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Integrated Assessment of Weldability of Steel with Increased Strength

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Abstract. Modern production of agricultural equipment and facilities, hulls of ships, stationary oil drilling platforms, wind energy installations and other metal structures makes extensive use of sheet steel of increased strength. The main manufacturing process is welding, the quality of which depends on multiple factors, including the ability of steel to resist welding. It is known that the properties of the thermal influence zone are highly dependent on phase transformations, the nature of which is determined by the intensity and development of diffusion processes of carbon redistribution and alloying elements under the impact of the welding thermal cycle. Therefore, it is necessary to evaluate the weldability of the steel of a certain chemical composition, in order to choose the optimal method and the technological parameters of the welding mode for the manufacture of a specific metal structure. In order to reduce material costs, you can use analytical calculation methods that were developed at the E.O. Paton Electric Welding Institute. They are based on the analysis of the literature and the study of about 150 diagrams of the thermokinetic decomposition of austenite. Mathematical models make it possible to predict with a sufficient degree of accuracy the phase composition and mechanical properties of the high-temperature thermal influence zone depending on the chemical composition and cooling time of the metal, heated to a maximum temperature of 1350°C, in the temperature range 850-500°C. However, such tests are quite expensive and do not allow optimization of weld properties when the welding mode, mode, welding materials and other underlying technological factors change. In this connection, the objective was to assess the reliability of the proposed methodology in the study of weldability of shipbuilding steel of the increased strength of the category E36, for the weakest T(transverse) – the orientation of the sheet of 50 mm thickness. A high performance of the steel category is achieved by a limited increase in the aluminium content or other grain-crushing elements (Nb, V, Ti), which ensures that the size of the austenitic grain is not greater than the fifth point. The research showed that analytical methods for calculating the mechanical characteristics of high temperature HAZ sites by chemical composition, taking into account the cooling rate after welding, provide a level of confidence sufficient for practical application and can be recommended for the primary evaluation of the properties of welded compounds of high-thickness steel plates of category E36 (T-orientation). The impact work (KV-40) of the high-temperature sections of the high-temperature thermal influence zone is not subject to an analytical evaluation with the degree of accuracy required for production practice

Keywords: steel of category E36, analytical calculation methods in welding, complex mechanical tests, mechanical characteristics, impact viscosity, steel hardness

INTRODUCTION

Modern production of agricultural equipment and facilities, hulls of ships, stationary oil drilling platforms, wind energy installations and other metal structures makes extensive use of sheet steel of increased strength. The main manufacturing process is welding, the quality of which depends on multiple factors, including the ability of steel to resist welding. It is known that the properties of the thermal influence zone are highly dependent on phase transformations, The nature of which is determined by the intensity and degree of development of diffusion processes of carbon redistribution and alloying elements under the impact of the welding thermal cycle [2; 3; 5; 16-20]. Naturally, the concentration of alloying elements and cooling rates have a significant

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impact on the diffusion mobility of carbon. Therefore, it is necessary to evaluate the weldability of the steel of a certain chemical composition, in order to choose the optimal method and the technological parameters of the welding mode for the manufacture of a specific metal structure.

In practice, as a rule, the development of a certain welding technology is carried out in accordance with the requirements of the ISO 15609 – ISO 15614 series of international standards [23; 24], which allows to record the properties of welds with a high degree of confidence. In order to reduce material costs, it is possible to use the analytical methods of calculation developed in the E.O. Paton Electric Welding Institute (PWI), based on the analysis of literary data and the study of about 150 thermocynthetic decay diagrams of austenite. Mathematical models (see formulas 1-4) allow to predict with a sufficient degree of accuracy the phase composition and mechanical properties of the high-temperature heat-affected zone (HAZ) depending on the chemical composition and cooling time of the metal, heated to a maximum temperature of 1350°C, within a temperature range of 850-500°C [1-3]:

Vickers hardness number (with correlation coefficient of R=0.95) [1-3] (1):

$$HV=M(309+494C+622C^2+17.7Mn)+B(234+122C)+ \\ +[F+P](98+275C+15.4Mn) \quad (1)$$

where F, P, B and M are quantities of ferrite, pearlite, bainite and martensite. Ultimate tensile strength (with correlation coefficient of R=0.91) (2):

$$\sigma_t\,(MPa)=M(798+3215C)+B(590+960C+39.7Mn+ \\ +200V)+[F+P](297+1360C+60Mn+140V) \quad (2)$$

Yield strength (with correlation coefficient of R=0.90) (3):

$$\sigma_{0.2}\,(MPa)=M(662+1610C)+B(500+460C-120C^2+ \\ +150V)+[F+P](187+925C+47Mn+90V) \quad (3)$$

Impact toughness of specimens (4):

$$KCV(T)=(KCV_{max}-KCV_o)\Phi(u)+KCV_o \quad (4)$$

where KCV_o is the minimum value of impact toughness at low temperatures (0.01...0.02KCV_{max}); $\Phi(u)$ – normal distribution function ($\Phi(u)=0.5(1+\mathrm{erf}(u/\sqrt{2}))$ (5):

$$\ln(KCV_{max})\ (MJ/m^2)=1.29-3.85C-0.181Si-0.204Cr- \\ -1.04Mo-0.328Ni-1.51V-1.67Ti-1.60Nb-0.285W+ \\ +0.160Co-2.49Zr-2.62S-5.84P-15.8N-10.7O- \\ -1.19C\cdot Mn+0.052Mn\cdot Cr-0.104Si\cdot Cr+0.062Cr\cdot Mo+ \\ +0.581C\cdot Ni-6.51C^2+0.038Cr^2-0.030Mo^2- \\ -0.229V^2+(0.028+0.954C-0.048Cr+0.356Mo+ \\ +0.455V+0.077Ni)\cdot \ln_{\ell}\ (R=0.93) \quad (5)$$

They can be used for steels containing not more than (% by mass 0.4C; 2Mn; 0.8Si; 2Cr; 1Mo; 1.5Ni; 0.3V; 0.06Ti; 0.06Al; 0.1Nb; 0.5W; 0.5Cu, in thermal cycles that provide a cooling time t within a specified temperature range of 5 to 200 s. It is also possible to determine the properties of a molded metal.

The most reliable way of assessing the weldability of sheet metal is the comprehensive testing of welded welds according to the requirements of the Qualification Societies Regulations (Lloyd's Register (LR), Bureau Veritas (BV), Det Norske Veritas (DNV), Germanischer Lloyd (GL), American Bureau of Shipping (ABS), Shipping Register of Ukraine (SRU)) [14]. However, such tests are quite expensive and do not allow optimization of weld properties when the welding mode, mode, welding materials and other underlying technological factors change. In this connection, the objective was to assess the reliability of the proposed methodology in the study of weldability of shipbuilding steel of the increased strength of the category E36, for the weakest T(transverse) – the orientation of the sheet of 50 mm thickness. The regulated requirements of the Qualification Societies Regulations for the mechanical performance of the specified thickness rolling stock are at the following level (T-orientation time resistance Rm=490-620 MPa, yield strength ReH 355 MPa, elongation A 21%, impact operation KV-20 24 J, hardness HV 350 Unit. A high performance of the steel category is achieved by a limited increase in the aluminium content or other grain-crushing elements (Nb, V, Ti), which ensures that the size of the austenitic grain is not greater than the fifth point. In addition, it is known that impact viscosity is a structurally sensitive characteristic and depends on the state of the grain boundary, the morphology of structural constituents including micro excretion (carbides, nitrides, MAC phase), chemical and structural microheterogeneity, content of impurities and dissolved gases whose permissible concentration, including nitrogen, is not always regulated by the DA Regulations [5; 22-25].

The purpose of this paper was to assess the validity of the proposed the analytical methods of calculation in the study of weldability of shipbuilding steel of the increased strength of category E36, for the weakest T (transverse) – the orientation of sheets of 50 mm thickness.

MATERIALS AND METHODS

Blanks of 50 mm thickness sheet metal (% by mass) were selected as the main metal as follows: 0.11C; 1.56Mn; 0.23Si; 0.003S; 0.010P; <0.005As; 0.03Cr; 0.02Ni; 0.03Cu; <0.005Ti; 0.025Al; 0.033Nb; 0.007N; <0.065V; <0.005Mo; <0.0005B; 0.0015Sn; <0.001Sb. The chemical composition and mechanical characteristics of the selected blanks were fully compliant with the requirements of the DA Regulation for steel of category E36, as confirmed by the standard set of mechanical tests [14].

Analytical evaluation of the properties of metal HAZ (R_m, R_{eH}, KV_{-40}, HV), depending on a given chemical composition and duration of metal cooling from a maximum heating temperature of 1350°C, in a temperature range of 850-500°C, using a dependency of 1-4. The pre-heating requirement for a thickness of 50 mm was taken into account. The calculated heating temperature was ~150°C.

Test specimen welding was performed automatically under the flux, a continuous cross-section wire (121 welding code) on the calculated linear energy HI=2.5 kJ/mm (*I*=550 A; U32 V; v=6.67 mm/s; η=0.95) and HI=4.2 kJ/mm (I=800 A; U=36 V; v=6.57 mm/s; η= 0.95) with the use of welding wire OK Autrod 12.20 (S), 4 mm and flux OK Flux 10.71, SA AB 1 67 AC H5 (EN 760) vacuum packaging. The pre-heating was in both cases up to a design temperature of ~150°C. The intergrading temperature was controlled at <200°C. After each welding, the welding direction was reversed. The ambient temperature during welding was +21 cc, relative humidity ~68%, atmospheric pressure ~$1.013\ 10^5$ Pa.

In order to assess the impact of the actual thermal welding cycle on the properties of the metal T of the given chemical composition, standard reference samples were welded in accordance with the requirements of DNV GL [21]. Size of welded plates: 50 mm thick; 200 mm wide; 2000 mm long. Type of weld connection: 2.5.5 ISO 9692-2 [25]. Welding was carried out in parallel to rolling the sheet to provide tenderloins for tensile and impact tests in the transverse direction of rolling (T-orientation).

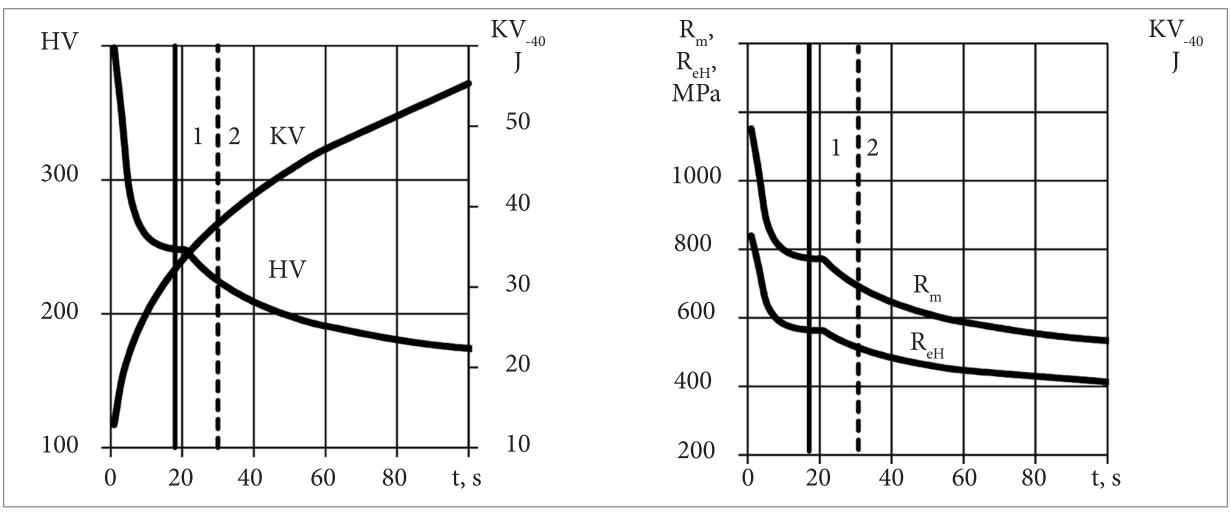
After welding, the welds were stretched and impacted. The tensile tests were carried out on cylindrical samples with a diameter of 14 mm with a linear base of five diameters.

Hardness measurements for different weld joints were performed using the Wickers method (HV10).

In order to determine the impact viscosity of the metal HAZ, we have carried out comprehensive impact bending tests in different areas of test welds (T-orientation of rolled sheeting). Five sets of standard samples (consisting of 3 samples with a V-cut for the Sharpe impact bend test) were tested for each weld joint. The incision was located along the metal of the seam, along the mold line and 2.5 and 20 mm from the mold line. The samples were cut from the straight edge of the weld.

RESULTS AND DISCUSSION

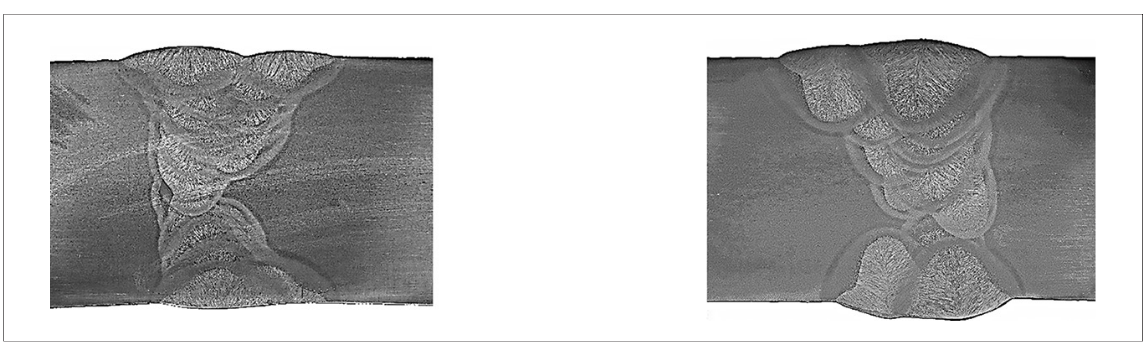
The results of calculations according to the above formulas 1-4 are presented in graphs in Fig. 1 (a. b).



a) b)

Figure 1. *Relationship of the properties of the experimental steel metal HAZ to cooling time in the range 850... 500ºC (1–HI=2.5 kJ/mm; 2–HI=4.2 kJ/mm): a) HV hardness and operation of KV-40; b) time resistance, MPA and yield stress*

The macrostructure of the investigated welded joints is shown Figure 1, 2. In all cases, the metallographic analysis confirmed the formation of the flat metal with a smooth interface with the base metal. Macro-rodefects such as unproves, cracks, slags, pores and similar have not been found. The geometrical dimensions of the weld were in accordance with the welding procedure [8-13].



a) b)

Figure 2. *Macro-structure of welded joints of steel of category E36: a) HI=2.5 kJ/mm; b) HI=4.2 kJ/mm (x1.5)*

The results of tensile tests performed on cylindrical samples are presented in Table 1. Given the fact that the cylindrical tensile samples included parts of metal with different properties (ABS, base metal, seam metal), the only valid value is the temporal resistance of the base metal, as it is the cause of destruction in all cases. The analysis of the results showed that the properties of welded joints fully met the qualification requirements of the DA Regulation for steel of category E36 (T-orientation) [14] (Table 1).

The results of hardness measurements of the investigated welded joints are shown in Figure 3.

