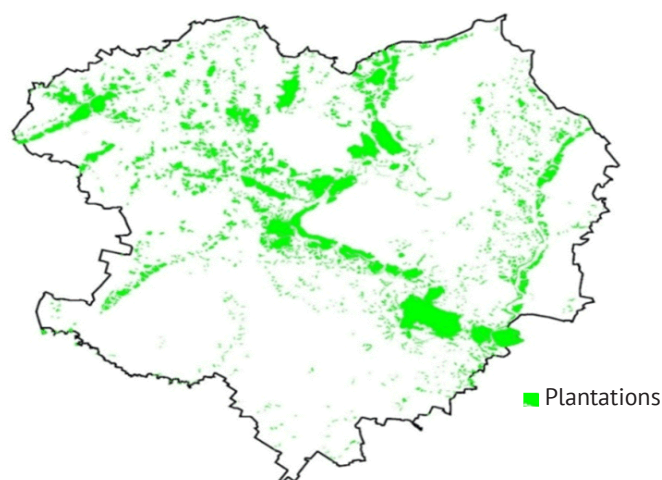


Figure 1. Diagrammatic map of forest distribution in the Kharkivska Oblast

At the second stage, diagrammatic map of forests, distribution of predominant tree species (common oak and Scots pine) in the Kharkivska Oblast has been compiled. It was done using *MapInfo Professional 12.5. Beta* and vector map of Ukraine. Thus, the geographical coordinates of the extreme points of the survey plot: in the North – 37° 29'33", 50° 27'26", in the South – 36° 17'50", 48° 31'56", in the West – 34° 51'27", 49° 59'11", and in the East – 38° 05'36", 49° 50'43". The total area of the investigated forests, which are subordinated to the State Forest Resources Agency of Ukraine, is 282.3 thousand hectares. The distribution of forests in the Kharkivska Oblast is uneven. They are mostly located in the floodplain of the Siverskyi Donets river and its tributaries.

RESULTS AND DISCUSSION

Species composition of forests in the Kharkivska Oblast is quite diverse. Thus, the largest concentration of species is in SE Izyumske forestry (37 species of trees) and SE Zhovtneve forestry (36 species of trees), and the least – in SE Chuguevo-Babchanske forestry (21 species of trees) and the Homilsha Woods NNP (16 species of trees), respectively (Table 1). A total of 18 forest site types have been identified on the territory of research facility. Thus, most of them are concentrated in the Izyumske forestry (18 site types), and the least – in the Homilsha Woods NNP (8 site types).

The distribution of forests in the Kharkivska Oblast

by trophotopes is characterised by certain peculiarities. Thus, the plantations are dominated by dubrava site type (65.6% of the total area covered by forest vegetation), 3.5 times less represented are subors (18.3%), and the least represented are sudubravas (9.9%) and pine forests 6.2%.

In total, 18 types of forest sites have been identified in the forests of the Kharkivska Oblast, in particular, in pine forests there are 3 site types, and in subors, sudubravas and dubravas – 5 site types in each. Pine forests with poor growing conditions are present on the territory of 10 enterprises, and their share varies from 0.3% (SE Kharkiv Forest Research Station) to 27.7% (SE Izyumske forestry). On the territory of two enterprises (SE Blyzniukivske forestry and Homilsha Woods NNP) pine woods are not detected at all. Subor types are common on the territory of all enterprises, and their share varies from 0.3% (Homilsha Woods NNP) to 32.3% (SE Izyumske forestry). Sudubrava types are present on the territory of all enterprises, and their share ranges from 2.1% (SE Kharkiv Forest Research Station) to 25.4% (SE Hutyanske forestry). In dubrava (rich) conditions, plantations grow on the territory of all enterprises, and their share varies from 25.1% (SE Izyumske forestry) to 94.4% (Homilsha Woods NNP). After analysing the distribution of plantating by trophotopes in the Kharkivska Oblast (Fig. 2), it was determined that the natural conditions are favourable for growing high-yielding plantations of common oak and Scots pine.

Table 1. Distribution of forest areas in the Kharkivska Oblast

State-owned enterprise	Number		Area	
	tree species	forest site types	ha	%
SE Balakliyske forestry	29	17	22,650.0	8.0
SE Blyzniukivske forestry	25	11	5,350.8	1.9
SE Vovchanske forestry	27	16	25,830.0	9.1
SE Hutyanske forestry	30	16	27,686.1	9.8
SE Kharkiv Forest Research Station	33	14	19,753.7	7.0
SE Zhovtneve forestry	36	16	45,321.8	16.1
SE Zmiivske forestry	28	17	23,752.1	8.4
SE Izyumske forestry	37	18	43,101.8	15.3
SE Krasnogradske forestry	28	15	12,083.3	4.3
SE Kupyanske forestry	33	18	33,633.1	11.9
Homilsha Woods NNP	16	8	3167.7	1.1
SE Chuguevo-Babchanske forestry	21	15	19,999.0	7.1
Total	56	18	282,329.4	100.0

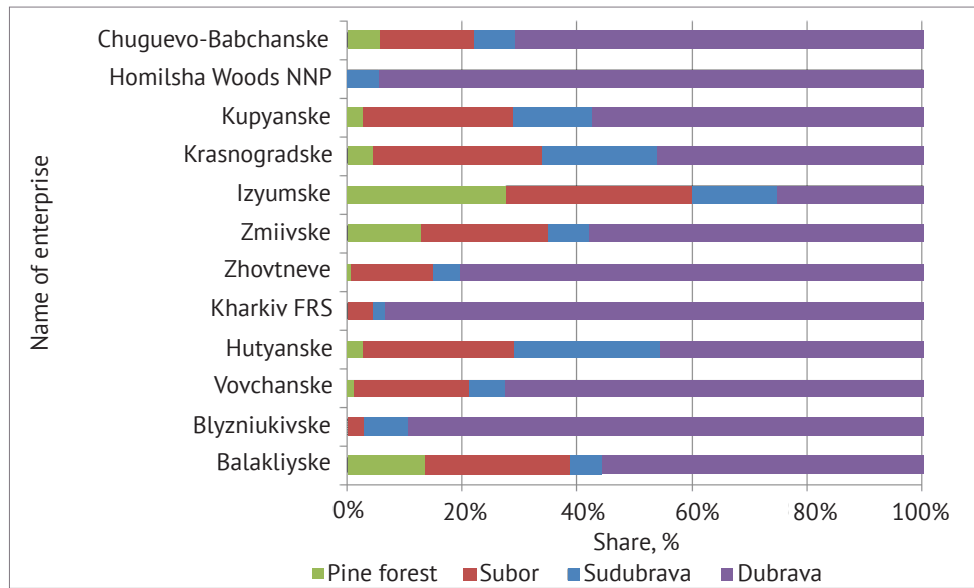


Figure 2. Distribution of plantation areas of enterprises by trophotypes, %

In each type of forest sites, foresters have allocated a different number of forest types. The pine forests are represented by four, the subors by seven, the sudubravas by eleven, and the dubravas by thirteen forest types. A total of 35 forest types were identified: one was very dry, six were dry, ten were fresh, nine were moist, five

were wet, and four were damp (Table 2). The typological variety of forests in the Kharkivska Oblast is quite diverse. Thus, the most common type of forest is fresh maple-linden dubrava (43.9% of the total area covered with forest vegetation), a slightly smaller share is fresh oak-pine subor (18.9%) and dry maple-linden dubrava (11.9%).

Table 2. Forest types in the Kharkivska Oblast

Forest type		Area	
Name	Index	ha	%
Very dry pine forest	A ₀ -P	19.2	0.01
Dry pine forest	A ₁ -P	5,543.4	2.0
Fresh pine forest	A ₂ -P	17,131	6.1
Moist pine forest	A ₃ -P	11.5	0.0
Dry oak-pine subor	B ₁ -oP	5,243.2	1.9
Dry eroded oak subor	B ₁ -Oe	4.9	0.0
Fresh oak-pine subor	B₂-oP	53,285.8	18.9
Moist oak-pine subor	B ₃ -oP	1,348.9	0.5
Moist floodplain sedge subor	B ₃ -Sf	201.1	0.1
Wet oak-pine subor	B ₄ -oP	142.8	0.1
Damp birch-pine subor	B ₅ -bP	4.3	0.002
Dry eroded Tatarian maple sudubrava	C ₁ -TmOe	3,602.1	1.3
Fresh oak sudubrava	C ₂ -O	919.3	0.3
Fresh eroded linden sudubrava	C ₂ -lOe	2,072.6	0.7
Fresh linden-oak-pine sudubrava	C ₂ -loP	15,571.8	5.5
Fresh floodplain oak sudubrava	C ₂ -Of	1,525.8	0.5
Moist maple-linden sudubrava	C ₃ -mLO	287.8	0.1

Continuation of table 2

Forest type		Area	
Name	Index	ha	%
Moist linden-oak-pine sudubrava	C ₃ -loP	1,330.0	0.5
Moist floodplain oak sudubrava	C ₃ -Of	1,619.8	0.6
Wet alder sudubrava	C ₄ -A	2,062.7	0.7
Wet poplar-willow sudubrava	C ₄ -pW	236.5	0.1
Damp alder sudubrava	C ₅ -A	155.0	0.1
Dry elm-Tatarian maple dubrava	D ₁ -eTmO	711.0	0.3
Dry maple-linden dubrava	D₁-mLO	33,608.6	11.9
Fresh elm-Tatarian maple dubrava	D ₂ -eTmO	404.1	0.1
Fresh maple-linden dubrava	D₂-mLO	123239.2	43.7
Fresh ash-linden dubrava	D ₂ -aLO	103.0	0.04
Fresh floodplain elm-Tatarian maple dubrava	D ₂ -etmOf	1,042.5	0.4
Moist maple-linden dubrava	D ₃ -mLO	707.9	0.3
Moist ash-linden dubrava	D ₃ -aLO	1,144	0.4
Moist floodplain elm-Tatarian maple dubrava	D ₃ -etmOf	7,204.4	2.6
Wet alder dubrava	D ₄ -A	1,110.3	0.4
Wet floodplain poplar-willow dubrava	D ₄ -pWf	177.8	0.1
Damp alder dubrava	D ₅ -A	518.9	0.2
Damp floodplain willow dubrava	D ₅ -Wf	38.2	0.01
Total			100.0

The greatest typological diversity is characteristic of the forests of the State Enterprise Izyumske forestry (34 forest types), and the least – for the forests of the Homilsha Woods NNP (12 forest types). The small number

of forest types is explained by the homogeneity of geomorphological, soil, and climatic conditions of plantation within the relevant forestry enterprises (Fig. 3).

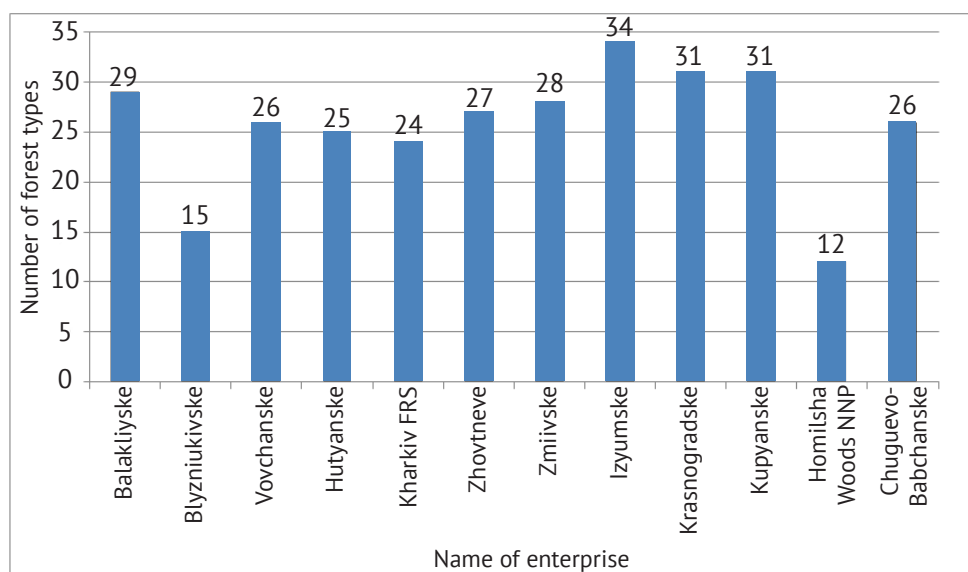


Figure 3. Distribution of the total number of forest types by enterprises

The nature of the distribution of wood species on the territory of the research facility is quite uneven (Fig. 4). Thus, in the Kharkivska Oblast there are 56 species of trees, of which the most common (Table 3) are common

oak (*Quercus robur* L.) – 53.4% (150798.4 ha of the total area covered by forest vegetation) and Scots pine (*Pinus sylvestris* L.) – 32.7% (92380.0 ha).

Table 3. Distribution of areas of predominant tree species in the Kharkivska Oblast, ha*

Tree species	Total	
	ha	%
European birch	2,727.1	1.0
Common alder	4,404.9	1.6
European elm	513.2	0.2
Common oak	150,798.4	53.4
Norway maple	3,387.0	1.2
Tatarian maple	1,248.9	0.4
Big-leaf linden	1,662.9	0.6
Black locust tree (false acacia)	7,142.3	2.5
Scots pine	92,380.0	32.7
European aspen	3,997.6	1.4
Silver poplar	1,622.5	0.6
Canadian poplar	752.9	0.3
Black poplar	684.2	0.2
European ash	7,062.3	2.5
Green ash	1,640.6	0.6
Other	2,304.6	0.8
Total	282,329.4	100.0

Note: * The table shows the data of the predominant tree species, the area of which is more than 150 ha, from the total area covered with forest vegetation on the territory of research facility

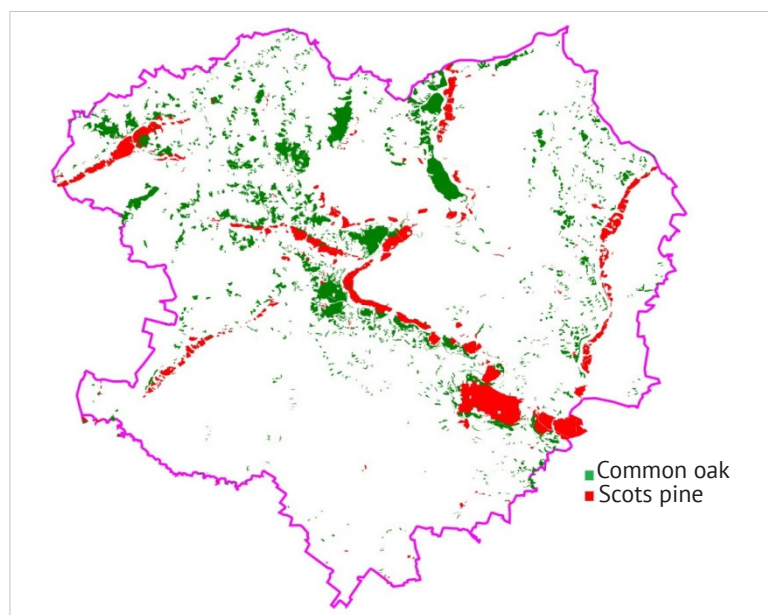


Figure 4. Diagrammatic map of the distribution of dominant tree species in the Kharkivska Oblast

With the increase of areas covered by forest vegetation, the number of forest types and tree species increases. This complicates the conditions for forest management activities in Kharkivska Oblast, and, in turn, increases biological diversity.

CONCLUSIONS

The species diversity of forests on the territory of the research facility is represented by 56 tree species. Among them, the largest share is occupied by common oak (53.4% of the total area covered with forest vegetation) and Scots pine (32.7%). Forest management activities on the territory of the research facility should be aimed at increasing the species diversity of forests by carrying

out certain economic activities.

The trophotopes are dominated by dubrava (oak) conditions, the share of which is 65.6% of the total area covered with forest vegetation. This contributes to the cultivation of highly productive oak forests. The typological structure of forests is represented by 35 forest types. Among the forest types, the most predominant are fresh maple-linden dubravas (43.9% of the total area covered with forest vegetation), fresh oak-pine subors (18.9%) and dry maple-linden dubravas (11.9%). According to the compiled diagrammatic maps of forests it is possible to determine the actual amount of woodland and peculiarities of plantation distribution. These materials can be used when creating new forests.