Table 1. *Results of tensile tests (d=14 mm)**

Steel category (static energy)	R_m, MPa	R_{eH}, MPa	A_5, %	Z, %
E36 (HI=2.5 kJ/mm)	507	355	23.6	72.0
	500	362	25.7	77.8
E36 (HI=4.2 kJ/mm)	510	369	24.7	70.5
	512	367	24.3	72.8

Note*: * – the tensile tests were carried out on cylindrical samples with a diameter of 14 mm with a linear base of five diameters*

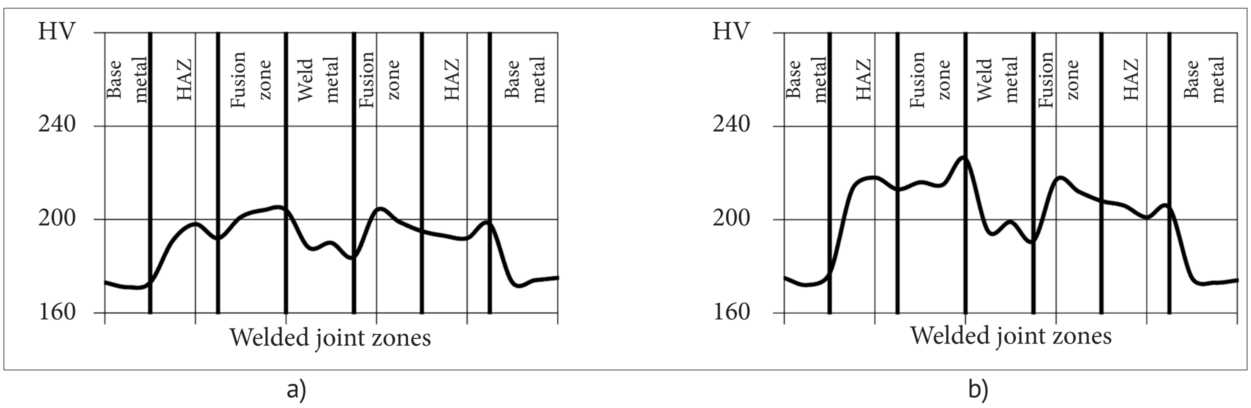


Figure 3*. Hardness distribution (HV10) in welded compounds E36 steel category: a) HI=2.5 kJ/mm; b) HI=4.2 kJ/mm*

Analysis of the hardness measurements showed that the HAZ of welds hardened the base metal and a good correlation of hardness with the thickness of the rolled metal. Increasing the torque energy of welding from 2.5 kJ/mm to 4.2 kJ/mm slightly equalizes the hardness of the metal HAZ. A comparison of the calculated and actual hardness of the HAZ in the heating of the main metal above 1350°C (the main metal adjacent to the molding line) shows that there is a fairly high degree of coincidence. For example, for welded 2.5 kJ/mm welded linear energy, the design hardness of the metal HAZ is 230 HV (see Fig. 1, a). The average effective hardness for a HAZ welded compound is 210 HV (see Fig. 3, a). In this case, the calculation error is +8.7%. For welding stroke energy 4.2 kJ/mm, the design hardness of the metal ABS is 224 HV. (see Fig. 1, a) and the average effective hardness of the HAZ is 216 HV (see Fig. 3, b). The calculation error is +3.6%. Therefore, the calculated and actual results of the metal hardness measurements of the high-temperature HAZ of E36 welds are fairly well harmonized and confirm the adequacy of the model (Eq. 1). It is not possible to determine the strength characteristics of the high-temperature sections of OT of welded compounds in practice due to their small length. However, by using known dependencies, they can be estimated with reasonable confidence. This assessment is well in line with the requirements of the international standard ISO 18265, which establishes the tensile strength relationship between Vickers, Brinell and Rockwell [15]. In this context, knowing the actual hardness indicators, it is possible to approximate the properties of the different welded compound sites. Experiment has shown that satisfactory error is also achieved. For example, the minimum hardness value of the base metal E36 for welded welding energy of 2.5 kJ/mm is 170 HV (see Fig. 3, a), which corresponds to a strength limit of ~545 MPa. Actual value of 500 MPa (cf. table 1). In this case, the theoretical error does not exceed +9%. For welding strokes of 4.2 kJ/mm, the minimum hardness of the base metal is 170 HV (see Fig. 3, b), which corresponds to a strength of ~545 MPa. Actual value 510 MPa (Table 1). In this case, the determination of the hardness limit of a metal does not exceed +7%.

By reasoning in this way it is possible to determine the strength of the metal of the high-temperature section of HAZ in terms of its hardness. For example, the mean hardness of the high-temperature HAZ. for welding energy of 2.5 kJ/mm is 210 HV (see Fig. 3, a), which corresponds to the strength limit of 675 MPa and is well in line with the design value of 770 MPa (see Fig. 1, b). The error is +12 per cent. For welding stroke energy of 4.2 kJ/mm, the mean hardness of the metal of the high-temperature segment of the ABS was 216 HV (see Fig. 3, b), which corresponds to the strength limit of 695 MPa and is well in line with the design value of 700 MPa (see Fig. 1, b). The error is less than 1%, which confirms the adequacy of the mathematical model (Eq. 2) with this degree of correlation.

Thus, knowing the exact chemical composition of steel, it is possible, using the given dependencies, Perform a primary assessment of the strength of the metal of the high-temperature sections of steel, depending on the cooling conditions of the weld joint during welding, with a sufficiently high degree of accuracy for practical purposes.

The plasticity of a metal HAZ and especially its impact viscosity depends not only on macro-indicators such as chemical composition, method of manufacture and thickness of the roller, cooling conditions during welding, structural state of the metal, Tenderloin directions, cut shape and test temperature conditions for the samples. Structural and chemical micro heterogeneity of the metal, quantity and morphology of non-metallic inclusions, purity of the grain boundary, concentration of dissolved gases and other multiple factors are also decisive, which are not included in the known regression models estimates of the impact viscosity (impact) of the metal of the high-temperature HAZ sites. This significantly reduces the reliability of the calculations. Correlation coefficients generally do not exceed 0.75 [3; 18; 19]. In this context, most authors simulate the impact strength of high-temperature HAZ areas for samples with a circular cut at room temperature. However, it is the evaluation of impact viscosity values for samples with a V-cut at negative temperatures that is of practical importance [3; 21].

The distribution of average impact work in the different zones of test welds is shown in Fig. 4 (a, b).

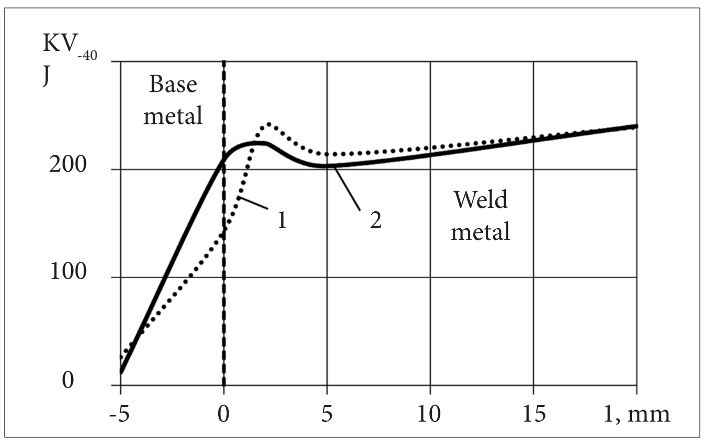


***Figure 4**. Average impact in different welded joint areas (T-orientation): a)HI=2.5 kJ/mm; b) HI=4.2 kJ/mm*

The analysis of the results showed that the minimum impact values in all cases exceeded the regulated value for E36 KVT_{-40} 24 J steel. However, there is significant anisotropy of properties in different welded areas. In addition, the range of actual impact values within the range of up to 25% in the high-temperature HAZ location of interest is variable, which makes accurate prediction problematic and once again confirms the low stability of the performance of the metal impact HAZ for the thickness of E36 steel (T-orientation). The greatest variation, however, is found at metal sites 2-5 mm from the molding line, probably due to the formation of the most unstable structure in this area with the maximum negative influence of the gases dissolved in the metal [4].

The estimated impact strength of high-temperature HAZ metal for sharp-cut samples and test temperature -40°C is KV_{-40}=32 J, for weld weld energy of 2.5 kJ/mm and KV_{-40}=38 J, for weld energy of 4.2 kJ/mm (see Fig. 1, a) which differs significantly from the real figures (see Fig. 4). In this context, the regression model for the calculation of the metal impact viscosity of the high temperature sections of the HAZ (Formula 4) by chemical composition, taking into account the cooling conditions of the weld, Does not provide a satisfactory correlation between design and actual data and cannot be recommended for practical application for the evaluation of properties of metal HAZ welded compounds of high-thickness steel of category E36 (T-orientation).

Thus, in practical terms, existing mathematical models for the evaluation of mechanical performance (R_m, R_{eH} and HV) to optimize weld compound properties and reduce related material costs HAZ metals can be used in the development of welding processes for E36-grade thick-steel steel structures. The operation of the impact (KVT_{-40}) is mandatory.

CONCLUSIONS

1. Analytical methods for calculating the mechanical characteristics of high-temperature HAZ sites (R_m, R_{eH} and HV) for chemical composition, taking into account the cooling rate after welding, Provide a level of confidence sufficient for practical application and can be

recommended for the primary evaluation of the properties of welded compounds of high-thickness steel plates of category E36 (T-orientation).

2. The minimum values of impact work in all cases exceed the regulated indicator for steel of category E36 – KVT_{-40}≥24 J. There is a significant anisotropy of properties in different zones of welded joints. In the high-temperature section of the HAZ, in both cases, the range of actual values of the impact work has a deviation of up to 25%, which makes accurate prediction problematic and once again confirms the low stability of the impact work of the HAZ metal for thick rolled steel of E36 category (T-orientation). At the same time, the greatest spread of values is typical for metal sections at a distance of 2-5 mm from the fusion line, which is probably due to the formation of the most unstable structure in this area with the maximum negative effect of gases dissolved in the metal.

3. Impact work (KV_{-40}) of high-temperature sections of the HAZ is not subject to analytical assessment, with the degree of accuracy required for industrial practice. For further application of the analytical evaluation, it is necessary to conduct studies of the effects of gases on the impact work. And also to make the necessary corrections of the coefficients in the analytical formulas.

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Комплексна оцінка зварюваності сталі підвищеної пружності

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Анотація. Сучасне виробництво сільськогосподарської техніки та обладнання, корпусів суден, стаціонарних нафтових бурових платформ, вітроенергетичних установок та інших металоконструкцій широко використовує листову сталь підвищеної міцності. Основним виробничим процесом є зварювання, якість якого залежить від багатьох факторів, у тому числі від здатності сталі протистояти зварюванню. Відомо, що властивості зони термічного впливу значною мірою залежать від фазових перетворень, характер яких визначається інтенсивністю та розвитком дифузійних процесів перерозподілу вуглецю та легуючих елементів під впливом зварювального термоциклу. Тому необхідно оцінити зварюваність сталі певного хімічного складу, щоб вибрати оптимальний спосіб і технологічні параметри режиму зварювання для виготовлення конкретної металоконструкції. З метою зниження матеріальних витрат можна використовувати аналітичні методи розрахунку, які були розроблені в Інституті електрозварювання ім. Е.О. Патона. Вони базуються на аналізі літератури та вивченні близько 150 діаграм термокінетичного розпаду аустеніту. Математичні моделі дозволяють з достатньою точністю прогнозувати фазовий склад і механічні властивості високотемпературної зони термічного впливу в залежності від хімічного складу і часу охолодження металу, нагрітого до максимальної температури 1350 °C., в діапазоні температур 850–500°C. Однак такі випробування є досить дорогими і не дозволяють оптимізувати властивості зварного шва при зміні режиму зварювання, зварювальних матеріалів та інших основних технологічних факторів. У зв'язку з цим ставилося завдання оцінити надійність запропонованої методики при дослідженні зварюваності суднобудівної сталі підвищеної міцності категорії Е36, для найслабшого Т (поперечного) – орієнтації листа товщиною 50 мм. Високі показники категорії сталі досягаються обмеженим збільшенням вмісту алюмінію або інших елементів (Nb, V, Ti), що забезпечує розмір аустенітного зерна не більше п'ятого бала. Дослідження показали, що аналітичні методи розрахунку механічних характеристик високотемпературних ділянок ЗТВ за хімічним складом з урахуванням швидкості охолодження після зварювання забезпечують достатній для практичного застосування рівень достовірності та можуть бути рекомендовані для первинної оцінки властивостей зварних з'єднань, листів великої товщини зі сталі категорії Е36 (Т-подібна орієнтація). Ударна робота (KV-40) високотемпературних зон термічного впливу не підлягає аналітичній оцінці з необхідним для виробничої практики ступенем точності

Ключові слова: сталь категорії Е36, оцінка зварюваності, аналітичні методи розрахунку в зварюванні, комплексні механічні випробування, механічні властивості, ударна в'язкість, твердість сталі

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Agrophysical Properties of the Soil Depending on the Surface Treatment with Various Tillage Units

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Abstract. An important direction in the greening of tillage is to preserve and improve the physical properties of soils in the optimal range of values, which is a necessary condition for the effective use of other agronomic measures that affect the formation of crop yields. With the advent of new, modern energy-efficient tillage tools, there is a need to conduct research on their effectiveness on the first stubble cultivation on the southern chernozem. The purpose of the research was to establish the influence of surface (stubble) cultivation with tillage tools of the "Lozovsky mashiny" brand after harvesting winter barley on the agrophysical properties of Southern heavy loamy low-humus chernozem in the conditions of the Southern steppe of Ukraine. In the research process, methods were used: field, laboratory, comparative-calculation, statistical. It was found that DUCAT-2,5 (short Harrow-Husker) best structured the soil among the studied aggregates. The lowest soil hardness values (0.48-1.33 MPA) and the tendency to form a plow sole were obtained in the version with vertical processing – Verti-till (turbo disk). The obtained scientific results of the research will contribute to the wider introduction into the production of new units of the "Lozivski mashini" brand for surface soil cultivation, which will contribute to the reduction of mechanical stress and the preservation of moisture in the soil

Keywords: stubble tillage, structural and aggregate composition, field moisture capacity, soil hardness, plow sole

INTRODUCTION

In today's conditions of limited resources, the primary task is the efficient use of land, the introduction of resource-saving technologies for growing agricultural crops that prevent a decrease in soil fertility, contribute to the optimization of the agrophysical state with minimal energy and money costs [1; 2]. The main means of optimizing the agrophysical state of the soil is its cultivation. Under conditions of intensive cultivation, the structure and physical properties of soils deteriorate, the equilibrium density increases, which leads to adverse economic and environmental consequences [3; 4]. Therefore, one of the ways to overcome this problem is to reduce gradually the intensity of mechanical impact on the soil.

An important direction in the greening of tillage is the preservation and improvement of the physical properties of soils, which is a necessary condition for the effective use of other agrotechnical measures (tillage, fertilization, sowing rates) that affect the formation of crop yields [5]. Therefore, in modern conditions, the search for technologies, cultivation systems and tillage tools that would help preserve moisture and reduce soil density is becoming relevant.

A significant number of studies have been devoted to the influence of various tillage systems on its agrophysical properties.

Thus, many researchers point to the negative impact of long-term use of plowing on the water-physical and agrophysical properties of soils, due to the formation of a plow sole, which inhibits the growth of plant roots in the lower layers of the soil. The root system, which does not penetrate the lower layers of the soil, often does not provide plants with water and nutrients when the upper horizons dry out, especially during droughts. In addition, plowing contributes to excessive loosening of the upper soil layer, leads to increased mineralization of organic matter and significant losses of humus reserves [6-8].

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A. Balaiev and Yu. Borysenko [9] prove that minimizing tillage improves its water-physical properties and ensures the preservation of moisture throughout the growing season. However, the improvement of tillage methods should be based on knowledge of equilibrium and optimal soil density, which are the theoretical basis for minimizing tillage [10].

Determined [11] that plowing created more favorable conditions for reducing soil density, and the use of shallow and zero processing technology was accompanied by a slight compaction of 0-30 cm of the layer. Other researchers, on the contrary, prove that minimizing cultivation improves the parameters of the physical properties of soils [12-14].

Studies of N.D. Reznichenko [13] found that the lowest folding density of the upper (0-10 cm) soil layer at the beginning of the growing season was formed with the use of disk and chisel loosening, and with prolonged use of shallow disk cultivation (12-14 cm) during two rotations of crop rotation led to an increase in the folding density in the layer of 10-20 cm compared to deep chisel loosening.

O.I. Tsyliuryk [15] determined that the use of flat – cutting loosening in the technology of growing corn significantly increased the hardness of the arable layer-by 2.2 times compared to shelf plowing, where arable land was turned over and the soil was maximally loosened and decompressed.

Studies conducted in the Right-Bank forest-steppe of Ukraine on chernozems of typical medium loam have established that minimizing cultivation leads to an increase in the density of the treated layer and a decrease in the overall porosity of the soil [16].

A.A. Horbatenko et al. [17] found that the use of shallow disk and non-polar main treatment of pure Steam does not lead to a deterioration in the agrophysical properties of ordinary chernozem compared to deep plowing and chisel treatment. Against the background of minimal cultivation, there is a tendency to increase the volume mass and hardness of the sub-seed layer of soil by 10-30 cm, as well as an increase in the content of agronomically valuable fractions of 10-0.25 mm in the arable layer.