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АНАЛІЗ ВИДОВОГО РІЗНОМАНІТТЯ ЛІСІВ НА ТЕРИТОРІЇ ХАРКІВСЬКОЇ ОБЛАСТІ

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Анотація. Наведено результати досліджень видового різноманіття лісів на території Харківської області. Дослідження проведено на території десяти лісогосподарських підприємств, Харківської лісової науково-дослідної станції та Національного природного парку «Гомільшанські ліси» на площі 282,3 тис. га, які знаходяться у підпорядкуванні Держлісагенства України. Метою дослідження було проаналізувати видове різноманіття та типологічну структуру лісів на території Харківської області. Дослідження видового різноманіття здійснювали на основі аналізу повидільної бази даних ВО «Укрдержліспроєкт». Класифікацію насаджень за трофотопами на території дослідного об'єкта здійснювали згідно із основними методичними положеннями лісівничо-екологічної (української) школи лісової типології. Побудовано загальну схему-карту лісів і переважаючих порід (дуба звичайного та сосни звичайної) на основі програми *MapInfo Professional 12.5* і векторної карти 12 дослідних об'єктів на території Харківської області. Визначено, що на території Харківської області ростуть 56 видів деревних порід. Серед деревних порід найбільш поширеними є дуб звичайний (53,4 %) та сосна звичайна (32,7 %). Розподіл насаджень за трофотопами характеризується певними особливостями. Так, у насадженнях домінують грудові умови (65,6 % від загальної площі вкритої лісовою рослинністю земель), у 3,5 рази менше представлені субори (18,3 %), а найменш представлені є сугруди (9,9 %) і бори (6,2 %). Серед типів лісу найбільш поширеним є свіжа кленово-липова діброва (43,7 %) і свіжий дубово-сосновий субір (18,9 %). Практична цінність статті полягає в тому, що результати аналізу видового різноманіття і типологічної структури лісів необхідно враховувати під час планування, організації та проведенні лісогосподарських заходів на території Харківської області

Ключові слова: дуб звичайний, сосна звичайна, деревна порода, типи лісорослинних умов, трофотоп, державне підприємство, національний природний парк

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ECOLOGICAL AND FIRE CHARACTERISTICS OF FOREST ECOSYSTEMS OF THE “DREVLANSKY” NATURE RESERVE

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Abstract. The paper deals with the ecological and fire situation in the forest ecosystem of the “Drevlyansky” nature reserve. The relevance of this study is that every year Ukraine's forests suffer from fires that destroy significant areas, and forests with radiation pollution suffer from fires the most. The purpose of the study was to investigate the impact of radiation pollution on the fire situation in the forest ecosystem of the reserve. The main task was to distribute the area of the reserve according to the level of radiation pollution and fire hazard classes with and without taking into account radiation pollution. To achieve the results, the area of the forest ecosystem of the Reserve was distributed according to the levels of radiation pollution. The average fire hazard class between 2008 and 2018 ranged from 2.02 to 2.06, which in turn improves the fire situation. However, since the territory of the reserve has been exposed to radiation pollution, the distribution of areas by fire hazard classes has undergone changes between the years of forest management. Thus, the fire situation, taking into account radiation pollution, has deteriorated compared to the area that was not exposed to radiation pollution, and between 2008 and 2018 it improved and amounts to 1.16 and 1.17, respectively. Consequently, the distribution of area by fire hazard classes depends not only on the level of radiation pollution, but also on the taxational specifications (land category, and in plantations it depends on the type of forest vegetation conditions, age, and tree species). The results of the fire that occurred on the territory of the reserve in the spring of 2020 are shown, along with a map of the fire danger of the forest fund of the “Drevlyansky” nature reserve in 2018. The prospect of further research is to re-conduct a study of the level of radiation pollution and to carry out actual measurements every 10 years, without using calculation methods. This will provide a more reliable distribution of forest fund areas by fire hazard classes and affect the planning of strategic tasks to prevent fires in the reserve

Keywords: radiation pollution, fire situation, fire hazard class, forest ecosystem



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INTRODUCTION

As a result of the Chernobyl accident in 1986, the forests of Polissya region in Ukraine were subject to significant radioactive contamination [1]. Due to high radiation pollution, the probability of fire in such forests increases [2]. As a result of fires in radioactively contaminated forests, there is an increase in the radioactive background of the territory, as well as the deterioration of the ecological situation in the surrounding area. Every year in Ukraine, when the air temperature rises in the spring and summer, fire safety in forests becomes a major problem. In recent years, the number of fires and their area is growing steadily. Such an expansion is primarily due to an increase in air temperature and low precipitation [3].

The most dangerous are the crown fires that start from underbrushes and belong to the first class of fire danger. The onset of crown fires is also affected by the negative sanitary condition of forest stands (clutter and dead trees), which begins with surface fires, spreads to tree trunks and continues to spread to tree crowns, and burns a large area of forest [4]. However, a significant role in the fire situation is played by radiation contamination of the territory. The peculiarity of forests contaminated with radionuclides is that they increase the possibility of forest fires and reduce the effectiveness of the developed fire prevention system. Therefore, the question arises as to the study of the state of the radioactively contaminated forests and protection of forests from fires.

However, not only in Ukraine there are significant forest fires as a result of climate change and lack of precipitation. In the Amazon rainforest, fires also occur each year, which tend to increase [5]. In addition to climate change, it is also affected by human activities, mainly related to changes in land use [6]. Even the permafrost suffers from fires. Thus, during August 2017 in Greenland, more than 2.0 thousand hectares of forests were affected by fires. This indicates that the area under a layer of snow and ice becomes vulnerable to forest fires as a result of global warming [7]. Forest fires are not only detrimental to biodiversity, but also to human health. Particularly great damage is caused by fires that occur in radioactively contaminated lands [8; 9].

The *purpose* of the study is to determine how radiation pollution affects the fire hazard of forest ecosystems of the "Drevlyansky" nature reserve (hereinafter – the Reserve). In accordance with the purpose of the study, the following *tasks* were set:

- to distribute the area of forest ecosystems of the reserve according to the levels of radiation pollution;
- to distribute the area of forest ecosystems of the reserve according to fire hazard classes with and without radiation pollution;
- to estimate and compare the average fire hazard classes between 2008 and 2018.

MATERIALS AND METHODS

To establish the total area of contamination and fire hazard class, forest management materials (mensurational descriptions for 2008 and 2018) were used by the State Enterprise "Narodytske spetsializovane lisove hospodarstvo" (Narodytske, Klishchivske, Zaliske forestries), namely the natural areas included in the territory of "Drevlyansky" nature reserve [10]. The distribution of the territory of the Reserve according to the density of radiation pollution took place in accordance with the forest management instructions [11], which indicates the density of radiation pollution by zones. The main indicators for calculating the fire hazard class were: land category, species, composition, age, type of forest vegetation conditions, clutter, as well as radiation contamination of the territory. The fire hazard class of each division was established according to the scale of natural fire hazard assessment of forest land plots [12]. The average fire hazard class of forest ecosystems was determined by the equation 1 [13]:

$$F_{ca} = \frac{F_1 S_1 + F_2 S_2 + \dots + \dots F_n S_n}{\sum S} \quad (1)$$

where F_1, F_2, \dots, F_n – fire hazard classes of allotments (quarters);

S_1, S_2, \dots, S_n – corresponding areas of taxation plots (quarters).

When performing mathematical calculations according to equation 1, the share is the average class of fire hazard. A special feature is that the calculation of the average class of fire hazard does not require assigning a separate coefficient to each class of fire hazard. It is done when calculating the average class of plant quality, especially when there are plantations with class 1a.

For convenient grouping of taxation plots by ignition sources, filtering of ignition sources in a Microsoft Excel spreadsheet processor was used, where taxational specifications of research quarters will be listed. During the assignment of certain class of fire hazard to the stratum, it is also necessary to take into account the density of radiation pollution. Because in one case the stratum belongs directly to class 1, and in the other it increases the fire hazard class by one. After that, the summation of all areas for each class of fire hazard is carried out. The total area of fire hazard classes should be equal to the sum of the areas of taxation plots (quarters) in which the calculations were carried out.

RESULTS AND DISCUSSION

As a result of the survey of the forest fund in 1991-1992, the current territory of the Reserve is divided into three zones according to the density of ^{137}Cs pollution; the areas are presented in the table 1.

Table 1. Division of part of the Reserve territory by zones of radiation pollution (density of soil pollution ^{137}Cs in Ci/km^2)

Total area of pollution, ha/%	In particular by the pollution density					
	Zone 1	Zone 2			Zone 3	
	More 15.0	Subzone			Subzone	
		a	b	c	a	b
5.1-7.0		7.1-10.0	10.1-15.0	1.1-2.0	2.1-5.0	
16823.0	15450.0	58.0	55.0	1211.0	0	49.0
100.0	91.83	0.34	0.33	7.21	0	0.29

The largest area of forest ecosystems belongs to the first zone of radiation pollution and amounts to 15450.0 hectares or 91.83% of the reserve. The second zone of radioactive contamination includes 1324.0 ha or 7.88% of territory. For its part, the second zone is divided into 3 subzones. Subzone "a" includes 58.0 hectares or 0.33%. Subzone "b" is slightly smaller – 55.0 hectares or 0.33%. The largest area is occupied by subzone "b", which is 1211.0 hectares or 7.21%. Zone 3 includes 49.0 hectares or 0.29% of the territory. This zone is represented only by subzone "b".