Studies of M.R. Nunes et al [18] based on a meta-analysis, the effects of chisel plowing, zero tillage (NT), and perennial cropping systems (PER) compared with plowing (MP) on soil structure parameters have been investigated and published. It was determined that reducing the intensity of tillage improves the soil structure.

Similar results were obtained for growing oats in the Left-Bank forest-steppe. The best structure and content of agronomically valuable soil aggregates in the germination phase of oat plants is formed in the variant with flat-cut processing [19].

O.V. Pikovska points out an increase in the content of agronomically valuable aggregates in the soil layers of 10-20 and 20-30 cm while minimizing cultivation compared to plowing [19].

Recently, in many farms of the steppe and forest-steppe zones of Ukraine, due to lack of moisture and some other factors, preference is given to minimal non-dump tillage stubble tillage with tillage units with simultaneous crumbling, pruning of the root system of weeds and crop residues of plants, partial sealing and mulching of the field surface. With this approach, plowing is not used at all. Especially widespread is the use of units for vertical tillage, which are able to carry out virtually universal tillage, which determines their wide versatility of application and allows the same unit to perform several tasks. As practice shows, after passing a properly configured vertical unit, you can immediately sow all types of crops [20].

So, the analysis of scientific publications has shown an improvement in the agrophysical indicators of the soil when using surface treatment, but with the advent of new, modern energy-efficient tillage tools, it becomes necessary to conduct research on their effectiveness at the first stubble treatment on Southern chernozem.

In the experiments of C. Chang and W. Lindwall, it is noted that more favorable conditions for the accumulation of productive moisture in the soil are created during surface or flat-cut mechanical soil cultivation, compared to plowing [21].

According to scientists, traditional methods of soil cultivation can be the reason for the reduction of macroaggregates, the occurrence of degradation phenomena in soils [22]. Soil cultivation with minimal mechanical impact on the arable layer leads to an increase in the content of water-resistant aggregates [23], which prompts the need to reduce the number of cultivations during crop cultivation.

The purpose of the research is to determine the agrophysical properties of the soil after harvesting spring barley under the influence of surface (stubble) tillage with tillage tools of the Lozivski mashini brand in the conditions of the Southern Steppe of Ukraine.

MATERIALS AND METHODS

The research was conducted during 2020-21 on the research field of the Educational-scientific-practical center of MNAU (Blagodarivka village, Mykolaiv district of Mykolaiv region). The soil of the research area is chernozem southern heavy loam low-humus.

The scheme of the experiment provided for variants of stubble tillage with tools of the "Lozovsky mashiny" brand:

1. Control (without processing);
2. DUCAT RST-6 chopping Rotary chopper (knife-rotor);
3. DUCATUVT-6 vertical Harrow Verti-till (turbo disc);
4. DUCAT-2.5 short disc harrow-Husker (variodisk);
5. LIRA XL-21 heavy spring tooth Harrow (strigel).

To simplify perception, these machines were named after the type of working body: knife-rotor; turbo-disk; variodisk; strigel.

The test conditions were generally characterized as typical for the Southern Steppe zone of Ukraine and contribute to high-quality surface treatment. The average daily air temperature for the study period was +25.4°C, the maximum one reached +33.5°C, and the minimum one was 17.5°C. The amount of precipitation for the reporting period was 14.2 mm.

Agro background was spring barley stubble, stubble height was 16.6 cm, soil condition in layers of 0-20 cm had humidity 22.1-23.9%, and hardness 0.54-0.94 MPa. Tillage was carried out immediately after harvesting spring barley.

Working speed: knife-rotor – 13.0 km/h turbo disc – 15.1 km/h, variodisk – 12.0 km/h, Strigel – 10.2 km/h.

Tools have a different structure of working bodies and modes of their operation, which ensures the quality and peculiarity of the technological process inherent in each machine.

The total area of the plot was 600 m^2, the accounting area was 100 m^2. The repetition in the experiment was threefold. The placement of land plots was consistent.

Field, statistical, and laboratory methods were used to conduct experimental work. The structural and aggregate composition of the soil was determined by the N.I. Savinov method (dry sieving) [24], the soil hardness was determined by the Kaczynski cutting ring method [24], and the volume water content (%) was measured using a portable device in layers every 5 cm of soil.

Soil samples were taken three times with an interval of 5 days – 12.07; 19.07; 23.07.

RESULTS AND DISCUSSION

Stubble treatment-surface treatment that includes loosening the soil to a depth of 5-8 cm without turning it over for the purpose of pruning crop residues, weeds, leveling the surface, mulching (mixing the soil with plant residues) in order to accumulate and preserve moisture and improve the agrophysical characteristics of the soil [25]. The structure of the soil determines the favorable structure of the arable layer, its water, and physical, mechanical and technological properties: such as soil density, hardness of the treated layer, in which the root system of plants develops, reserves of productive moisture. Optimal conditions of water and air regimes are formed in soils with a fine-grained and granular structure [24].

The soil structure according to the size of aggregates is divided as follows: lumpy (aggregates >10 mm); lumpy-granular, or macrostructure (aggregates 10-0.25 mm); powdery, or microstructure (aggregates 0.25 mm). In the resistance of soils to wind erosion, the main role is played by the clumsiness of the upper layer (0-50 mm) [26].

The vast majority of researchers note that flat-cut cultivation has a better effect on the structure than plowing, and minimizing soil cultivation is an effective means of improving the structure of ordinary chernozem by increasing the content of agronomically valuable aggregates [27; 28].

According to the results of A.A. Pavlichenko's research, it was established that the best structural condition was observed during long-term shallow tillage, where 60.2 and 64.2% of water-resistant aggregates were found in the plow layer, or 1.5 and 1.2% more than in control [29].

Shallow (10-12 cm) moldboard cultivation contributed to growth of the topsoil bulk density of chernozem by 0.3-0.5 g cm^{-3} and decrease in total porosity by 0.6-0.9% compared to plowing by depth of 20-22 cm in field experiment of the National University of Life and Environmental Sciences of Ukraine [30].

In studies, the structural and aggregate composition of the upper soil layer due to treatment with various tillage tools had significant differences between the variants (Fig. 1).

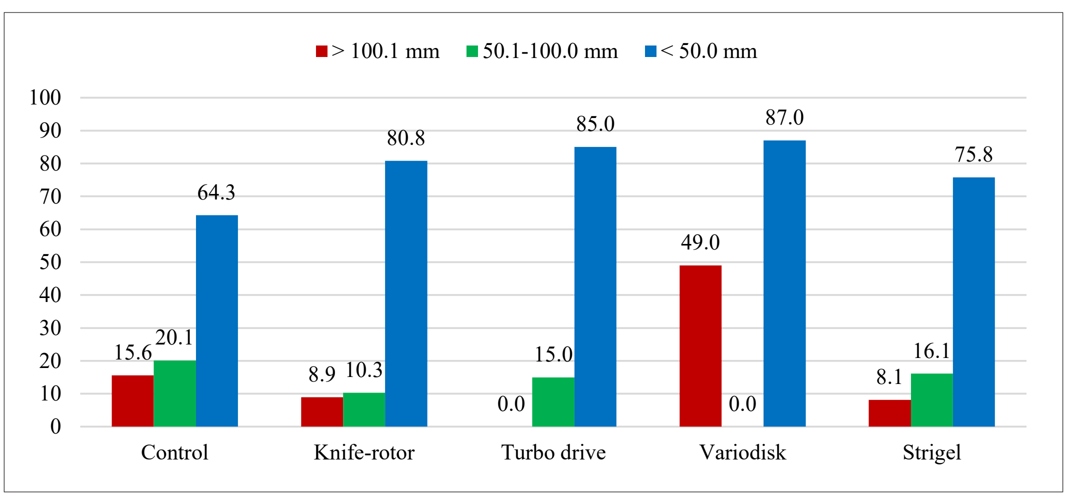

Figure 1. *Influence of stubble treatment with tillage tools on the content of soil aggregates in a layer of 0-8 cm, %*

A larger number of units up to 50 mm in size were formed as a result of crumbling the soil by working bodies with a short disc harrow-Husker (variodisk), a vertical processing harrow Verti-till (turbo disk) and a chopping Rotary chopper (knife-rotor). Lumpiness in these variants ranged from 80.8 to 87.0%, which exceeded the content of lumps up to 50.0 mm in the control variant by 16.5-22.7%.

Accordingly, the blockiness of the structure (aggregates >10 mm) was the lowest in the variant when processing with a short disc harrow-husker (variodisk) – 4.9%, and the maximum destruction of blocks occurred when processing with a vertical harrow treatment Verti-till (turbo disk). The increased content of block aggregates was observed in the control version – 15.6%.

To prevent the development of wind erosion in the post-harvest period, which is important in the conditions of the Southern Steppe, stubble treatment with a turbo disk and a knife-rotor can be a significant factor in the soil's anti-erosion resistance. The most agronomically valuable structure is the content of particles of 0.25-10 mm of at least 70%, less than 40% is unfavorable. In studies, the optimal amount of agronomically valuable aggregates in the upper layer of the soil was created by mulching treatment with a short disc harrow-husker (variodisk) and a chopping rotary chopper (knife-rotor) – 74.7-78.7% (Fig. 2).

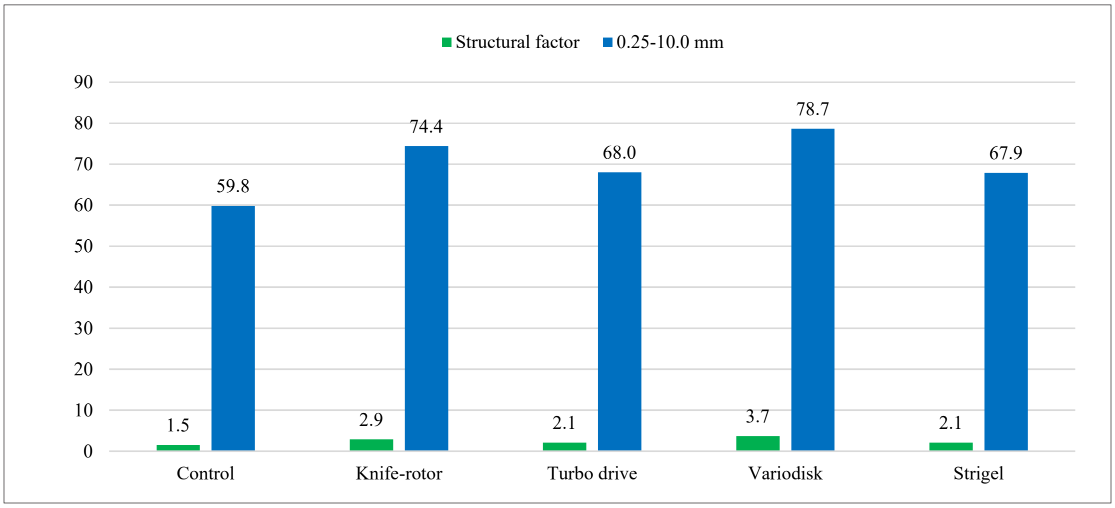

Figure 2. *Content of agronomically valuable aggregates (0.25-10 mm) in a layer of 0-8 cm, depending on the tillage of various aggregates %*

Soil hardness – the property of the soil in its natural composition to resist compression and prospection. This is one of the main indicators that characterizes its physical condition, determines the environment in which the root system of the plant is located, and, accordingly, it determines the efficiency of nutrition. Hardness often leads to a decrease in seed germination, affects the water, air and thermal conditions of the soil, the traction resistance of tillage machines and tools [30].

Stubble treatment with tillage tools significantly affected the hardness indicators in the soil layers and depended on the working bodies of the mechanisms. The lowest hardness was observed in the 0-5 cm layer and gradually increased down the profile in all variants of the experiment. The lowest hardness of the upper soil layer was observed with the Verti-till vertical harrow (turbo disk) – 0.48 MPA and in the control – 0.54 MPA (Table 1).

Table 1. *Soil hardness in different layers depending on stubble treatment with different tillage units, MPa*

Layers of soil, cm	Tillage units				
	Control	Knife-rotor	Turbo drive	Variodisk	Strigel
0-5	0.54	1.05	0.48	0.71	0.72
5-10	0.66	1.10	0.92	1.10	1.22
10-15	0.84	1.18	1.12	1.23	1.46
15-20	0.92	1.29	1.33	1.14	1.41

The highest hardness in the 0-5 cm layer was observed in the version when processing with a chopping rotary chopper (knife-rotor) – 1.05 MPa, which was 0.51 MPa higher than the soil hardness from the control version. In all soil layers, the lowest hardness values were in the control version (0.54-0.92 MPa).

When processing stubble with tillage tools, the best results were obtained in the version with the Verti-till vertical harrow (turbo disk) – 0.48-1.33 MPa. The greatest compaction and hardness in the soil layer of 5-20 cm was facilitated by processing with a heavy tooth spring harrow (strigel) – 1.22-1.46 MPa. Using this indicator, you can determine the depth, thickness, and density of the plow sole, the formation of which depends on the tillage technology. Increasing the hardness increases the energy intensity of tillage, reduces water permeability, it slows down the development of roots until they completely stop due to the inability to penetrate through the compacted layer. The results of assessing the propensity of the soil to form a plow sole using the falling cone method are shown in Figure 3.

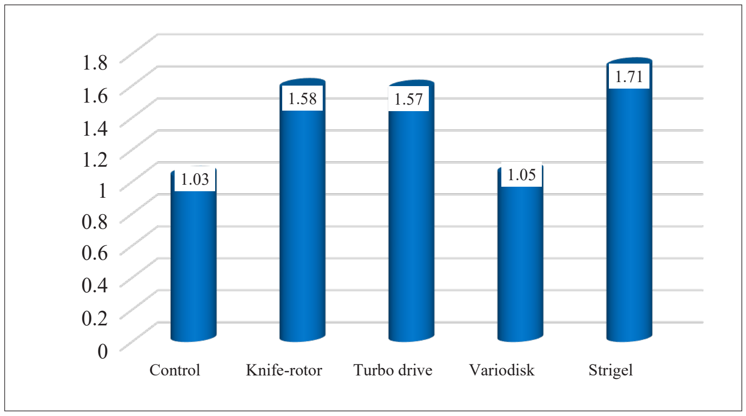

Figure 3. *Influence of tillage on the tendency to form a plow sole by the height of immersion of the falling cone, cm*

The least susceptible to the formation of a plow sole was the soil in the version when treated with working bodies with a short disc harrow-husker (variodisk) – 1.05 cm, which was at the level of the control Version (1.03 cm). The soil in the version of processing with a heavy tooth spring harrow (strigel) was most susceptible to the formation of a plow sole in terms of the height of immersion of the falling cone – 1.71 m. Processing with a verti-till vertical harrow (turbo disc) and a rotary chopper (knife-rotor) revealed the same tendency for forming a plow sole – 1.57-1.58 cm.

Soil hardness and humidity are related indicators. With a decrease in the moisture content in the soil, the hardness increases significantly and negatively affects the root system of plants. Therefore, before installing moisture supply, the soil hardness is determined to identify areas of over-compaction. In recent years (2020-2021), the risks of arid conditions have been increasing more and more, so modern technologies require significant improvement, in particular in the search for agricultural measures aimed at preserving natural moisture resources.

The most important physical property of the soil that determines its humidity is moisture capacity (capillarity) – a value that quantifies the water-retaining ability of the soil: the ability to absorb and retain a certain amount of moisture from draining under the influence of capillary and sorption forces. The degree of soil moisture retention was determined using the volume water content indicator, or field moisture capacity ("FMC"), which is a numerical indicator of soil moisture (Table 2).