There are villages in the forest ecosystems of the Reserve (Mali Klishchi, Shyshelivka, Zvizdal, Mali Minky, Khrypilya, Severivka, Rohy, Peremoha). These villages are located near the territories with the level of radiation pollution over 15 Ci/km^2 which are referred

to the zone of unconditional (obligatory) resettlement. [14]. Territories belonging to zone 2 are located near the Loznitsa village and near the road in the direction of village Mali Klishchi village, as well as alone in the middle of the forest. Furthermore, the quarters belonging to zone 2 (subzone "c") are located south of the Mali Klishchi village and north of the Mali Minky village. In the spring of 2020, the territory belonging to zone 3 was affected by fires, the radiation background of which became higher than the initial one. As the fire hazard class is established on the basis of taxational specifications (Tables 3-4), the forest ecosystem area of the Reserve was distributed by fire hazard classes for 2008 and 2018 without taking into account the level of radiation pollution (Table 2).

Table 2. Distribution of lands by fire hazard classes with and without taking into account radiation pollution between years of forest management

The year of forest management	(Area, ha) %	Fire hazard classes					Average class
		1	2	3	4	5	
Distribution by classes without taking into account radiation pollution							
2008	16823.0 100.0	<u>5289.4</u> 31.44	<u>7930.5</u> 47.14	<u>2177.4</u> 12.94	<u>819.4</u> 4.87	<u>606.3</u> 3.61	2.02
2018		<u>4955.2</u> 29.45	<u>8084.0</u> 48.05	<u>2270.8</u> 13.50	<u>906.7</u> 5.39	<u>606.3</u> 3.61	
Distribution by classes taking into account radiation pollution							
2008	16823.0 100.0	<u>15928.3</u> 94.68	<u>194.7</u> 1.16	<u>106.4</u> 0.63	<u>7.6</u> 0.05	<u>586.0</u> 3.48	1.16
2018		<u>15877.4</u> 94.38	<u>242.9</u> 1.44	<u>108.8</u> 0.65	<u>7.6</u> 0.05	<u>586.3</u> 3.48	

Table 3. Distribution of taxational specifications by fire hazard classes without taking into account radiation pollution between forest management years

Taxational specifications	Years of forest management	
	2008	2018
Class 1		
Coniferous plantations under 40 years old	3550.4	3319.2
Coniferous plantations over 40 years old (FST * 0 1)	416.2	420.4
Free-growing forest plantations	145.5	41.0
Cuttings after conifers	13.2	9.8
Other non-wooded lands located among coniferous plantations	1164.1	1164.8

Continuation of table 3

Class 2		
Coniferous plantations over 40 years old (FST 2)	7925.5	8079.0
Deciduous plantations (FST 0 1)	5.0	5.0
Class 3		
Coniferous plantations over 40 years old (FST 3 4)	1726.3	1810.5
Deciduous plantations (FST 2)	451.1	460.3
Class 4		
Coniferous plantations over 40 years old (FST 5)	17.1	17.1
Deciduous plantations (FST 3 4)	802.3	889.6
Class 5		
Deciduous plantations (FST 5)	20.0	20.0
Roads (forest), compartment line, fire line, etc	335.1	334.5
Water bodies	251.2	251.8

Note: *FST – forest site type

Table 4. Distribution of taxational specifications by fire hazard classes taking into account radiation pollution between forest management years

Taxational specifications	Years of forest management	
	2008	2018
Class 1		
Plantations of coniferous and deciduous species with the level of radiation pollution over 15 Ci/km ²	13714.6	13798.0
Meadows, bio-meadows	350.5	350.5
Aree-growing forest plantations	145.5	41.0
Cuttings after conifers	13.2	9.8
Coniferous plantations under 40 years old	496.3	453.5
- radiation pollution 10.1-15.0 Ci/km ²	482.9	432.8
- radiation pollution 7.1-10.0 Ci/km ²	0.2	5.3
- radiation pollution 5.1-7.0 Ci/km ²	13.2	15.4
Coniferous plantations over 40 years old (FST 0 1)	1.6	1.6
- radiation pollution 10.1-15.0 Ci/km ²	1.6	1.6
Coniferous plantations over 40 years old (FST 2)	393.0	408.8
- radiation pollution 10.1-15.0 Ci/km ²	302.2	316.7
- radiation pollution 7.1-10.0 Ci/km ²	17.4	17.4
- radiation pollution 5.1-7.0 Ci/km ²	31.9	33.2
- radiation pollution 2.1-5.0 Ci/km ²	41.5	41.5
Other non-wooded lands located among coniferous plantations	813.6	813.6
Class 2		
Deciduous plantations (FST 2)	60.9	68.6
- radiation pollution 10.1-15.0 Ci/km ²	58.9	66.6
- radiation pollution 5.1-7.0 Ci/km ²	2.0	2.0
Coniferous plantations over 40 years old (FST 3 4)	133.8	174.3
- radiation pollution 10.1-15.0 Ci/km ²	111.2	151.7
- radiation pollution 7.1-10.0 Ci/km ²	11.1	11.3
- radiation pollution 5.1-7.0 Ci/km ²	5.2	10.4
- radiation pollution 2.1-5.0 Ci/km ²	6.3	6.3

Continuation of table 4

<i>Class 3</i>		
Deciduous plantations (FST 3 4)	93.9	96.3
- radiation pollution 10.1-15.0 Ci/km ²	87.8	90.2
- radiation pollution 7.1-10.0 Ci/km ²	4.9	4.9
- radiation pollution 5.1-7.0 Ci/km ²	1.2	1.2
Coniferous plantations over 40 years old (FST 5)	12.5	12.5
- radiation pollution 7.1-10.0 Ci/km ²	12.5	12.5
<i>Class 4</i>		
Deciduous plantations (FST 5)	7.6	7.6
- radiation pollution 10.1-15.0 Ci/km ²	5.1	5.1
- radiation pollution 7.1-10.0 Ci/km ²	2.5	2.5
<i>Class 5</i>		
Roads (forest), compartment line, fire line, etc	334.8	334.5
Water bodies	251.2	251.8

Thus, the distribution of forest lands without radiation pollution is as follows: 5289.4 ha (31.44%) belonged to class 1 in 2008, and 4955.2 ha (29.45%) in 2018; to class 2 – 7930.5 ha (47.14%) and 8084.0 ha (48.05%); to class 3 – 2177.4 ha (12.94%) and 2270.8 ha (13.50%); to class 4 – 819.4 ha (4.87%) and 906.7 ha (5.39%) respectively; 606.3 ha (3.61%) belonged to the class 5 in 2008 and 2018. As can be seen from the distribution of the territory, the largest area is occupied by class 2 and 1, so the average class of fire danger between 2008 and 2018 decreased from 2.02 to 2.06.

But given the fact that the territory of the Reserve is in the zone of radioactive contamination, where radiation affects the fire situation, the distribution of fire hazard classes is as follows: class 1 – 15928.3 ha (94.68%) and 15877.4 ha (94.38%); class 2 – 194.7 ha (1.16%) and 242.9 ha (1.44%); to class 3 – 106.4 ha (0.63%)

and 108.8 ha (0.65%); class 4 – 7.6 hectares (0.05%) in 2008 and 2018; to class 5 – 586.0 ha (3.48%) and 586.3 ha (3.48%). Thus, the fire situation taking into account radiation pollution increased by 0.86 and 0.89 units between 2008 and 2018 without and taking into account radiation pollution and is 1.16 and 1.17. Therefore, the fire danger, taking into account radiation pollution between 2008 and 2018, has hardly changed.

Given the fact that in the Reserve the average class of fire danger, taking into account radiation pollution is close to the first, throughout the fire-hazardous period, ground fires are possible, and in areas with a forest stand – crown fires [15]. As a confirmation of this fact, a fire broke out on the territory of the Reserve in the spring of 2020, as a result of which more than 3.0 thousand hectares of the forest ecosystem were burned (Fig. 1).



A



B

Figure 1. Consequences (A) and scale (B) of the fire on the territory of the “Drevlyansky” nature reserve, which occurred in April 2020

Source: A) author of the photo M.P. Lutsko; B) view from the Sentinel-2 satellite

Since the taxational specifications are divided into fire hazard classes, the first class is formed by: coniferous plantations under the age of 40 (3550.4 ha or 67.12% of the area of the class, 21.20% of the area of

the Reserve in 2008 and 3319.2 ha or 66.98%, 19.73% in 2018), planting of coniferous plantations over 40 years of age in very dry (0), dry (1) conditions (416.2 ha or 7.87%, 2.47% and 420, 4 ha or 8.48%, 2.50%), forest

lands not covered with forest vegetation (158.7 ha or 3.00%, 0.94% and 50.8 ha or 1.03%, 0.30%), others not covered with forest vegetation and non-forest lands along with coniferous plantations (1164.1 ha or 22.01%, 6.92% and 1164.8 ha or 23.51%, 6.92%).