Table 2. *Dynamics of moisture reserves in the surface layer (0-25 cm) depending on stubble treatment with various tillage units, %*

Tillage units	Layers of soil				
	0-5	5-10	10-15	15-20	20-25
First term					
Control	7.4	20.2	44.9	42.1	56.1
Knife-rotor	16.0	38.9	50.0	46.8	65.5
Turbo drive	11.5	25.4	46.0	45.6	66.1
Variodisk	0.0	41.6	64.1	60.5	62.8
Barbell	0.0	44.4	48.1	63.3	63.9
Second term					
Control	4.2	7.5	27.3	31.5	35.0
Knife-rotor	0.0	23.9	34.5	36.7	40.7
Turbo drive	6.7	8.2	38.3	44.4	55.4
Variodisk	0.0	28.0	46.3	56.1	59.3
Barbell	6.3	14.0	29.8	42.6	50.0
Third period					
Control	6.3	10.6	27.8	31.4	35.7
Knife-rotor	2.1	14.4	24.1	30.4	34.2
Turbo drive	1.9	5.8	36.0	42.0	50.0
Variodisk	9.9	24.1	47.3	52.2	28.1
Barbell	4.7	5.5	30.3	38.6	49.4

The control variant had the lowest values of field moisture capacity in all soil layers. Thus, the moisture reserves in the soil layer from 0-25 cm were higher in the variant with Ducat-2.5 variodisk and in dynamics they were: 45.8% (first term); 37.9% (second term) and 38.3% (third period) respectively (Fig. 4).

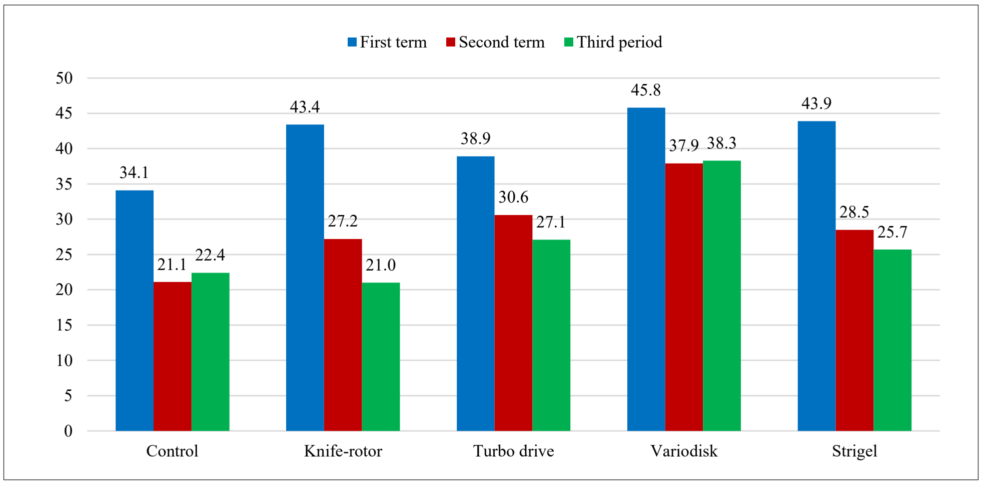

Figure 4. *Dynamics of moisture reserves (%) depending on stubble treatment with various tillage units, average at a depth of 0 to 25 cm*

Lower moisture reserves in the 25 cm soil layer were in the control version (without cultivation) – 34.1% (first term); 21.1% (second term) and 22.4% (third period).

Among the four tillage units studied, in the 25 cm layer the lowest moisture reserves were observed in the knife-rotor variant: such as 43.4, 27.2 and 21.0%, respectively. The water permeability of the soil depends on the mechanical composition and structure of the soil, the amount of swelling, the composition of absorbent bases, worm passages, etc. the optimal value is at least 30 mm/hour. Therefore, the regulation of soil water permeability should be reduced for improving the structure and structure of the soil by appropriate mechanical treatment, the introduction of organic (especially green manure) fertilizers.

The water permeability of the loosened soil was optimal after treatment with the studied aggregates in all variants (Table 3).

Table 3. Influence of tillage with tillage units on water permeability soil through a fixed area, mL/cm^2/min

Time interval, min	Tillage units							
	Knife-rotor		Turbo drive		Variodisk		Strigel	
	Subsided soil	Soles	Subsided soil	Soles	Subsided soil	Soles	Subsided soil	Soles
1	3.63	3.4	3.9	1.9	4.8	2.8	4.0	2.0
2	3.82	4.3	4.1	1.9	5.3	3.2	4.2	2.0
3	4.36	4.6	4.6	2.3	5.4	3.2	4.4	2.0
4	4.54	5.3	4.9	2.7	5.7	3.8	4.5	2.0
5	5.04	5.9	5.5	2.7	6.2	3.8	4.5	2.3
6	5.38	6.3	5.8	2.7	6.5	3.9	4.8	2.3
7	5.91	7.0	6.3	3.3	7.1	4.3	4.8	2.3
8	5.91	7.3	6.7	3.5	7.2	4.5	4.8	2.4
9	6.3	7.9	7.2	3.6	7.6	5.0	5.0	2.5

However, the soil was better able to pass the added water when treated with Ducat-2.5 variodisk both after 1 minute and after 9 minutes of research – 4.8-7.6 ML/cm^2/min. In addition, good results of water absorption along the loosened layer were obtained in the Verti-till vertical harrow treatment variant (turbo disk) – 3.9-7.2 mL/cm^2/min.

A valuable indicator of tillage is the water permeability of the sole, which affects the provision of moisture to the root system of plants. According to the table data, in all variants of studies on this indicator, the option for processing with a ducat RST rotary chopper (knife-rotor) was distinguished as 6 – 3.4-7.9 mL/cm^2/min. Lower rates of moisture absorption by the sole were shown by the option for stubble treatment with a heavy tooth spring harrow (strigel) LIRA XL-21 from 2.0 to 2.5 mL/cm^2/min.

CONCLUSIONS

Based on the results of a scientific study of the effectiveness of using surface tillage of tillage tools of the

"Lozovsky mashiny" brand, the following conclusions can be drawn:

– the best structured soil was a short harrow-husker DUCAT-2.5; the content of agronomically valuable aggregates of 0.25-10 mm was 78.7% (K page=3.7). The content of lumpy fractions of 0-50 mm in size of more than 70% in the treated layer was provided by all aggregates, which was an excellent indicator;

– the lowest indicators of soil hardness and the tendency to form a plow sole were obtained in the Verti-till vertical treatment variant (turbo disk) – 0.48-1.33 MPA. The greatest compaction and hardness in the soil layer of 5-20 cm was facilitated by processing with a heavy tooth spring harrow (Strigel) – 1.22-1.46 MPA;

– preservation of soil moisture in terms of moisture capacity (VWC) was best provided by a short disc harrow-husker (variodisk) DUCAT-2.5 (variodisk).

In connection with the significant mechanical load on soils and climate changes, especially in the Southern Steppe zone of Ukraine, the obtained scientific results are relevant and will be implemented in production. In addition, further tests of the "Lozivski mashini" brand tools on irrigation, which will contribute to the preservation of moisture in the soil, are promising.

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Агрофізичні властивості ґрунту залежно від поверхневого (стерньового) обробітку ґрунтообробними знаряддями

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Анотація. Важливим напрямком в екологізації обробітку ґрунту є збереження та покращення фізичних властивостей ґрунтів в оптимальному інтервалі значень, що є необхідною умовою ефективного використання інших агротехнічних заходів, які впливають на формування урожайності сільськогосподарських культур. З появою нових, сучасних енергоефективних ґрунтообробних знарядь виникає необхідність у проведенні досліджень з їх ефективності на першому стерньовому обробітку на чорноземі південному. Метою досліджень було встановити вплив поверхневого (стерньового) обробітку ґрунтообробними знаряддями бренду «Лозівські машини» після збирання ячменю озимого на агрофізичні властивості чорнозему південного важкосуглинкового малогумусного в умовах Південного Степу України. У процесі дослідження використовувалися методи: польовий, лабораторний, порівняльно-розрахунковий, статистичний. Встановлено, що серед досліджуваних агрегатів найкраще структурував ґрунт DUCAT-2,5 (коротка борона-лущильник). Найнижчі показники твердості ґрунту (0,48–1,33 МПа) та схильність до утворення плужної підошви було отримано у варіанті з вертикальним обробітком – Verti-till (турбо-диск). Отримані наукові результати досліджень сприятимуть широкому впровадженню у виробництво нових агрегатів бренду «Лозівські машини» для поверхневого обробітку ґрунту, що допоможе зменшувати механічне навантаження та зберігати вологу в ґрунті

Ключові слова: стерньовий обробіток ґрунту, структурно-агрегатний склад, польова вологоємність, твердість ґрунту, плужна підошва

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

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

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

INTRODUCTION

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

MATERIALS AND METHODS

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

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

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

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

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

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

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

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

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

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

RESULTS AND DISCUSSION

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

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

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

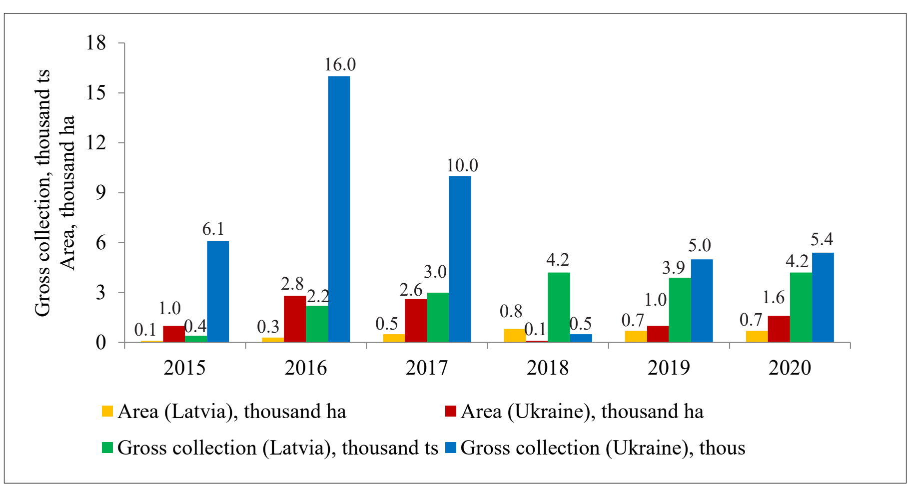

***Figure 1**. Hemp sowing area and gross seed collection in Latvia and Ukraine*
***Source:** constructed by the authors based on data [19; 20]*

An important indicator of the volume of agricultural production in the states is the gross harvest. It depends both on the amount of harvested area and on the productivity formed by the culture. In Latvia, the largest gross collection of seeds (4.2 thousand tons) was recorded in 2018 and 2020 [20]. Ukrainian farmers collected the largest amount of seeds (16.9 thousand tons) in 2016 thanks to the larger area for collecting hemp seeds. In general, during the analyzed period (2015-2020), the area of hemp seed cultivation in Ukraine increased by 60% (Table 1).

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

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

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

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

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

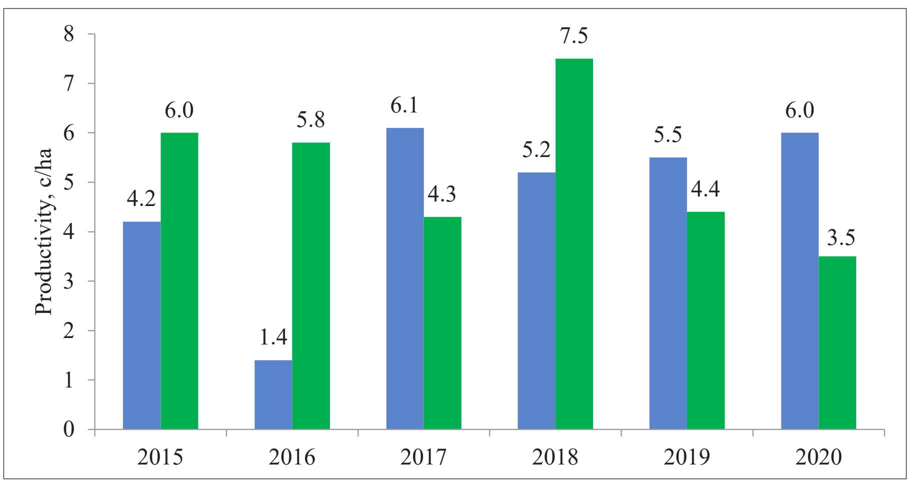

Figure 2. *Yield of hemp seeds in Latvia and Ukraine*

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

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

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

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

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

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

L.S. Bezugla [22] claims that modern Ukrainians consider hemp a narcotic plant, although it has been grown in Ukraine since ancient times as a food, fodder, and technical crop. Hemp seeds are intended for the production of valuable oil, and meal – as a product for feeding livestock. Hemp fiber is suitable for the production of ecological textiles, firewood – as bedding for animals, mulch – for covering the ground cover under plants and even for the production of building materials [17; 22; 23].

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

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

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

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

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

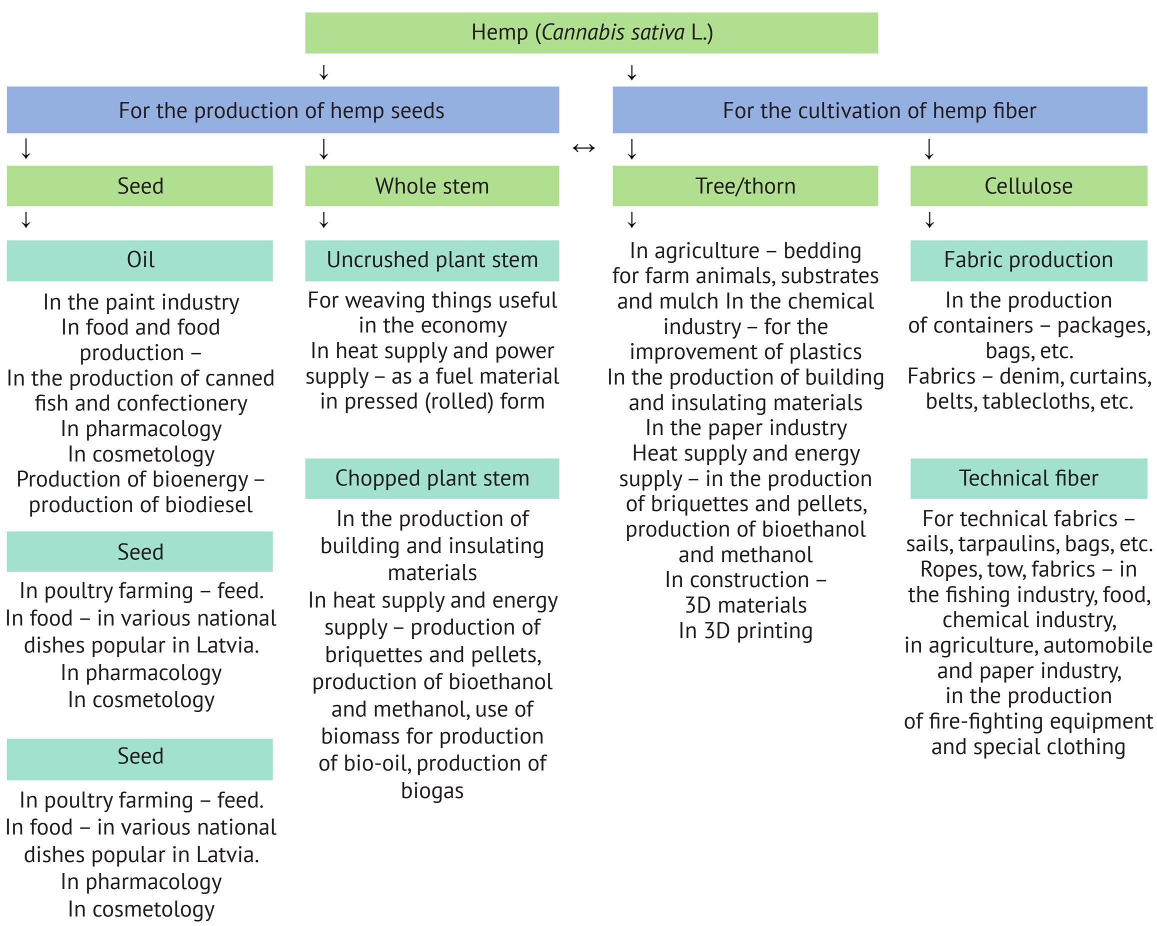

Figure 3. *Options for the use of cannabis Cannabis sativa L. (L. Poiša)*

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

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

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

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

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

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

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

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

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

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

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

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

It was determined [36] that the collection of hemp fiber and its quality are significantly influenced by the norms of sowing seeds and providing plants with the main macronutrients. It has been established that in order to obtain the yield of hemp, which will be characterized by high-quality fiber (more than 2200 kg/ha), it is necessary to plant them with a seeding rate that will ensure a density of 329 plants/ha. Nitrogen should be applied in doses of 251-273 kg/ha, phosphorus – 85-95 kg/ha, and potassium – 212-238 kg/ha.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Table 3, Continued