The largest area is occupied by lands belonging to the class 2, which include lands of coniferous plantations over 40 years of age in fresh (2) conditions (7925.5 ha or 99.94%, 47.11% and 8079.0 ha or 99.94%, 48.02%) and deciduous plantations in very dry (0) and dry (1) growth conditions (5.0 ha or 0.06%, 0.03% in 2008 and 2018). In the class 3 a significant area is occupied by deciduous plantations in fresh (2) conditions (451.1 ha or 20.72%, 2.68% and 460.3 ha or 20.27%, 2.74%) among deciduous plantations species and a slightly smaller area among coniferous plantations over 40 years old are occupied by plantations in moist (3) and damp (4) conditions (1726.3 ha or 79.28%, 60.26% and 1810.5 ha or 79.73%, 10.76%).

The largest area forming the class 4 is deciduous plantations in moist (3) and damp (4) conditions (802.3 ha or 97.91%, 4.77% and 889.6 ha or 97.91%, 5.29%). The smallest area among coniferous plantations over 40 years of age is occupied by plantations in wet (5) conditions (17.1 ha or 2.09%, 2.20% in 2008 and 2018, respectively). The main part of class 5 belongs to infrastructural facilities and water bodies, which total 586.3 hectares. Deciduous plantations in wet (5) conditions (alder near rivers [16]) amount to 20.0 ha. Areas did not change between the years, the same situation in the total share of the area of the class and the Reserve (infrastructural facilities and water bodies – 96.70% and 3.48%), deciduous plantations – 3.30% and 0.13%).

Thus, in coniferous plantations there is an increase in the average age of plantations in each type of FST, which in turn affects the reduction of the area in young stands with appropriate typological conditions. The increase in the area of deciduous plantations (different typological conditions) is due to the decrease in the area of free-growing forest plantations [17]. However, the territory of the Reserve is located in the zone of radioactive contamination, so radiation pollution is taken into account to establish the areas of fire hazard classes.

The largest area, just like the general indicator of the fire hazard class, is occupied by deciduous and coniferous plantations with the level of radiation pollution over 15.0 Ci/km² (13714.6 ha or 86.11% of the total area of the class, 81.52% of the area Reserve in 2008 and 13798.0 hectares or 86.91%, 82.01% in 2018).

Almost equal parts of the area are occupied by forest lands not covered with forest vegetation (5092.2 ha or 3.71%, 3.03% and 501.3 ha or 3.16%, 2.98%), coniferous plantations under 40 years of age (496.3 ha or 3.12%, 2.95% and 453.5 ha or 2.86%, 2.70%), coniferous plantations over 40 years of age in very dry (0), dry (1), fresh (2) conditions (394.6 ha or 2.48%, 2.35% and 410.4 ha or 2,585, 2.44%), other forest lands not covered with forest vegetation, located near plantations with coniferous species (813.6 ha or 5.84% of the class and 4.84% of the area of the Reserve in 2008, 5.12% of the class and 4.84% of the Reserve in 2018).

Other classes of fire danger are formed with much smaller areas. Class 2 consists of deciduous plantations in fresh (2) conditions (60.9 ha or 31.28%, 0.36% and 68.6 ha or 28.25%, 0.41%) and coniferous plantations aged over 40 years in moist (3) and damp (4) conditions (133.8 ha or 68.72%, 0.80% and 174.3 ha or 71.76%, 1.04%). Class 3 consists of deciduous plantations that grow in moist (3) and damp (4) conditions (93.9 ha or 88.25%, 0.56% and 96.3 ha or 88.51%, 0.57%) and coniferous plantations in wet (5) growth conditions (12.5 ha or 11.75%, 0.07% in 2008, as well as 11.49%, 0.07% in 2018). The smallest area is represented by deciduous plantations in wet (5) growing conditions (7.6 ha or 0.05% of the area of the Reserve), which forms the class 4. Infrastructural facilities and water bodies together amount to 586.0 ha in 2008 and 586.3 ha in 2018, which is 3.48% of the area of the Reserve [17].

As can be seen, the areas of plantations that belonged to the 2, 3, 4 and 5 classes of fire danger due to the radiation background were classified as class 1 (over 15.0 Ci/km²) and increased by one class (2.1-15.0 Ci/km²). According to the streamlining of 2018 on the official website of SE "LIAC" in the section "Map" (Fig. 2) there is a map of fire danger of land plots of the forest fund, a significant area of which (almost all) is marked with colour 1 (most dangerous class). Separate "islands" can be observed in forest areas of 2, 3 and 4 classes of fire danger. Class 5, which are water bodies and the quarter grid (other infrastructural objects are not marked on the map due to the scale) are not shown because they are "superimposed" with a "compartment line" layer. The rivers are the boundaries between forests in a specialized forest economy or environmental research units (ERU) in the Reserve, as well as outside the quarters. Therefore, this map is a confirmation of the distribution of forest ecosystem areas of the Reserve by fire hazard classes, taking into account radiation pollution in 2018 (Table 4).

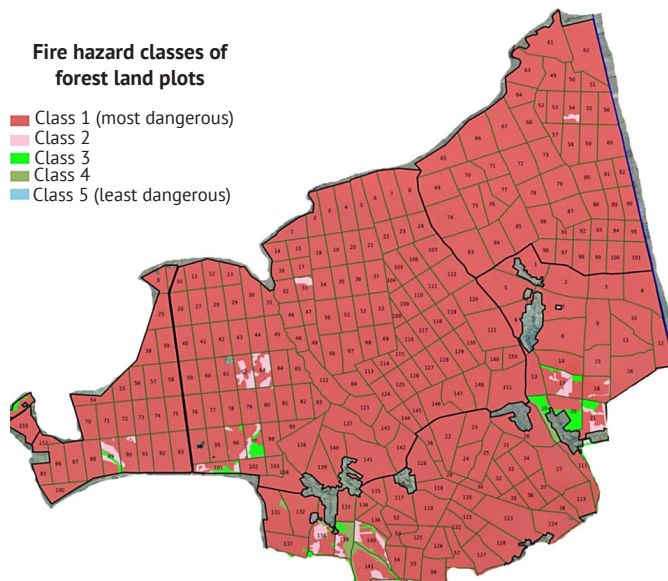


Figure 2. Fire hazard map of the “Drevlyansky” nature reserve according to SE “LIAC” in the section “Map”

Source: [18]

CONCLUSIONS

In the process of computational analytical study, the area of the Reserve was divided by zones of radiation pollution and fire hazard classes. According to the results of the distribution, it was established that the territory of the Reserve has a density of radiation pollution over 15.0 Ci/km^2 (15450.0 ha or 91.83%). According to the results of the division of the Reserve territory by fire hazard classes without radiation pollution, almost half of the area belongs to the class 2 (in 2008 the area was 7930.5 ha or 47.14% of the Reserve territory, and in 2018 – 8084.0 ha or 48.05%), and the average class between 2008 and 2018 decreased from 2.02 to 2.06

Distributing the areas of the Reserve taking into account radiation pollution, almost the entire area belongs to class 1 (in 2008 15928.3 ha or 94.68% of the territory, and in 2018 – 15877.4 ha or 94.68%), and the average class changed from 1.16 to 1.17. This sharp increase was conditioned by the fact that the radiation background was more than 15.0 Ci/km^2 , which refers the area immediately to class 1. Given that 30 years have passed since the radiological survey, the density of ^{137}Cs contamination in the area has decreased (except for areas affected by fires). The result of this survey may be changes in the distribution of areas of radiation pollution, which will improve the average class of fire hazard.

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ЕКОЛОГО-ПОЖЕЖНА ХАРАКТЕРИСТИКА ЛІСОВИХ ЕКОСИСТЕМ ПРИРОДНОГО ЗАПОВІДНИКА «ДРЕВЛЯНСЬКИЙ»

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Анотація. У роботі представлено екологічну та пожежну ситуацію у лісовій екосистемі природного заповідника «Древлянський». Актуальність цієї роботи полягає у тому, що щороку ліси України потерпають від пожеж, які знищують значні площі, а найбільшої шкоди від пожеж зазнають ліси із радіаційним забрудненням. Метою статті є встановити вплив радіаційного забруднення на пожежну ситуацію у лісовій екосистемі Заповідника. Головним завданням було розподілити площу Заповідника за рівнями радіаційного забруднення та за класами пожежної небезпеки з та без врахування радіаційного забруднення. Для досягнення результатів було розподілено площу лісової екосистеми Заповідника за рівнями радіаційного забруднення. Середній клас пожежної небезпеки між 2008 та 2018 роками становив від 2,02 до 2,06, що зі свого боку покращує пожежну ситуацію. Але, оскільки територія Заповідника зазнала радіаційного забруднення, розподіл площ за класами пожежної небезпеки між роками лісовпорядкування зазнав змін. Отже, пожежна ситуація із врахуванням радіаційного забруднення погіршилася, як порівняти із територією, що не зазнала радіаційного забруднення, а між 2008 та 2018 роками покращилася і становить відповідно 1,16 та 1,17. Отже, розподіл площ лісового фонду за класами пожежної небезпеки залежить не тільки від рівня радіаційного забруднення, а й від таксаційних показників (категорія землі, а в насадженнях від типу лісорослинних умов, віку та деревної породи). Також показано результати пожежі, яка відбулася на території Заповідника весною 2020 року та продемонстровано карту пожежної небезпеки лісового фонду природного заповідника «Древлянський» за даними лісовпорядкування 2018 року. Перспективою подальших досліджень є повторне проведення дослідження рівня радіаційного забруднення, а також кожні 10 років разом із лісовпорядкованими роботами проводити фактичні заміри без використання розрахункових методик для проведення більш достовірного розподілу площ лісового фонду за класами пожежної небезпеки, що зі свого боку вплине на планування стратегічних завдань щодо недопущення пожеж на території Заповідника

Ключові слова: радіаційне забруднення, пожежна ситуація, клас пожежної небезпеки, лісова екосистема

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INFLUENCE OF CARBONISED BIOMASS ON SOIL IMPROVEMENT, INCREASE IN YIELD OF AGRICULTURAL CROPS AND MITIGATION OF CLIMATE CHANGE IMPLICATIONS

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Abstract. The relevance of the study is conditioned by the need to develop and implement new technological solutions for tillage, which will improve the soil properties. The purpose of this study is to assess the impact of carbonised biomass on the properties and quality of soils, as well as the associated environmental consequences. The tasks addressed by the study were solved with the help of scientific theoretical methods: analysis, systematisation and generalisation of results. The scientific works related to the problem of the influence of carbonised biomass on soil quality were analysed in this paper. An assessment of the effectiveness of its use as an organic ameliorant and its effect on improving the agronomic properties of soils, their fertility, and on the ecological situation has been carried out. It is substantiated that the use of obsolete agricultural technologies during agricultural activities and their violation have a negative impact on soil fertility and increase in greenhouse gases in the atmosphere. It is argued that this could lead to a global food crisis. It has been emphasised that due to the use of biochar as an organic ameliorant the physical and microbiological properties of soils are improved, the availability of nutrients is optimised, and the content of toxic elements is reduced. It is shown that carbonised biomass has a positive effect on yields and also helps to reduce greenhouse gas emissions into the atmosphere. The main current problems that exist in Ukraine regarding the use of soil improvement technology with the help of carbonised biomass are identified. The ways of their solution for the further development of these technologies and their implementation in the agro-industrial sector are proposed. The practical value of the study consists in determining the effectiveness of using carbonised biomass when it is introduced into the soil to improve its quality, increase crop yields, and slow down climate change

Keywords: slow pyrolysis, biochar, hydrochar, organic ameliorant



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INTRODUCTION

Climate change on our planet is associated with an increase in the concentration of greenhouse gases (GHGs) in the atmosphere caused by human activities. Agricultural activities (tillage, application of ameliorants, mineral and organic fertilisers, plowing of crop residues) significantly increase GHG emissions from soils. The main GHG coming from soils is carbon dioxide CO₂, it is formed as a result of decomposition of organic matter, as well as during the combustion of biomass. According to the Food and Agriculture Organisation of the United Nations (FAO) [1], 0.2 billion tonnes of CO₂ are released into the atmosphere each year due to biomass combustion, which is 4% of all greenhouse gas emissions in the agricultural sector. The second greenhouse gas is nitric oxide N₂O, its global warming potential exceeds that of CO₂ by 310 times. According to various estimates, agricultural soils account for 40 to 60% of the total amount of N₂O that enters the atmosphere of the planet from all existing sources.

Climate change negatively affects soils, and this poses a threat to global food security. To strengthen the global food security agenda and combat climate change, agriculture and land use practices that increase soil organic carbon need to be improved and updated.

In the report "The State of the World's Soil Resources" (drawn up by the FAO Intergovernmental Group of Experts and timed to coincide with World Soil Day (04.12.2015, Rome) [2]) it is noted that soils are extremely important for crop production. It has also been shown that as primary carbon storage, soils help regulate carbon dioxide and other greenhouse gas emissions and are therefore a key component of climate regulation. Although, "33% of the world's soil resources are in satisfactory, poor, or very poor condition". It is reported that 28% of the world's chernozemic soils and a third of all arable land in Europe are concentrated in Ukraine. Active exploitation of agricultural land with violations of agricultural technologies, the impact of climate change, etc. leads to a rapid decline in soil quality and increase in greenhouse gas emissions. Due to various reasons, the development of national approaches to combating land degradation has been slowed down. As of 2020, Ukraine has approved the "Action Plan for the implementation of the Concept for the implementation of state policy in the field of climate change until 2030" in 2017 [4], adopted the "Low Carbon Development Strategy until 2050", began working on legislation to monitor greenhouse gas emissions [5]. Therefore, the introduction of innovative tillage technologies should ensure resilience to climate change and maintain a favourable microbiological and physical condition of soils. Therefore, it is necessary to look for new technological solutions in this direction. Development and implementation of tillage technologies by adding carbonised biomass (other names depending on the production technology: a) biochar, or biocoal are

obtained by slow pyrolysis in a certain temperature range; b) hydrochar (by the method of hydrothermal carbonisation); can be one of the options of innovative tillage technologies. To do this, first of all it is necessary: to determine the effect of biochar on the properties and composition of soil; to determine its impact on greenhouse gas emissions; to identify factors that affect the composition and properties of this product and its dependence on source components and pyrolysis conditions.

In recent years, a large number of scientific publications have been published, which cover these issues. Thus, the change in the chemical and hydro-physical properties of the soil due to the introduction of carbonised biomass was investigated by A.Ye. Ajay, R. Horn [6]. Factors that affect the composition and properties of this product are listed in the work of A.Yu. Krylova, EG Gorlov and A.V. Shumovskii [7], and the properties of carbonised biomass obtained by pyrolysis are disclosed in the work of N.P. Buchkina, E.V. Balashov, V. Szymanski, D. Igaz, J. Horak [8]. The dependence of the yield of biochar on the initial components and conditions of pyrolysis is mentioned in the work of Z. Tan, C.S.K. Lin, X. Ji & T.J. Rainey [9]. Physico-chemical properties of biochar obtained from different types of vegetable raw materials, studied by Ch. Liu, W. Nyu, H. Chu, T. Zhou, Ch. Nyu [10]. H.V. Smirnova, K.G. Giniyatullin, A.A. Valeeva, & E.S. Vaganova [11], show the dependence of the elemental composition of the biochar on the content of the original biomass and the final pyrolysis temperature. The influence of dosages and fractions of biochar on the properties and physical state of soils was studied by I.O. Dubrovina, M.G. Yurkevich, V.A. Sidorova and T.V. Bogdanova [12; 13]. The effect of improving additives based on biochar and a complex of microorganisms on reducing the transition of the radioactive isotope cesium into plants, on their growth and development was studied by I. Cheshyk, O. Nikitin [14]. Assessment of the impact of biochar on the microbiological parameters of the soil was made by L.M. Sungatullina, S.A. Zabelkin, R.R. Shagidullin [15], and G. Blanco-Kanki [16] investigated the effect of biochar on soil porosity. S. Garbuz, M. Camps-Arbestein, A. McKay, B. De Vantier, M. Minor [17] conducted a study of the interaction of biochar in acidic soils with some soil fauna, namely earthworms.

The *purpose* of this study is to assess the impact of carbonised biomass on changes in the properties and quality of soils, their productivity, sustainability, and yield, as well as on the associated environmental changes.

To achieve this goal, based on the studies by scientists from different countries, the following tasks were set: to investigate changes in physical and microbiological properties of soils after the introduction of carbonised biomass; to determine the main factors influencing the composition and properties of this product;

to find out the physico-chemical properties of biochar and the dependence of their output from the initial components and the technological conditions for their production; as well as to consider the ecological and agricultural effect of their introduction into the soil.

MATERIALS AND METHODS

The theoretical and methodological basis of this paper were fundamental and applied studies on carbonised biomass efficiency (biochar, biocoal, and hydrochar as an organic ameliorant, their impact on improvement of physico-chemical and biological properties of soils, their productivity and stability, as well as reduction of greenhouse gas emissions into the atmosphere.