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

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

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

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

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

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

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

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

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

CONCLUSIONS

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

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

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

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

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

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

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

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

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

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Productivity of Cows of the Ukrainian Red-Spotted Dairy Breed with Different Genotypes According to the TLR1, SLC11A1 and CSN2 Loci

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Abstract. The use of methods of marker-associated selection opens up new perspectives in the context of maximum realization of the productive potential of animals, which makes the issue of the application of modern scientific approaches in animal husbandry particularly relevant. Considering this, the analysis of the productive qualities of cattle with different genotypes according to the set of candidate genes is one of the most urgent tasks of animal genetics and breeding. Therefore, the purpose of this study is to analyze the productive qualities of cows of the Ukrainian red-spotted dairy breed with different genotypes according to the TLR1, SLC11A1 and CSN2 loci. Genotyping of cattle individuals was performed using the PCR-RFLP method for TLR1 and SLC11A1 and AS-PCR for CSN2. The analysis of productive qualities of animals was carried out by comparing the parameters of three lactations for each group of animals according to the indicators of average milk yield for 305 days of lactation (kg), protein content in milk (%) and milk fat content (%). The study was carried out on the basis of previously obtained results of individual typing of individuals according to research loci. According to the results of studies conducted in the experimental population of cows for the toll-like receptor 1 (TLR1) locus for the first and third lactations, the dominant values of the yield index are characteristic of homozygotes with the GG genotype, while for the second lactation the highest values of yield are observed for homozygous individuals for allele A. At the same time, a probable difference between the indicators of individuals with different genotypes was not established.No significant difference between the groups of cows with the studied genotypes in the parameters of fat and protein content in milk by the TLR1 locus was also found. SLC11A1 is characterized by a characteristic difference from the previous gene, as two mutations forming haplotypes – CC-AA, CG-AA and CG-AT out of nine potentially possible variants were found in this locus. According to indicators of milk productivity, animals with the CG-AA haplotype had higher values of milk compared to other haplotypes during all three lactations (the difference is probable). The greatest differences were observed with the CG-AT haplotype. According to the indicators of the content of milk protein and fat, no probable differences between individuals with different haplotypes were established. The variability of signs for all lactations was at a low level. As for the beta-casein locus, according to the results of the conducted research, no significant difference in the indicators of milk productivity of cows with different genotypes was found. The highest confidence values are characteristic of individuals with the A1A1 genotype, however, the difference with individuals with other genotypes is unlikely. In any case, the A2 allele, according to the value of the indicators of homozygous individuals (genotype A2A2), does not have a negative effect on the parameters of milk productivity of animals

Keywords: polymorphism, allele, population, productivity, cows

INTRODUCTION

The basis of the high efficiency of selection work in animal husbandry is based on the principle of following the advanced achievements of genetics as the fundamental basis of selection. Over the past several decades, DNA-oriented technologies have become the most widely used – from the use of various types of molecular genetic markers to genomic selection. The possibility of direct assessment of an animal's genotype by DNA, in the absence of phenotypic assessment at this stage, made it possible to carry out large-scale passporting of populations of representatives of various agricultural animal species, as well as to identify carriers of productive and counterproductive alleles

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and genotypes. Today, in Ukraine, despite the difficult circumstances associated with the difficulties of financing scientific research programs in animal husbandry, work is being carried out on the use of methodical approaches of marker-associated selection (MAS), aimed at determining the characteristics of the genetic and population parameters of research groups of animals, as well as for the analysis of the productive qualities of individuals with different genotypes based on the set of potential candidate genes. Toll-like receptor 1 (TLR1), transmembrane protein SLC1 (SLC11A1) and beta-casein (CSN2) genes are among the most promising in cattle genetics. The presence of marker alleles, which are associated with economic and valuable traits of animals within experimental groups, is quite important for targeted selection in order to maximize the productive potential of cattle. Undoubtedly, traditional methods of animal selection based on phenotypic traits (selection by phenotype) are of great importance in the selection process. However, from the point of view of world practice, it is the selection by genotype (MAS) that makes it possible to significantly increase the efficiency of the work being carried out.

According to the results of numerous studies, the presence of a number of mutations in the above-mentioned loci has been established, which in some breeds of cows are associated with adaptive qualities of animals [1-3]. On the other hand, the relationship with indicators of milk productivity of animals (protein content, fat content, etc.) has practically not been investigated. Considering the above, the purpose of further research was to analyze the productive qualities of cows of the Ukrainian red-spotted dairy breed with different genotypes according to the TLR1, SLC11A1 and CSN2 loci.

Vertebrate TLR1 and SLC11A1 genes are associated with the regulation of immune responses against a wide range of pathogenic microorganisms, and their products, proteins, by their function mostly belong to receptors involved in the processes of innate immunity. Individual mutations of the TLR1 gene reduce the effectiveness of the immune response against lipopeptide and lipopolysaccharide components of the cell wall of various types of bacteria [4; 5]. In turn, the SLC11A1 gene encodes a transmembrane protein known as one of the potential targets that contribute to innate immunity against various intracellular pathogens (tuberculosis [1], bovine brucellosis [2; 3]).

An important role of the TLR1 gene in the implementation of adaptive immunity lies in its ability to influence antimicrobial activity in the skin, mucous membranes of the respiratory tract, and the gastrointestinal tract of animals [6]. With the help of phylogenetic analysis, it was established that the TLR1 gene, together with TLR6 and TLR10, is characterized by a common origin and is located in a tandem that forms a gene cluster of ~69 kb TLR6-TLR1-TLR10 on Bos taurus chromosome 6 (bta6) [7]. According to the results of the mapping of quantitative traits QTL (Quantitative Trait Loci) in the cattle genome, it was established that this cluster is located in a dense QTL region, which is important for a number of traits of technical parameters of milk and the manifestation of clinical mastitis [8]. Under these circumstances, the TLR1 locus turned out to be a promising candidate for the study of animal resistance/susceptibility parameters to diseases such as mastitis [9]. Different authors found out that mutations in genes of the TLR family lead to a decrease in the efficiency of pathogen recognition and activation of the link of the innate immune system [10; 11]. In particular, Cinar and co-authors [12] revealed the association of research genotypes of cows with the risk factor for infection of animals with paratuberculosis (John's disease, pTB). Based on the results of immunoenzymatic analysis, it has been proven that East Anatolian Red and Anatolian Black breeds are more resistant to paratuberculosis compared to Holsteins, therefore, selection of animals for a certain genotype of TLR1 (+1380A/G) can potentially reduce the risk of developing this disease in cattle. Other scientists have demonstrated that some mutations of the TLR1 gene are associated with the manifestation of clinical signs of such infections as brucellosis and bovine tuberculosis [13; 14]. Instead, Russell and co-authors established an association between different SNPs in the TLR1 locus, reduced levels of clinical mastitis (CM) and increased protein and fat content in milk [15].

The SLC11A1 gene, located on chromosome 2, consists of 15 exons and 14 introns, with a total size of ~11 kb. In addition to associations of this gene with parameters of resistance/sensitivity to various infectious diseases, a reliable connection between research genotypes of the Holstein breed and the manifestation of clinical mastitis has been proven. It can be assumed that the SLC11A1 locus is a potentially valuable candidate gene, first of all, for improving resistance to mastitis, as well as for determining the parameters of productive traits in dairy cattle populations [16]. This is confirmed by the studies of other scientists, who found a correlation between NRAMP1 (alternative name SLC11A1) polymorphisms and the number of somatic cells in the milk of cows [17].

In contrast to the above, the beta-casein gene refers to objects related not to the functioning of the body's immune system, but to milk proteins. In cow's milk, beta-casein belongs to one of the most common fractions, while two variants – A1 and A2 – are the most interesting and promising for research. Variant A1 is (potentially) associated with a set of pathological effects on the human body if milk containing beta-casein of this type is consumed. In turn, the A2 option is completely devoid of these features. However, the question of potential counterproductiveness of the "desired" A2 allele (association with low milk yield compared to A1) remains open. In this regard, in addition to the issues of general typing of animals of different cattle populations according to A1 and A2 alleles, it is also advisable to investigate the productive qualities of individuals with different genotypes.

Previously, in our research, we determined the features of the genetic structure of research populations of cattle of various breeds based on the TLR1, SLC11A1, and CSN2 loci [18]. In this work, we focus on the study of productive parameters (milk yield) of cattle (Ukrainian red-spotted dairy cow breed) with different genotypes according to the above-mentioned loci.

MATERIALS AND METHODS

The study was conducted in the laboratory of molecular genetic and physiological and biochemical research in animal husbandry of the Institute of Animal Husbandry of the National Academy of Sciences and in the laboratory of molecular genetic research of the Department of Animal Biology of the National University of Bioresources and Nature Management of Ukraine.

As an object of research, we used a population of cows of the Ukrainian red-spotted dairy breed (DPDG "Gontarivka", Kharkiv region, Vovchanskyi district). DNA was isolated from individual samples of biological material (hair bulbs) using a commercial kit of reagents "DNA-Sorb-B" (Amplisens) according to the manufacturer's recommendations. Genotypes were determined using the PCR-RFLP (Polymerase Chain Reaction – Restriction Fragment Length Polymorphism) method for TLR1 (Bc1I polymorphism) and SLC11A1 (PstI polymorphism), and using AS-PCR for CSN2.

To separate the restriction/amplification fragments, electrophoresis was performed in a 1.5% agarose gel with the addition of ethidium bromide as a dye. A UV transilluminator with a wavelength of 312 nm was used for visualization.

The value of average milk yield for 305 days of lactation (kg), indicators of milk fat content (%) and protein content in milk (%) were used to study parameters of milk productivity of animals. Performance analysis was performed by comparing the parameters of the first three lactations for each studied locus.The analysis of productive parameters of cows with different genotypes for the TLR1, SLC11A1 and CSN2 loci was carried out using one-way analysis of variance (ANOVA) and the Tukey-Kramer multiple comparisons test as a tool for post-hoc testing. Calculations were made in Microsoft Excel using the Real Statistics Resource Pack. Distribution was tested for normality using the Shapiro-Wilk test. In case of deviation from the normal probability distribution, the non-parametric Mann-Whitney U-test was used.

RESULTS AND DISCUSSION

Based on the results of the research, the milk productivity parameters of cows of the Ukrainian red-spotted breed with different genotypes according to the TLR1 locus were determined (Table 1). Taking into account the peculiarities of the genetic structure of the experimental group of cows, parameters were compared between individuals with all possible (according to this locus) genotypes – AA, AG and GG.

Table 1. *Indicators of milk productivity of cows of the Ukrainian red-spotted breed with different genotypes according to the TLR1 locus*

Indicator	Genotype		
	AA	AG	GG
First lactation			
Milking, 305 days, kg	5370.5±306.02[a]	5135.9±158.20[a]	5375.7±280.27[a]
C_v, %	13.96	14.11	18.79
Fat, 305 days, %	3.82±0.021[a]	3.86±0.017[a]	3.87±0.034[a]
C_v, %	1.32	2.05	3.13
Protein, 305 days, %	3,32±0,048[a]	3,31±0,028[a]	3.319±0.022[a]
C_v, %	3.55	3,86	2.35
Second lactation			
Milking, 305 days, kg	6214±267.85[a]	5949.3±159.42[a]	6127.5±281.33[a]
C_v, %	10.56	12.28	16.55
Fat, 305 days, %	3.73±0.032[a]	3.76±0.015[a]	3.77±0.026[a]
C_v, %	2.11	1.81	2.48
Protein, 305 days, %	3.26±0.066[a]	3.25±0.025[a]	3.26±0.026[a]
C_v, %	4.95	3.58	2.88
Third lactation			
Milking, 305 days, kg	6760.5±301.21[a]	6576.5±129.53[a]	6783.7±240.83[a]
C_v, %	10.91	9.03	12.80
Fat, 305 days, %	3.67±0.030[a]	3.69±0.013[a]	3.70±0.022[a]
C_v, %	2.02	1.56	2.12
Protein, 305 days, %	3.19±0.057[a]	3.17±0.027[a]	3.15±0.032[a]
C_v, %	4.41	4.02	3.63

Note*: different subscripts (a, b) indicate the probability of difference (p<0.05) within the indicator*

According to the research results, it was found that for both the first and third lactation, the maximum values of the lactation index are characteristic of homozygotes for the G allele, however, AA homozygotes have practically identical values. In turn, on the second lactation, the situation changes somewhat – the highest milk yield values are characteristic of individuals homozygous for the A allele, while for homozygotes GG, a slight difference in this indicator was noted (87 kg). Based on the obtained results, no probable difference between the values of the indicators was found (Table 1). In addition, according to the yield index for 305 days, the value of the coefficient of variation was mostly within the average level of variability of the indicator (it did not exceed the limit of 19%) for all three lactations.

It should be noted that the sample was characterized by a small number of individuals of individual genotypes, which is explained by the inclusion of only individuals of the first three lactations, which thus reduced the total number of animals in groups relative to one or two lactations.

No significant difference was found between the groups of cows with the tested genotypes for the TLR1 locus regarding the indicators of milk fat and protein content. According to the parameters of the content of milk fat and protein in relation to the value of the coefficient of variation, all groups of animals are characterized by a low level of variability (the value of Cv in each case is below 5%).

The SLC11A1 locus is significantly different from the TLR1 described above. In this locus, two mutations that form haplotypes – CC-AA, CG-AA and CG-AT out of nine possible variants were investigated. Other variants of haplotypes were not detected in the research population of cows. In more detail, the results of studies of the features of the genetic structure of cow populations of various breeds of Ukrainian selection based on the TLR1 and SLC11A1 genes are considered in our previous work [18]. Features of the distribution of haplotypes in the research population of animals (ratio of frequencies of individuals with different haplotypes) made it possible to analyze the productive indicators of cows (Table 2). It should be noted that in this case, the analysis of performance indicators of animals with different haplotypes has more practical value compared to individual genotypes. This is due to the fact that the haplotype is a single functional unit.

***Table 2.** Indicators of milk productivity of cows of the Ukrainian red-spotted breed with different haplotypes at the SLC11A1 locus*

Indicators	Haplotype		
	CC-AA	CG-AA	CG-AT
First lactation			
Milking, 305 days, kg	5006.8±129.79^{ab}	5587.5±222.17^{b}	4814.6±211.28^{ac}
C_v, %	9.69	17.3	11.61
Fat, 305 days, %	3.88±0.026^{a}	3.84±0.02^{a}	3.89±0.031^{a}
C_v, %	2.57	2.28	2.11
Protein, 305 days, %	3.31±0.027^{a}	3.335±0.029^{a}	3.29±0.029^{a}
C_v, %	3.09	3.76	2.40
Second lactation			
Milking, 305 days, kg	5884.4±119.33^{ab}	6295.9±233.92^{b}	5696.3±213.31^{ac}
C_v, %	7.59	16.19	9.90
Fat, 305 days, %	3.776±0.019^{a}	3.74±0.019^{a}	3.78±0.021^{a}
C_v, %	1.91	2.29	1.48
Protein, 305 days, %	3.26±0.029^{a}	3.26±0.029^{a}	3.22±0.034^{a}
C_v, %	3.42	3.87	2.84
Third lactation			
Milking, 305 days, kg	6518.2±133.62^{ab}	6899.7±200.68^{b}	6358.1±67.03^{ac}
C_v, %	7.67	12.68	2.79
Fat, 305 days, %	3.72±0.017^{a}	3.68±0.016^{a}	3.7±0.019^{a}
C_v, %	1.74	1.94	1.35
Protein, 305 days, %	3.18±0.027^{a}	3.17± 0.029^{a}	3.13±0.057^{a}
C_v, %	3.24	4.07	4.84

Based on the results of the research, it was found that according to the indicators of milk productivity, individuals with the CG-AA haplotype are characterized by higher yield values compared to individuals with other haplotypes (the difference is probable, $p<0.05$). Moreover, the biggest difference is observed with the CG-AT haplotype (772.9 kg). This tendency (predominance of index values in individuals with the CG-AT haplotype) was noted during all three lactations. For individuals with the CG-AA haplotype, the maximum value of the coefficient of variation was also established, which indicates the average level of trait variability, but these values do not go beyond the definition of the homogeneity of the sample. In our opinion, this is due, in addition to everything else, to the need to analyze a much larger sample of animals in the case of a large number of potential variants of variability (9 possible haplotypes).

Based on the indicators of the content of milk protein and fat, no probable differences between individuals with different haplotypes were established. The variability of signs for all lactations was within the insignificant (low) level.

It should be noted that the situation may be different for the SLC11A1 locus due to the variability of the distribution of haplotypes in the group, but, in any case, the results of the research indicate the perspective of further research on other populations and breeds of cattle (subject to the mandatory condition of increasing the sample of animals, which will it is possible to analyze the productive parameters of individuals with other haplotypes).

Regarding the above two loci, it should be noted that most studies are devoted to the analysis of the relationship between TLR1, SLC11A1 gene polymorphisms and resistance/susceptibility to various infectious diseases, in contrast to our study, which covers the parameters of milk productivity of animals. In various scientific works, it is stated that genes of the TLR family are associated with the innate immune response in various animal species [1; 12]. In the studies of Bjelka and co-authors [19], performed on breeding cows of the Czech Red breed, the association of the synonymous polymorphism 798 C>T TLR1 with reproductive and physical characteristics of cows, namely the connection with ease of calving and duration of productivity, was proven.

In the case of SLC11A1, Bagheri and other authors established [16] that the g.1139 C>G mutation in exon 11 of the indicated gene of the Holstein breed had a probable connection with the signs of clinical mastitis ($P<0.05$). A. Ateya et al., [20], using the example of Holstein and Brown Swiss dairy cattle, also found nucleotide sequence variations (SNPs) associated with resistance/sensitivity to mastitis, which, in turn, makes it possible to consider the SLC11A1 gene as a valuable gene – a candidate for solving the problems of improving resistance to mastitis and, accordingly, productive traits in dairy cattle populations.

According to the results of research on the features of the genetic structure of the experimental group of cows, the productive parameters of animals with different genotypes at the CSN2 locus were analyzed (Table 3). It should be noted that in this case, all possible variants of the genotypes – A1A1, A1A2 and A2A2 – were analyzed, but the number of individuals for each fluctuated significantly (which was reflected in the error value of the mean).

Table 3. *Indicators of milk productivity of cows of the Ukrainian red-spotted breed with different genotypes according to the CSN2 locus*

Indicator	Genotype		
	A^1A^1	A^1A^2	A^2A^2
	First lactation		
Milking, 305 days, kg	5502,0±410.12^a	5170,0±173.39^a	5266,4±213.42^a
C_v, %	14.90	13.83	17.66
Fat, 305 days, %	3.81±0.038^a	3.86±0.022^a	3.88±0.022^a
C_v, %	2.02	2.28	2.50
Protein, 305 days, %	3.36±0.024^a	3.31±0.024^a	3.32±0.029^a
C_v, %	1.40	3.02	3.86
	Second lactation		
Milking, 305 days, kg	6384,00±363.55^a	5967,4±169.32^a	6047,2±214.12^a
C_v, %	11.39	11.70	15.43
Fat, 305 days, %	3.68±0.027^a	3.76±0.014^a	3.78±0.020^a
C_v, %	1.49	1.54	2.33
Protein, 305 days, %	3.22±0.040^a	3.24±0.019^a	3.27±0.033^a
C_v, %	2.17	2.50	4.40
	Third lactation		
Milking, 305 days, kg	6754,3±269.69^a	6727,9±158.81^a	6603,4±181.90^a
C_v, %	7.99	9.73	12.01
Fat, 305 days, %	3.64±0.029^a	3.69±0.013^a	3.70±0.018^a
C_v, %	1.57	1.41	2.11
Protein, 305 days, %	3.16±0.024^a	3.16±0.027^a	3.18±0.033^a
C_v, %	1.52	3.54	4.56

According to the results of the research, no significant difference in milk productivity indicators of cows with different genotypes at the beta-casein locus was found. The highest values of confidence are characteristic of individuals with the A1A1 genotype, but, as already noted, the difference is unlikely. According to the value of the coefficient of variation, the lactation indicator is characterized by an average level of variability, its variability slightly decreases by the third lactation. In any case, the A2 allele, according to the value of the indicators of homozygous individuals (genotype A2A2), does not have a negative effect on the parameters of milk productivity of animals. The research results are consistent with the data obtained by other authors on various breeds of cattle [21; 22]. Thus, the differences between individuals with different genotypes at the CSN2 locus lie in the qualitative composition of milk beta-casein (beta-casein type – A1 or A2). However, this conclusion can be true only for the experimental group of cows (Ukrainian red-spotted dairy breed). In the case of another population, provided that the modifying effect of the genetic background is taken into account (the peculiarities of the influence of the genetic structure at a number of other loci), the effect may be different, which indicates the need for analytical studies in each individual situation.

Targeted studies on the study of the genetic structure of populations by gene complexes that are related to productive parameters are of great importance for selection work on improving economic and useful traits in various breeds of cattle, in particular breeds of Ukrainian selection and preserving their genetic potential. Based on the results of the conducted research, it is possible to draw a conclusion regarding the need for targeted and intensive selection work with various breeds of farm animals, taking into account the data on genotyping individuals by a number of markers and analyzing their associations with economic and useful traits of animals.

Taking into account the results of the research, only the analysis of individuals by genotype according to the set of candidate genes and the use of modern genetics methods will allow obtaining experimental groups of cows that will be characterized by clearly defined complex genotypes (at certain loci), which in the future will allow to carry out directed selection work with the aim of maximum implementation of the productive potential of animals.

CONCLUSIONS

Based on the results of the research, it was established that for cows of the Ukrainian red-spotted dairy breed, according to the locus of toll-like receptor 1 (TLR1) according to the parameter of standard milk, the maximum values of the indicator for the first and third lactations are characterized by individuals with the homozygous genotype GG, while for the second lactation, the highest milk yield values are typical for individuals homozygous for allele A. Probable differences in milk productivity indicators between individuals with different genotypes for the TLR1 locus (1596G>A) have not been established.

Based on the results of the analysis of the productive qualities of animals with different haplotypes at the SLC11A1 locus, it was found that during all three lactations, animals with the CG-AA haplotype were characterized by higher milk yield values in 305 days compared to individuals of other haplotypes. At the same time, the biggest difference is observed with the CG-AT haplotype. According to the indicators of the content of milk fat and protein, no significant differences between animals with different haplotypes were established. The variability of signs for all lactations was at a low level.

According to the beta-casein (CSN2) locus, according to the results of research conducted for individuals with different genotypes (A1A1, A1A2 and A2A2), no probable differences were found during three lactations in terms of milk productivity (milk yield, fat content, protein content).

According to the results of the research, promising genotypes for the TLR1, SLC11A1 and CSN2 loci were identified in experimental groups of cows of the Ukrainian red-spotted dairy breed, which makes it possible to use the obtained data for further breeding work to obtain experimental populations of animals with the desired genotypes.

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Продуктивність корів української червоно-рябої молочної породи з різними генотипами за локусами TLR1, SLC11A1 та CSN2

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Анотація. Застосування методів маркер-асоційованої селекції відкриває нові перспективи в контексті максимальної реалізації продуктивного потенціалу тварин, що робить питання застосування сучасних наукових підходів у тваринництві особливо актуальним. З огляду на це, аналіз продуктивних якостей особин великої рогатої худоби з різними генотипами за сукупністю генів-кандидатів належить до одного з найактуальніших завдань генетики і селекції тварин. Отже, мета даного дослідження, – провести аналіз продуктивних якостей корів української червоно-рябої молочної породи з різними генотипами за локусами TLR1, SLC11A1 та CSN2. Генотипування особин ВРХ проводили за використання методу PCR-RFLP для TLR1 та SLC11A1 і AS-PCR для CSN2. Аналіз продуктивних якостей тварин проводили за рахунок порівняння параметрів трьох лактацій для кожної групи тварин за показниками середнього надою за 305 днів лактації (кг), вмісту білка в молоці (%) та жирномолочності (%). Дослідження проведено на основі отриманих раніше результатів індивідуального типування особин за дослідними локусами. За результатами проведених досліджень у дослідній популяції корів за локусом толл-подібного рецептора 1 (TLR1) для першої та третьої лактацій домінуючі значення показнику надою характерні для гомозигот з генотипом GG, у той час, як для другої лактації найбільші значення надою спостерігаються для гомозиготних особин за алелем А. При цьому вірогідної різниці між показниками особин з різними генотипами не встановлено. Значної різниці між групами корів з досліджуваними генотипами за показниками вмісту жиру та білка в молоці за локусом TLR1 також не виявлено. Для SLC11A1 властива характерна відмінність від попереднього гену, оскільки в цьому локусі виявлено дві мутації, що формують гаплотипи – CC-AA, CG-AA та CG-AT із дев'яти потенційно можливих варіантів. За показниками молочної продуктивності тварини з гаплотипом CG-AA мали більші значення надою порівняно з іншими гаплотипами протягом всіх трьох лактацій (різниця вірогідна). Найбільші відмінності спостерігали з гаплотипом CG-AT. За показниками вмісту молочного білка та жиру вірогідних відмінностей між особинами з різними гаплотипами не встановлено. Варіативність ознак для всіх лактацій перебувала на низькому рівні. Що стосується локусу бета-казеїну, за результатами проведених досліджень значної різниці в показниках молочної продуктивності корів з різними генотипами не виявлено. Найвищі значення надою притаманні для особин з генотипом А1А1, проте, різниця з особинами з іншими генотипами не є вірогідною. У будь-якому випадку, алель А2, за значенням показників гомозиготних особин (генотип А2А2), не проявляє негативного впливу на параметри молочної продуктивності тварин

Ключові слова: поліморфізм, алель, популяція, продуктивність, корови

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Influence of Lactation Number, Year and Season of Calving on Milk Productivity of Cows

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Abstract. The main characteristics of the milk productivity of Holstein dairy cattle differ in different countries due to differences in terrain, management and breeding objectives. At the same time, the manifestation of non-genetic (that is, environmental) factors during milk production, as a rule, mask the real breeding value of animals. The main goal of this study was to analyze the influence of lactation number, year and season of calving on the milk productivity of 238 Holstein cows during a 4-year period (2014-2017). The study was conducted using primary data on the dairy productivity of livestock in the conditions of PJSC Plemzavod Stepnoi of the Kamian-Dnipro district of the Zaporizhia region.The following characteristics were evaluated for each animal: duration of lactation, hope for 305 days of lactation, hope for the entire lactation, fat content and protein content in milk. P. Wood's model was used to approximate lactation curves within each subgroup. All signs of milk productivity were analyzed based on the algorithm of one- or two-factor analysis of variance with fixed factors using the statistical package STATISTICA v. 6.0 (Statsoft Inc.).Lactation number was found to have a significant effect on all milk yield traits that were examined (in all cases: $p<0.001$). Hope for 305 days of lactation increased with the growth of lactation number. The highest values of this characteristic were noted during the 2nd and 3rd lactations. The lowest estimate of milk yield for 305 days of lactation of dairy cows of this farm was obtained in 2014, and the highest in 2016. The calving season probably influenced the indicators of milk productivity (primarily, the content of fat and protein in milk) of firstborns. In addition, the milk yield score at 305 days of lactation was lower among winter- or spring-calved gilts compared to fall-calved animals. No influence of the calving season was noted among adult cows. Lactation number and year of calving probably influenced the estimates of the coefficients and parameters of P. Wood's model. The shape of the lactation curves of firstborns was flatter compared to mature cows. Estimates of peak milk yield were lower, but the index of constancy of the lactation curve was higher during the 1st lactation. Thus, we found that obtaining real (unbiased) estimates of milk productivity traits of Holstein cattle requires preliminary adjustment of data regarding the influence of lactation number, year and season of calving

Keywords: milk productivity, number of lactations, year and season of calving, P. Wood model, dairy cattle

INTRODUCTION

Improving the productivity of dairy cattle requires an understanding of the factors that affect this productivity. Among the factors of the external environment, it is possible to distinguish factors that can be measured (animal age, year, season of the year, milking frequency, etc.) and factors with an unmeasured influence (infectious diseases, parasitic infestations, etc.). Accordingly, the first of them can be identified and used in dairy farm management. Housing and feeding conditions, lactation number (or age of the animal), year and season of calving are the leading environmental factors affecting the efficiency of lactation performance of cattle. In addition, breed affiliation, stage of lactation and frequency of milking also affect the level of milk productivity [1].

On the other hand, the use of the test-day model makes it possible to increase the assessment of the genetic value of breeding stock by 4…8%, and the prediction of milk yield of dairy cows based on the characteristics of their lactation curves is considered an important management tool in dairy farming [2].

The peculiarity of the lactation curve is that milk production per unit of time is peaked and shifted to the right. The variety of mathematical formulas presented in the literature that can be used to model the lactation

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curve is due to the fact that each of them fits certain sets of empirical data better than others. In order to provide significant adequacy to the original data, the shape of the fitted curve must be sufficiently flexible. One of the most widely used formulas for describing the lactation curve is the incomplete gamma function proposed by P. Wood [3]. In addition, P. Wood's model can adequately approximate the dynamics of fat content in milk during lactation, which was recently demonstrated for Holstein cows in China [4].

A more important characteristic of the lactation curve is its persistence, which reflects how quickly the daily milk yield decreases after reaching the peak level of productivity. It has higher values in animals that have lower milk yields and reach peak milk productivity later. The analysis of the relationship between the constancy of the lactation curve of cows and other functional characteristics of their milk productivity in [5] showed that genetic improvement of this indicator is possible and favorable.

In addition, the age of insemination of heifers is an important factor affecting the assessment of the stability of the lactation curve. Thus, in work [6] it was shown that the shape of the lactation curve of heifers that calved at a younger age tended to be lower and flatter than for heifers that calved at an older age; the latter are characterized by a sharper rise in the lactation curve and its subsequent faster decline after reaching the peak of productivity.

It was established [7] that the estimates of the heritability coefficient (h2) of the parameter of constancy of the lactation curve of Holstein cows during the first three lactations had a tendency to decrease, mainly due to the increase in the value of the residual variance, and were 0.17, 0.16 and 0. 14, respectively. The estimation of genetic correlation coefficients between the parameter of constancy of the lactation curve for different lactations was 0.26 (between the 1st and 2nd), 0.32 (between the 2nd and 3rd) and 0.23 (between the 1st and 3rd lactations).

During the study of paratypical factors that influenced the variability of the lactation curves of Holstein and Jersey cows, the likely influence of the lactation number and the calving season on the coefficients of P. Wood's model, as well as on the indicator of the constancy of the lactation curve, was established. At the same time, a probable combined effect of "lactation number × calving season" on the accuracy of approximation of actual data by this model was found (estimation of the coefficient of determination R^2). On the other hand, the probable influence of the "year of calving" factor on the estimates of P. Wood's coefficients was noted only among cows of the Jersey breed, but not among Holstein cows [8].

As indicated in the paper [9], the influence of the lactation number on the estimates of the coefficients and indicators of P. Wood's model can be explained by the fact that the older the animal, the higher its lactation begins with higher milk yields, but since at a certain stage of the lactation activity there is an inhibitory effect of body size (regardless of the level of productivity), the rate of decline in milk productivity is higher in more mature cows. That is, body weight has a more significant inhibitory effect on the productivity of adult animals due to their higher productivity [9]. At the same time, the influence of lactation number was more noticeable for breeds bred in tropical regions than among European and American breeds of cattle [10].

Another explanation for the influence of the lactation number on the shape of the lactation curve may be the presence of a difference in the rate of depletion of the body; adult cows use their reserve much faster in the earlier stages of lactation, which leads to higher values of the coefficient "b" and, conversely, to lower values of the coefficient "c" of P. Wood's model, than among first-born cows [9]. Accordingly, the later period of peak milk yield among first-borns compared to adult cows can be explained by differences in rates of depletion of body reserves between adult cows and heifers. Higher rates of exhaustion in the early stages of lactation in adult cows lead to an early peak of productivity [8; 9]. Climatic factors also significantly affect the estimates of the coefficients and parameters of P. Wood's model. At the same time, the estimates of total and peak hope are the lowest among cows that calved in the summer due to a limited feeding ration and the effect of heat stress [11].