The solution of the tasks addressed by the study was carried out using a number of well-known scientific theoretical methods: analysis, systematisation and generalisation of results. To study this issue, the works of scientists from different countries were studied and analysed, which consider:

- technologies for obtaining carbonised biomass;
- factors that affect the composition and properties of carbonised biomass;
- the problem of global warming and the greenhouse effect due to greenhouse gas emissions, and the preconditions for their emergence as a result of human anthropogenic activities;
- the use of carbonised biomass as an organic ameliorant;
- ways to improve and restore soils by adding carbonated biomass, its impact on improving the physico-chemical and biological properties of soils, their stability and yield;
- ecological aspects of introduction of organic and inorganic fertilisers into the soil;
- issues of optimising the availability of nutrients for agricultural plants through the use of carbonised biomass, reducing the content of toxic elements in the soil;
- aspects of reducing greenhouse gas emissions into the atmosphere as a result of the introduction of carbonised biomass into the soil;
- the need to introduce innovative tillage technologies.

The most relevant studies from the standpoint of the efficient use of carbonised biomass as one of methods of increasing productivity and sustainability of soils and influence of its use on ecology were selected from the received material. These works formed the information base of this study. The analysis was used to process the obtained information on the impact of carbonised biomass on individual properties of soils, which considered the scientific and practical achievements of specialists in this field and summarised these results.

For this purpose, by comparing the results with a sample of studies in which this problem occurred, an assessment was made of the effectiveness of using carbonised biomass as an organic ameliorant, and its

effect on improving the agronomic properties of soils, their fertility, as well as the impact on the ecological situation. The criteria were various qualitative and quantitative characteristics, such as: alkalinity, density, water-physical and physico-chemical properties, mineral content, biological activity, plant growth and development, as well as emissions of carbon dioxide and other greenhouse gases. Based on the findings, conclusions were made on the impact of carbonised biomass on the improvement of physical and microbiological properties of soils and crop yields and reduction of greenhouse gas emissions into the atmosphere.

RESULTS AND DISCUSSION

Technologies for production of carbonised biomass and analysis of factors influencing its composition and properties

The study considers the impact of carbonised biomass on improvement of soil and ecology. Notably, only raw materials of plant origin are considered for its production: utilised agricultural waste; organic crop waste; waste from the forest and woodworking industry.

Biomass processing can be performed with dry or wet biomass, the moisture content of which is crucial to determine the best process for this raw material. Depending on this factor, a distinction is made between:

- biochar and biocoal – obtained by slow pyrolysis at different temperatures (biochar is a by-product of synthesis gas production);
- hydrochar – obtained in the process of hydrothermal carbonisation.

According to [8], biochar can also be obtained by rapid pyrolysis, but in this case it is only a by-product in the production of electricity and heat. Slow pyrolysis is the most effective technology for the conversion of raw materials into carbonised biomass [7]. The carbonised biomass obtained by this technology at temperatures from 450 to 600 °C has a higher reclamation effect than its analogues, which are formed as a result of high-temperature slow pyrolysis (at temperatures above 600 °C – biocoal) and rapid pyrolysis [8]. It is a product with a high content of stable polyaromatic hydrocarbons, low density of composition and high adsorption capacity, which can be used for application into the soil to improve its chemical, physico-chemical, biological and hydrophysical properties. Any carbonised biomass is suitable for reducing greenhouse gas emissions, regardless of the technology of its production. Depending on the initial components and pyrolysis conditions, the yield of the biochar usually varies within 20-70% of the initial weight [9]. Slow pyrolysis is characterised by a low heating rate of 0.1-1 K/s [7], relatively low temperature and long residence time (from hours to days) in an environment with limited oxygen content. Pyrolysis of biomass at higher temperatures is aimed at obtaining bio-oil [18] and synthetic gas.

The study [19] shows that the biochar obtained

during pyrolysis has different characteristics. Its composition and properties are influenced by many factors, such as: the nature of the raw material; the chemical composition of the raw material (the higher the lignin content in the raw material, the higher the yield of biochar); particle size of raw materials and its initial humidity; technological conditions: process temperature and heating rate, duration of stay of raw materials at a certain temperature; final heating temperature; speed of gas flow circulation through a layer of raw materials, etc. [7; 10; 11]. The dependence of biochar composition on pyrolysis conditions is mentioned in [20], where the authors show that the product produced under various technological conditions, obtained in the pyrolysis process, will differ in physical and mechanical composition, namely: in porosity, bulk density, strength, hygroscopicity and moisture absorption; elemental composition; ash content; aromaticity, acidity pH, etc. Together, these indicators have a different effect on the bulk density of the soil, its water-physical and physico-chemical properties, the content of mineral substances, biological activity and on the growth and development of plants [8]. The ash content depends on the composition of the raw material; in the biochar from straw and husk, the ash content is higher than in the biochar obtained from wood. In addition, the size of pores (macro-, meso- and micropores) and their distribution in the biochar depend on the initial biomass.

The impact of the use of carbonised biomass on soil improvement

Biochar changes the physical, chemical and hydrophysical properties of soils due to direct and indirect effect on them [6; 11]. The study [21] on the effect of biochar on soil hydrology concluded that the direct effect changes the filtration capacity of the soil and the moisture supply available to plants. A study [12] showed that the indirect effect of biochar is associated with changes in the microaggregate and structural composition of soil. The efficiency of biochar enrichment is regulated by the size of the applied biochar and the particle size distribution of the soil [13]. All this affects the availability of nutrients and leaching of solutes; the activity of soil fauna; the course of microbiological processes, in particular those that promote the generation of greenhouse gases such as CO_2 , N_2O and CH_4 .

The paper [22] shows that biochar promotes plant growth, increases crop yields and reduces the amount of pollutants. Due to the neutral or alkaline acidity, biochar is able to increase the pH of acidic soils [12], which helps to optimise the availability of nutrients and their use by plants. It also reduces the content of toxic elements for plant growth such as Al_{3+} and Mn_2 . The positive effect of biochar on soils and plant growth is associated with the effect of liming, which is substantiated in [23; 24]. Soils with pH = 5.5 or less reduce plant yields and limit the choice of crops. The study [25] claims that cereals

react negatively to acidic soils and the application of biochar to increase soil pH promotes good crop yields. At the same time, the authors note that on soils with a pH of 7.1-8.0, the biochar does not significantly affect yields.

In [14] it is reported that soil-improving additives based on biochar reduce the bioavailability of Cs-137 and its transition to the aboveground mass of plants, while also having a positive effect on plant growth and development. In addition, the introduction of biocoal contributes to an increase in gross nitrogen in the soil [15].

The most important property of the biochar is the porous structure, as it provides a great potential for colonisation by soil microorganisms appropriate in pore size. Biochar has a porosity of 70 to 90% [16]. In [26], it is shown that due to its fine-porous structure, the biochar helps to improve soil quality: it increases the availability of nutrients and moisture, as well as binds carbon. The [27] shows that the presence of micro- and mesopores in the biochar causes its high inner surface, which plays an important role in chemical reactions, and macropores promote access of adsorbents to the inner surface of the biochar. The porous space of the biochar obtained by slow pyrolysis is covered with resins that do not burn during slow pyrolysis, but harden, covering a thin layer of pores that serve as a refuge for some microorganisms. Their activity is expressed in the increase of CO_2 emissions due to increased decomposition of organic matter and is associated with the release of nutrients, which is an important factor that affects soil fertility and yield. In addition, resins have a high ability to ion exchange, i.e., ions of the useful substance can easily join them and be assimilated by plant roots or hyphae of mycorrhizal fungi, which increases crop yields. In addition, the use of biochar can increase the porosity of the soil from 2 to 41% [16].

The interaction of the biochar with the soil fauna has not been studied enough. However, it is well known that its interaction with worms improves the spatial distribution of the soil and the availability of nutrients and creates good productivity potential for acidic soils [17]. This can lead to an increase in plant consumption of inorganic nitrogen, which in turn will improve their yield.

The biochar obtained in the process of hydrothermal carbonisation (hydrochar) is inferior in its properties to the biochar obtained by slow pyrolysis. Comparison of hydrochar with biochar obtained from the same raw material showed that hydrochar is more acidic [28]. High concentrations of hydrochloride can adversely affect plants because it may contain toxic phenolic and aromatic substances. Due to the fact that hydrochars have a much higher calorific value than biochar, more homogeneous and dense structure, lower ash content and CO_2 emissions during combustion, they are more suitable for heat generation and electricity generation.

A number of experiments have shown that biochar in some cases can have not only a positive but also

a negative impact on the water properties of the soil and their ability to cause erosion [29]. Furthermore, in some cases there was a negative impact of biochar on the physical, physico-chemical and biological state of soils [8]. These results are explained by insufficient amount of nutrients (nitrogen, phosphorus), suboptimal dose of biochar, and irreversible adsorption of non-aromatic compounds. Aldehydes, phenols adsorbed on the surface of biochar, and polyaromatic carbohydrates generated during the thermal decomposition of lignocellulosic raw materials can have toxic effects on plants and microorganisms. Biochar can serve as a sorbent for pesticides and therefore promote weed growth.