Since most studies of the influence of the year and season of calving on the level of milk productivity of Holstein cows, as cited above, were conducted in arid and hot climates [1; 8; 10; 11], the results of a similar analysis in the conditions of the temperate climate of Ukraine deserve special attention .

The purpose of this study was to analyze the influence of lactation number, year and season of calving both on the total milk productivity of cows and on the peculiarities of the formation of their lactation curves.

MATERIALS AND METHODS

Primary data on the milk productivity of Holstein cattle in the conditions of PJSC Plemplant Stepnoi of the Kamian-Dnipro district of the Zaporizhzhya region (n=238 heads) served as the material for the work. Data for the first three lactations of animals that calved during 2014-2017 were included in the analysis.

The following traits were evaluated for each animal: duration of lactation (DIM), 305 day lactation (MY305), total lactation (TMY), milk fat content (FP) and milk protein content (PP). In addition, the daily expectation of animals was determined for 10 control days (TD1-TD10), corresponding to the 30th, 60th, 90th, etc. days of lactation If data for a certain control day were missing for the corresponding animal, the daily intake estimate was calculated by linear interpolation for the two days before and after the control date, respectively.

For each feature, the arithmetic mean value and its error (Mean±SE) were calculated. Testing of the hypothesis regarding the lack of influence of lactation number, year of calving and season of calving on the characteristics of milk productivity was carried out based on the algorithm of one- or two-factor analysis of variance (ANOVA) with fixed factors.

The seasons of the year were defined as follows: winter (December – February), spring (March – May), summer (June – August) and autumn (September – November).

P. Wood's model [3] was used to approximate the lactation curve based on data for 10 control days:

$$Yt=ab^{t}e^{(-ct)} \quad (1)$$

where Yt is daily hope (in kg) at time t (control days from TD1 to TD10); a – initial hope; b – the rate of growth of hope until reaching the peak; c is the rate of decrease of the load after reaching the peak.

The estimate of peak yield (in kg) was calculated according to the formula:

$$Ymax = a\left(\frac{b}{c}\right)^{b} e^{-b} \quad (2)$$

and the moment of reaching peak fertility (in days) according to the formula:

$$Tmax = \frac{b}{c} \quad (3)$$

Persistence of the lactation curve (persistence) in P. Wood's model was calculated according to the formula:

$$St=c^{-(b+1)} \quad (4)$$

The quality of the approximation of the initial data by P. Wood's model was evaluated on the basis of the coefficient of determination (R^2).

All statistical calculations were carried out using the algorithms described in the manual [12] using the software STATISTICA v. 6 (StatSoft Inc.).

RESULTS AND DISCUSSION

Effect of lactation number. It was established that the number of lactation probably influenced all the investigated signs of milk productivity of cows (Table 1).

Table 1. *Indicators of variability (Mean±SE) of signs of milk productivity of cows depending on the lactation number*

Lactation	n	DIM, days	TMY, kg	MY 305, kg	FP, %	PP, %
I-a	238	337.9±4.8	10224.0±153.5	9374.8±84.5	4.26±0.01	3.28±0.01
II-a	238	377.8±7.9	12277.0±241.9	10711.6±127.7	4.30±0.01	3.30±0.01
III-я	107	357.7±9.7	11567.8±342.6	10631.4±247.8	4.30±0.01	3.30±0.01
F(2; 579)	–	452.50	16.04	34.81	26.53	23.03
p	–	<0.001	<0.001	<0.001	<0.001	<0.001

The average duration of lactation significantly exceeded 305 days and varied from 337.9 (for first-borns) to 377.8 days (during the second lactation). A similar pattern was noted in relation to the total milk yield – it ranged on average from 10,224.0 (for first-borns) to 12,277.0 kg (during the second lactation). The first-borns were also characterized by the lowest estimate of milk yield for 305 days of lactation (9374.8 kg), which was significantly inferior to the corresponding estimates obtained for animals of the experimental herd during the II and III lactations.

Qualitative characteristics of milk productivity also showed age variability – both the protein content and the fat content in milk increased in full-aged cows compared to first-born cows (see Table 1).

As might be expected, age-related differences in the level of milk production were closely related to the shape of the lactation curve of the animals. In general, firstborns were characterized by relatively low and more or less stable milk yields at different stages of lactation, and during the II and III lactations, the shape of the lactation curves acquired a typical shape with a rapid increase at the beginning and a gradual decrease in daily milk yields after reaching the peak value (Fig. 1).

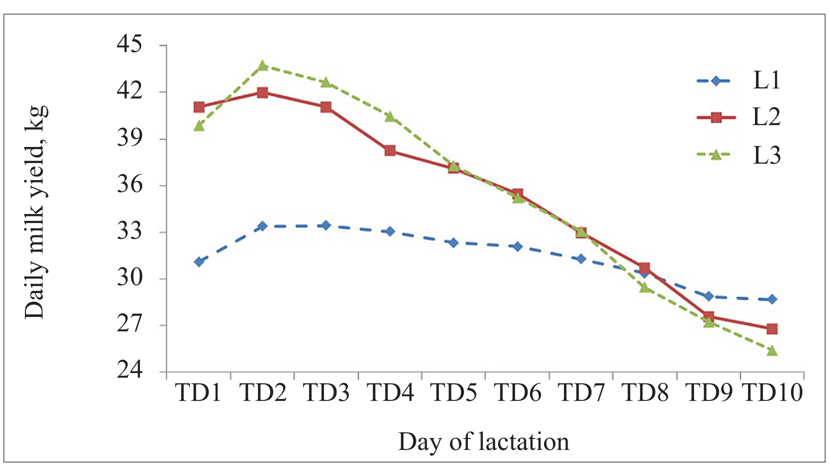

Figure 1. *Lactation curves of cows depending on lactation number (L1-L3)*

In general, probable differences between the daily milk yields of animals depending on the lactation number were noted on control days TD1-TD6 (one-way analysis of variance: in all cases $p<0.001$) and for TD10 ($p=0.023$). The obtained lactation curves were quite well approximated by P. Wood's model – the coefficient of determination (R^2) estimates for animals of different groups ranged from 97.66 to 99.42% (Table 2).

The first-borns were characterized by the lowest estimates of the coefficients "a" and "c" of P. Wood's model and, accordingly, the minimum amount of peak lactation (*Ymax*), but at the same time, their lactation curve had the highest assessment of indicators of constancy (St) and the moment of reaching peak lactation (*Tmax*). While during the 2nd and 3rd lactations, the animals of the experimental herd had the highest estimates of the coefficients "a" and "c" of the Wood model, as well as a high value of the peak yield when it was reached earlier, but a lower constancy of the lactation curve (see Table 2).

Table 2. *Coefficients and indicators of P. Wood's model of the lactation curve of cows depending on the lactation number*

Lactation	*a*	*b*	*c*	R^2, %	*St*	*Tmax*, days	*Ymax*, kg
I	32.83±0.24	0.149±0.014	0.049±0.004	97.66	32.0	92.7	33.4
II	44.87±0.47	0.157±0.022	0.089±0.006	99.25	16.5	53.8	41.9
III	45.57±0.49	0.270±0.022	0.123±0.006	99.42	14.3	67.0	43.0

A plausible effect of lactation number on milk yield traits has previously been demonstrated for Holstein cattle kept on a large commercial farm in Mexico. Thus, the yield of first-borns for 305 days of lactation was 7607±145 kg of milk, while among adult animals (6th lactation and above) it reached 9548±181 kg of milk. The total weight gain per lactation of firstborns was about 4500 kg less than the similar indicator of adult cows, which was 13544±5491 kg with an average duration of lactation of 454±154 days [13].

Similar results were obtained for Holstein cows in the conditions of Arizona (USA). The average yield of milk among firstborns was 6656±193 kg, and during the II, III and IV lactations – 7335±193, 7769±193 and 7894±194 kg, respectively. The maximum manifestation of hope was reached during the 5th lactation and in older cows [14].

For animals of the same breed under the conditions of Turkey, it was established that the firstborns were significantly inferior in terms of the level of milk yield for 305 days of lactation (5885±48 kg) to the estimates obtained during the II lactation (6096±55 kg), but in the future, a tendency to a gradual decrease was observed decrease in milk yield during the fifth lactation [15].

For Holstein cows in the arid conditions of North Africa (Tunisia), it was also established that firstborns were characterized by a low level of milk productivity (5412±52 kg), and during the II and III lactations it increased significantly (5721±55 and 5614±47 kg, respectively). Although in the future, the amount of milk obtained gradually decreased until the 5th lactation [1].

Thus, the reviewed studies demonstrated that milk production increases with increasing lactation number and is maximized during IV or V lactation. This may be associated with an increase in the size of the udder and an increase in the number of secretory cells in adult animals [16]. At the same time, the influence of lactation number on the level of milk productivity may vary depending on the year of its initiation [17].

Effect of year of calving. As for the influence of the year of calving, the highest estimate of the average duration of lactation was noted for cows of the II lactation that calved in 2016 (405.7 days). Accordingly, these animals also had the highest estimate of the total yield (13.155.0 kg). On the other hand, the highest estimate of milk yield for 305 days of lactation (11.210.2 kg) was noted for cows of the 3rd lactation, which also calved in 2016 (Table 3).

Table 3. *Indicators of variability (Mean±SE) of signs of milk productivity of cows depending on the year of calving and lactation number*

Year of calving	n	DIM. days	TMY. kg	MY305. kg	FP. %	PP. %
			I-st lactation			
2014	61	353.1±11.6	10396.8±329.7	9215.9±117.8	4.14±0.02	3.21±0.01
2015	107	335.6±6.3	9997.6±222.5	9212.5±130.1	4.30±0.01	3.30±0.01
2016	67	330.3±8.1	10555.0±261.0	9843.4±170.2	4.30±0.01	3.30±0.01
F(2; 232)		1.75	1.32	5.94	162.33	170.11
p		ns	ns	0.003	<0.001	<0.001
			II-nd lactation			
2015	59	381.1±19.1	12340.2±503.2	10589.2±201.5	4.29±0.01	3.29±0.01
2016	105	405.7±12.7	13155.0±392.9	10980.7±177.1	4.30±0.01	3.30±0.01

Table 3, Continued

Year of calving	n	DIM. days	TMY. kg	MY305. kg	FP. %	PP. %
2017	72	337.7±7.2	11082.6±316.3	10488.0±284.0	4.31±0.01	3.31±0.01
F(2; 232)		4.89	5.02	1.31	6.20	5.11
p		0.003	0.002	ns	0.001	0.001
			III-rd lactation			
2016	49	394.4±17.0	12883.5±514.7	11210.2±330.3	4.30±0.01	3.30±0.01
2017	56	327.1±9.5	10429.4±421.3	10112.3±363.8	4.32±0.01	3.30±0.01
F(1; 103)		12.80	13.86	4.89	8.14	3.30
p		0.001	<0.001	0.029	0.005	ns

Note: *ns – p>0.05*

In general, no effect of year of calving was noted only for duration of lactation and total milk yield among first-borns, milk yield for 305 days of lactation during the 2[nd] lactation and protein content in milk during the 3[rd] lactation. Thus, in most cases, the year of calving probably influenced the quantitative and qualitative characteristics of milk productivity of cows of the experimental herd.

In general, the animals that calved in 2016 (taking into account the influence of the lactation number) were characterized by the highest estimates of milk productivity in comparison with 2014, 2015 and 2017 (see Table 3).

A combined effect of lactation number and year of calving was noted only for milk fat and protein content (two-way analysis of variance with fixed factors: $p < 0.001$ in both cases). This may be due to the fact that both the protein content and the fat content of the milk were significantly lower for the firstborns that calved in 2014 than in the other groups (see Table 3).

Probable differences between daily milk yields depending on the year of calving were noted for first-borns on all control days (in all cases $p<0.05$), except for the first two (TD1-TD2). During the 2[nd] lactation, on the contrary, the daily milk yield for separate control days did not differ among animals that calved in different years; only milks for TD2, TD3 and TD8 were excluded (in all cases $p<0.05$). Finally, during the third lactation, a significant effect of year of calving was noted for daily milk yield in the second half of lactation (TD6-TD8) (in all cases $p<0.05$).

Approximation of lactation curves by P. Wood's model for experimental animals of different calving years and lactation numbers was also quite high – the coefficient of determination (R^2) estimates in most cases amounted to 95…98%, with the exception of firstborns that calved in 2014 (Table 4).

Table 4. *Coefficients and indicators of the P. Wood model of the lactation curve of cows depending on the year of calving and lactation number*

Year of calving	*a*	*b*	*c*	*R*^{2}*. %*	*St*	*Tmax. days*	*Ymax. kg*
			I-st lactation				
2014	33.49±1.46	0.085±0.075	0.043±0.015	91.43	30.3	60.2	32.6
2015	32.83±0.21	0.106±0.012	0.042±0.003	98.30	33.5	77.3	32.6
2016	32.86±0.36	0.206±0.021	0.056±0.005	94.90	32.2	111.8	34.9
			II-nd lactation				
2015	43.34±0.58	0.089±0.028	0.067±0.007	98.40	19.1	40.8	40.7
2016	45.35±0.68	0.132±0.031	0.080±0.008	98.29	17.4	50.1	42.4
2017	45.77±0.86	0.261±0.040	0.124±0.011	98.33	13.8	63.9	42.8
			III-rd lactation				
2016	46.09±0.68	0.261±0.031	0.115±0.008	98.74	15.3	69.4	44.0
2017	45.28±1.11	0.292±0.052	0.135±0.014	97.42	13.2	65.8	42.3

It was established that both the year of calving and the lactation number had a significant effect on the estimations of lactation stability (St) obtained for different groups of animals (two-way analysis of variance with fixed factors: in both cases $p<0.05$). As for the peak yield, only a probable effect of lactation number ($p=0.007$) was established, while the moment of peak yield (*Tmax*) for different groups of animals showed completely random variability and did not depend on the factors used in the analysis (see table 4).

The effect of year of calving was established for Holstein cows under the conditions of Turkey. The lowest level of milk productivity for 305 days of lactation was noted in 1995 (4391±109 kg), but further its gradual increase was observed, reaching a maximum in 2004 (7280±81 kg). The reasons for this increase may be the use of bulls with high genetic ability, effective breeding for milk yield, high intensity of culling of animals from the herd, and improvement of conditions for keeping and feeding dairy cows [15].

For Holstein cows in the arid conditions of Tunisia, a probable influence of the year of calving on the level of milk productivity was also proven. At the same time, the lowest estimate of yield in 305 days (4879±118 kg) was noted in 1998, and the highest (6251±186 kg) in 2003. It has been established that such fluctuations can be associated with changes in herd size, age of animals and improvement of dairy herd management practices implemented from year to year [1].

Influence of calving season. A certain influence of the calving season on the characteristics of milk productivity was established only among firstborns (Table 5). At the same time, an almost probable trend to interseasonal differences was established for fat in 305 days (p=0.057), primarily due to significant differences between the estimates of animals that calved in the winter period (8957.1 kg) and animals that calved in the summer or in autumn (9552.3…9606.9 kg).

Table 5. *Indicators of variability (Mean±SE) of signs of milk productivity of firstborns depending on the calving season*

Calving season	n	DIM. days	TMY. kg	MY305. kg	FP. %	PP. %
Winter	41	358.8±16.4	10429.2±536.8	8957.1±241.2	4.30±0.01	3.30±0.01
Spring	73	340.4±6.6	10182.7±238.1	9284.8±143.6	4.26±0.01	3.28±0.01
Summer	85	328.5±6.4	10130.9±212.1	9552.3±138.2	4.23±0.01	3.26±0.01
Autumn	38	331.5±8.1	10290.5±399.3	9606.9±181.1	4.31±0.01	3.30±0.01
$F(3; 232)$		1.74	0.16	2.54	8.79	6.82
p		ns	ns	0.057	<0.001	<0.001

For qualitative signs of milk production, the influence of the season of calving was highly probable (in both cases p<0.001) and was accompanied by higher estimates of fat and protein content in first-borns that calved in the cold seasons of the year (autumn-winter) and low – in the warm seasons of the year (spring-summer) (see table 5).