There are difficulties in the study of biochars and their effects on different soils due to their different properties depending on the raw materials used, heat treatment, climatic conditions, soil type and many other factors. Therefore, sometimes the results of the introduction of biochar into the soil have an adverse or unpredictable result. The same is shown in [30], which concludes that although biochar can be recommended to improve the structural condition of unstructured soils, the long-term effects of its introduction on soil properties still need to be studied. Therefore, long-term experimental studies are needed to recommend the use of carbonised biomass. But the acquired knowledge about the structure and composition of various biochars, as well as about their interaction with soils allows producing a specific biochar for solving many specific problems.

Influence of the use of carbonised biomass on climate change mitigation

Greenhouse gas emissions from agriculture account for 13% and are mainly caused by three gases: carbon dioxide (CO_2), nitrous dioxide (N_2O), methane (CH_4) [31].

One of the many methods to mitigate the effects of greenhouse gas emissions is waste management technology (conversion to carbonised biomass), fertiliser management and restoration of degraded land, in particular through the use of carbonised biomass.

The study [32] suggests that the introduction of carbonised biomass into the soil helps to reduce greenhouse gas emissions. Confirmation of this can be found in [33], where the authors note that when introduced into the soil, it mineralises much more slowly than the original biomass. It provides long-term sequestration of the main greenhouse gas CO_2 (released from agricultural soils by microbiological decomposition of plant precipitation and organic matter soil), and can reduce its increasing concentration in the atmosphere, increase CO_2 sequestration by creating stable carbon effluents, as well as mitigate the effects of other greenhouse gas emissions [31]. The introduction of carbonised biomass into the soil can mitigate the effects of carbon emissions by 12% [34].

Another greenhouse gas that enters the atmosphere

from soils is nitrous oxide N_2O , which is released mainly by organic and inorganic fertilisers introduced into the soil. Agricultural soils are the main source of N_2O emissions, accounting for 62% of all nitrous oxide emissions of human origin [31].

The lifespan of the N_2O molecule in the atmosphere is 150 years. Most agricultural soils emit N_2O in the amount of 1.5% of the applied nitrogen, reducing its use reduces N_2O emissions. Only half of the nitrogen input is captured by crop biomass, the rest is lost to the system by leaching and gaseous losses. Therefore, any method that strengthens the links between soil nitrogen release and growing crops improves fertilisation efficiency and reduces the need for exogenous nitrogen while reducing N_2O emissions. Numerous field and laboratory studies of carbonised biomass have shown that it has a positive effect on reducing N_2O emissions from soils [35]. Its introduction into the soil improves the water and air regimes of the soil and reduces its high density. This results in a large number of pores with low oxygen content, which helps to reduce the denitrification process. Changing soil pH increases the overall diversity of soil biota and its efficiency. The reduction of N_2O emission from the soil by 50-80% was experimentally confirmed [36] after the introduction of biochar. Furthermore, the reason for the decrease in nitrogen emissions from the soil may be due to the increased intensity of plant growth. The carbon contained in biochar and fertilisers promotes increased nitrogen uptake by plants, which reduces the available mineral nitrogen for the generation of N_2O .

The third greenhouse gas coming from the agricultural sector is methane CH_4 . In terms of heat retention in the atmosphere, its effect is 21 times stronger than CO_2 . Sources of methane emissions are: cattle (intestinal fermentation, manure management); rice cultivation (methane release occurs as a result of anaerobic decomposition of rice in flooded rice fields); recommended burning of shrouds; burning of agricultural residues [31]. Thus, agricultural soils are both a source and a runoff for CO_2 in the atmosphere. It has been experimentally proven that biocoal increases the level of carbon in the soil [37]. Of paramount importance is the influence of carbonised biomass on the stabilisation or conversion of stable carbon in the soil [38].

Improving the cultivation of arable land can lead to the accumulation of carbon in the soil. Improving the physical and chemical condition of the soil will change the balance between N_2O and non-greenhouse N. CH_4 emissions in the agricultural sector can be reduced by converting agricultural residues into carbonised biomass instead of direct combustion.

Today, in Ukraine and in the world, there is no comprehensive soil improvement programme with biochar. Its use in the fight against greenhouse gases is mainly experimental, not widely used and is at various stages of development. Given that this is a relatively

new approach, it is necessary to inform farmers and energy producers about the sequestration of biochar and its positive impact on soil characteristics. Inexpensive pyrolysers available to farmers need to be developed and their production expanded. Studies have shown that pyrolysis can be cost-effective by combining sequestration and energy production when the cost of a tonne of CO₂ reaches USD 37 [39]. Binding of carbon and mitigation of greenhouse gas emissions allows taking advantage of quotas on carbon emissions in the quota market. Carbon credits sold by carbon sequestration in the biochar are economically competitive when prices reach USD 58/t CO₂-eq [40].

Efforts must be made to make the use of biochar a sustainable carbon sequestration procedure that will ensure higher unrealised carbon emissions. Further dissemination of this technology depends to a large extent on the progress of global negotiations on climate change in terms of financing climate-safe technologies.

CONCLUSIONS

1. Based on the study of the impact of carbonised biomass as an organic ameliorant on soil improvement, increase in its productivity, stability, yield, as well as the associated reduction of greenhouse gas emissions into the atmosphere, it was found:

- carbonised biomass obtained by slow pyrolysis has

a higher reclamation effect than its analogues obtained by high-temperature slow pyrolysis and rapid pyrolysis;

- introduction of carbonised biomass into the soil has a positive effect on the physical, physico-chemical and biological condition of soils, which provides high crop yields, as well as water properties of the soil. However, under certain conditions, the result can be zero or even negative;

- any carbonised biomass is suitable for reducing greenhouse gas emissions, regardless of the technology of its production;

- due to the use of carbonised biomass, the content of toxic elements in the soil can be reduced.

2. The findings suggest that the technology of increasing productivity and stability of soils through the use of carbonised biomass is promising for development, both in Ukraine and globally. However, due to the fact that this trend is relatively new today, it has not gained wide popularity. Therefore, it is necessary to conduct further research, which will allow developing mechanisms to address the problem of using biochar as an organic ameliorant. For this purpose, it is necessary to inform farmers and energy producers about the sequestration of biochar and its positive impact on soil characteristics, to develop pyrolysers and promote the expansion of their production.

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**ВПЛИВ КАРБОНІЗОВАНОЇ БІОМАСИ НА ПОКРАЩЕННЯ ҐРУНТІВ, ПІДВИЩЕННЯ
ВРОЖАЙНОСТІ СІЛЬГОСПКУЛЬТУР І ПОМ'ЯКШЕННЯ
НАСЛІДКІВ ЗМІНИ КЛІМАТУ**

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Анотація. Актуальність дослідження обумовлена необхідністю розробки та впровадження нових технологічних рішень щодо обробки ґрунтів, які сприятимуть поліпшенню їх властивостей. Мета даної роботи – розглянути вплив карбонізованої біомаси на властивості та якості ґрунтів, а також на пов'язані з цим екологічні наслідки. Рішення поставлених у статті завдань здійснювалося за допомогою наукових теоретичних методів: аналіз, систематизація та узагальнення результатів. У роботі проаналізовано наукові праці, що стосуються проблеми впливу карбонізованої біомаси на якості ґрунтів. Проведена оцінка ефективності її використання в якості органічного меліоранту, та її впливу на поліпшення агрономічних властивостей ґрунтів, їх родючість, і на екологічну ситуацію. Обґрунтовано, що використання застарілих аграрних технологій під час проведення сільськогосподарських заходів та їх порушення в процесі експлуатації має негативний вплив на родючість ґрунтів і збільшення парникових газів в атмосфері. Аргументовано, що це може привести до глобальної продовольчої кризи. Підкреслено, що завдяки застосуванню біочару як органічного меліоранту поліпшуються фізичні та мікробіологічні властивості ґрунтів, відбувається оптимізація доступності поживних речовин і знижується вміст токсичних елементів. Показано, що карбонізована біомаса позитивно впливає на врожайність, а також сприяє зменшенню викидів парникових газів в атмосферу. Визначено основні сучасні проблеми, які існують в Україні щодо використання технології покращення ґрунту за допомогою карбонізованої біомаси. Запропоновано шляхи їх вирішення для подальшого розвитку цих технологій і впровадження їх в агропромисловому секторі. Практична цінність наукової роботи полягає в визначенні ефективності використання карбонізованої біомаси при внесенні її у ґрунті для покращення їх якості, збільшення врожайності сільськогосподарських культур, та уповільненні змін клімату

Ключові слова: повільний піроліз, біочар, гідрочар, органічний меліорант

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