Probable differences between daily milk yields of firstborns depending on the calving season were noted for all control days (in all cases p<0.05), with the exception of the very last one (TD10). During the 2nd lactation, on the contrary, the daily milk yields for individual control days were likely to differ only during the first part of lactation (TD2-TD4) (in all cases p<0.05), that is, when the level of milk productivity is the highest. Finally, during the third lactation, a probable effect of calving season was noted for daily milk yield only at the beginning of lactation (TD1-TD2) (in all cases p<0.05).

Approximation of lactation curves by P. Wood's model for experimental animals of different lactation number and calving season was again high – the coefficient of determination (R^2) in most cases was 90…98%, with the exception of first-borns that calved in winter (Table 6). For first-borns (regardless of calving season), the lactation curves differed significantly from the typical shape, while during the II and III lactations, the shape of these curves was very close to the typical shape (Fig. 2)

Table 6. *Coefficients and indicators of the P. Wood model of the lactation curve of cows depending on the calving season and lactation number*

Calving season	*a*	*b*	*c*	*R². %*	*St*	*Tmax. days*	*Ymax. kg*
			I-st lactation				
Winter	31.90±1.12	0.109±0.069	0.043±0.017	65.11	33.1	78.2	31.7
Spring	31.56±0.31	0.097±0.019	0.031±0.005	90.17	45.3	95.9	32.0
Summer	33.64±0.52	0.201±0.030	0.058±0.007	91.67	30.3	105.0	35.3
Autumn	35.18±0.36	0.219±0.025	0.077±0.006	97.52	22.7	86.6	35.5
			II-nd lactation				
Winter	46.89±0.89	0.183±0.041	0.107±0.011	98.21	14.1	52.1	43.1
Spring	43.96±0.87	0.101±0.042	0.073±0.011	96.99	17.8	42.2	41.1
Summer	43.32±0.54	0.172±0.026	0.089±0.007	98.85	17.1	59.1	40.9
Autumn	47.38±0.41	0.167±0.018	0.091±0.005	99.48	16.4	55.9	44.4
			III-rd lactation				
Winter	49.32±1.07	0.132±0.047	0.093±0.012	97.47	14.7	43.2	45.3
Spring	42.30±1.60	0.306±0.081	0.139±0.021	94.41	13.2	67.3	39.7
Summer	42.41±0.53	0.340±0.026	0.133±0.007	99.19	14.9	77.9	41.5
Autumn	50.07±0.71	0.215±0.030	0.112±0.008	98.98	14.2	58.3	46.4

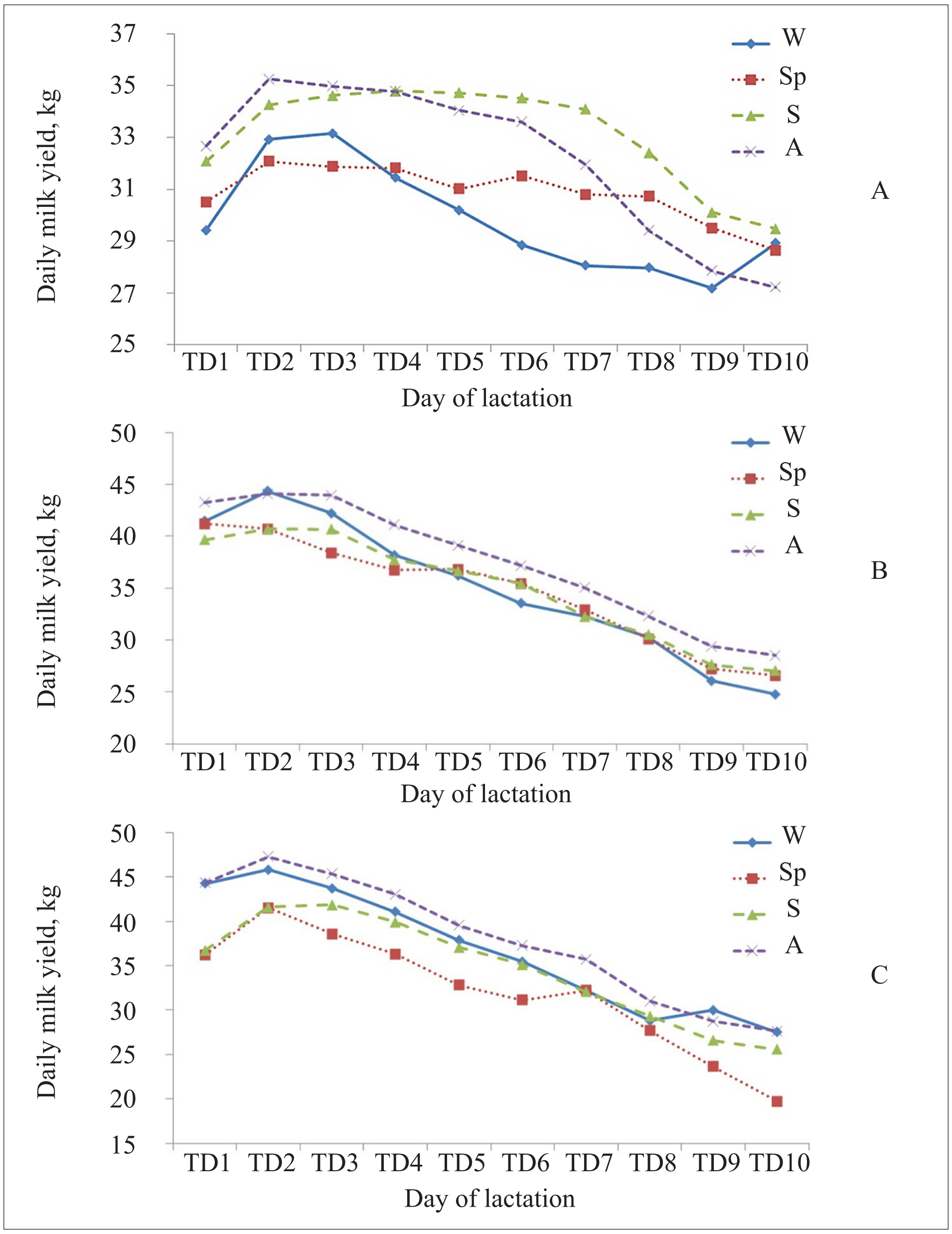

Figure 2. *Lactation curves of cows depending on the calving season of firstborns (A), animals of the II lactation (B) and III lactation (C): W – winter; Sp – spring; S – summer; A – autumn*

It was established that the calving season probably did not affect the estimates of lactation stability (St), peak milk yield (*Ymax*) and the moment of its achievement (*Tmax*) obtained for animals of different groups, while a probable influence was proved only in relation to the lactation number (two-factor variance analysis with fixed factors: in all cases p<0.01).

In work [13] it was shown that the milk productivity of Holstein cows during 305 days of lactation was lower in animals that calved in spring (8804±153 kg) and summer (8724±163 kg), in contrast to individuals that calved in autumn (9079±151 kg) or in winter (9085±143 kg).

In the conditions of Arizona (USA), the highest yield for 305 days of lactation was obtained from Holstein cows that calved in spring (7690±195 kg) and in winter (7765±193 kg), which significantly exceeded the corresponding estimates of animals calving in summer (7387±193 kg) or in autumn (7543±193 kg). A similar regularity was also noted in relation to the influence of the calving season on the total hope for the entire lactation [14].

It was also noted that these cows had a simultaneous influence on the level of milk productivity of both the lactation number and the calving season – firstborns that calved in the spring were characterized by a lower amount of milk in 305 days of lactation than animals with winter calvings (6625 and 6783 kg, respectively). At the same time, older animals did not show significant differences depending on the calving season. Moreover, for almost all groups of adult cows, the 305-day survival was much higher in animals that calved in the fall compared to females of the same age with summer calvings [14].

Thus, under the influence of heat stress, firstborns gave priority to growth and maintenance of their own viability due to milk synthesis. And cows that calved in spring and summer were obviously more sensitive to heat stress at the beginning of lactation, when their energy needs were the highest [14].

For Turkish Holsteins, the highest level of milk yield for 305 days of lactation was noted for cows with winter calvings (5890±64 kg), and the lowest – with summer calvings (5506±68 kg). For winter-calving cows, this was likely due to adequate feeding levels in the early months of lactation and the addition of alfalfa to the diet when milk yields began to decline. On the other hand, cows that calved in the summer had low milk yields due to the fact that they were exposed to high environmental temperatures in the first 3-4 months of lactation [15].

It was previously established that the season of calving affected the weight in 305 days and for Simmental cows – the highest weight (4819±82 kg) was also noted in animals with winter calvings, and the lowest estimate of this trait in cows that calved in summer (4477±81 kg) [18].

A highly probable effect ($p<0.001$) of the calving season on the 305-day lactation yield was also found for Tunisian Holstein cows – the highest scores (5827±69 kg) were given to animals calving in winter, while cows calving in summer yielded almost 614 kg of milk [1].

The effects of heat stress (on the basis of the THI coefficient) were studied on Holstein-Friesian cows in the conditions of Turkey [17]. It was proved that the milk yield of cows started to decrease slowly starting from April, and decreased sharply in May, when the value of the THI coefficient exceeded 65...70. During the summer months, when this value exceeded 70, the hope continued to decrease. However, milk yield started to increase again at the end of August and, finally, in October reached May values.

In general, P. Wood's model adequately described the initial data. Only for firstborns that calved in winter, the coefficient of determination was low (65.11%) and, accordingly, the shape of their lactation curve was atypical. It was previously established that in 15...42% of Holstein cows in the conditions of Tunisia, individual lactation curves may have an atypical shape [11]. And in work [19] it was shown that 26.3% of 1278 analyzed full lactation curves of Turkish Holstein cows in the conditions of Turkey had an atypical shape.

In work [10] it was noted the likely influence of the number of lactation on the constancy of the lactation curve; the lactation curves of firstborns of the Friesian × Bunaji cross had a flatter shape and a lower level of daily milk yield than adult animals. These authors also indicated that the milk productivity of firstborns is determined to a greater extent by environmental factors than the lactation activity of more mature cows [10].

Similar regularities in the formation of lactation curves of Holstein cows in the conditions of Tunisia are also indicated in the paper [11]; lactation curves of firstborns were characterized by lower daily milk yields than mature cows, but at the same time had higher estimates of the stability index. On the other hand, adult cows reached peak milk yield earlier (within 5-6 weeks of lactation) than first-born cows (within 7-10 weeks of lactation). And the value of the peak milk yield was higher in adult cows (23...34 kg) than in first-born cows (17...20 kg) [11].

CONCLUSIONS

It was established that the number of lactation had a significant effect on all the examined signs of milk productivity of cows (in all cases: $p<0.001$). Age differences in the level of milk productivity were closely related to the shape of the lactation curve of animals; first-borns were characterized by relatively low and stable daily milk yields at all stages of lactation, and after the II-th and III-th calvings, the shape of the lactation curves acquired a typical shape with a rapid increase at the beginning and a gradual decrease in daily milk yields after reaching the peak value.

In most cases, the calendar year of calving probably influenced the quantitative and qualitative characteristics of the milk productivity of the cows of the experimental herd. In general, the animals that calved in 2016 (taking into account the influence of the lactation number) were characterized by the highest estimates of milk productivity in comparison with 2014, 2015 and 2017.

Some trend towards the effect of calving season on milk yield traits was found only among firstborns ($p=0.057$), primarily due to significant differences between the scores of animals that calved in winter and animals that calved in summer or autumn. For the qualitative signs of milk productivity, the influence of the calving season was highly probable and was accompanied by higher estimates of fat and protein content in firstborns calved in the cold seasons of the year (autumn-winter) and low in the warm seasons of the year (spring-summer).

Thus, the obtained results will make it possible to develop breeding programs that will take into account the influence of important paratypic factors on the manifestation of milk productivity of cows of a dairy herd, as well as to increase the accuracy of obtaining estimates of the breeding value of breeders in the conditions of a given farm.

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Вплив номеру лактації, року та сезону отелення на молочну продуктивність корів

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Анотація. Основні ознаки молочної продуктивності голштинської молочної худоби відрізняються в різних країнах через відмінності в місцевості, менеджменті та селекційних цілях. При цьому, прояв не-генетичних (тобто, екологічних) факторів під час виробництва молока, як правило, маскують реальну племінну цінність тварин. Головною метою даного дослідження був аналіз впливу номеру лактації, року та сезону отелення на молочну продуктивність 238 корів голштинської породи протягом 4-річного періоду (2014–2017 рр.). Дослідження було проведено з використанням первинних даних щодо молочної продуктивності худоби в умовах ПрАТ «Племзавод «Степной» Кам'янсько-Дніпровського району Запорізької області. Для кожної тварини були оцінені наступні ознаки: тривалість лактації, надій за 305 днів лактації, надій за всю лактацію, вміст жиру та вміст білка в молоці. Для апроксимації лактаційних кривих в межах кожної субгрупи було використано модель П.Вуда. Всі ознаки молочної продуктивності було проаналізовано на підставі алгоритму одно- чи двофакторного дисперсійного аналізу із фіксованими факторами за допомогою статистичного пакету STATISTICA v. 6.0 (Statsoft Inc.). Було встановлено, що номер лактації вірогідно впливав на всі ознаки молочної продуктивності, що було досліджено (у всіх випадках: $p<0,001$). Надій за 305 днів лактації підвищувався зі зростанням номеру лактації. Найвищі значення цієї ознаки було відмічено протягом II-ї та III-ї лактації. Найнижчу оцінку надою за 305 днів лактації корів дійного стада даного господарства було отримано у 2014 році, а найвищу – у 2016 році. Сезон отелення вірогідно впливав на показники молочної продуктивності (насамперед, вміст жиру та білка в молоці) первісток. Крім того, оцінка надою за 305 днів лактації була нижчою серед первісток, які отелились взимку або навесні у порівнянні із тваринами, які отелились восени. Серед повновікових корів впливу сезону отелення не відмічено. Номер лактації та рік отелення вірогідно впливали на оцінки коефіцієнтів та параметрів моделі П. Вуда. Форма лактаційних кривих первісток була більш пласка у порівнянні з повновіковими коровами. Оцінки пікового надою були нижчі, але показник сталості лактаційної кривої був вище під час I-ї лактації. Отже, нами було встановлено, що отримання реальних (незміщених) оцінок ознак молочної продуктивності голштинської худоби потребує попереднього корегування даних щодо впливу номеру лактації, року та сезону отелення

Ключові слова: молочна продуктивність, номер лактації, рік та сезон отелення, модель П. Вуда, молочна худоба

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Peculiarities of Photosynthetic Activity of Winter Pea Plants Depending on the Sowing Rates

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Abstract. Peas are a crop that is quite picky about weather conditions, therefore, against the backdrop of worsening climatic conditions, it is necessary to pay attention to the wintering form. The main advantage of overwintering peas is that it uses the moisture of the winter period and thanks to this forms above-ground and underground biomass of plants even before the onset of summer drought. At the beginning of the recovery of spring vegetation, plants have a well-developed root system that penetrates deep into the soil up to 10 cm, while spring peas at this time are just beginning to sow. As a result, the potential yield of winter peas is 2-3 times higher than that of spring peas. The purpose of the research was to determine the influence of varietal features of plants, seed sowing rates on the photosynthetic activity of crops and grain yield of winter peas in the conditions of southern Ukraine. Research methods: field, laboratory, computational, statistical. As a result of the research, the peculiarities of the growth of the above-ground mass of plants, the photosynthetic activity of crops and the formation of grain yield of winter pea varieties were studied. The optimal rate of winter pea seed sowing, at which the genetic potential of varieties is fully realized, has been revealed. The norm of seed sowing was established, at which winter pea plants formed the maximum area of the leaf surface. Research has established that in most cases the maximum level of biomass harvest is formed at the minimum density of plants in the budding phase. As the density increases, the biomass gradually decreases, which is a reliable sign of the significant advantage of crops with lower sowing rates in terms of photosynthesis productivity.It was determined that the highest winter pea grain yield, on average over the years of research and according to the studied sowing rates, was formed by the Enduro variety. Research has established that wintering peas form a small area of the leaf surface, which is characterized by a high level of difference in productivity at a reduced seeding rate. The practical aspects and conclusions reflected in the article are aimed at improving the processes of wintering pea productivity in the conditions of southern Ukraine, in particular, at significantly more efficient use of moisture during the growing season of plants for the formation of a unit of harvest

Keywords: photosynthetic activity, leaf surface, above-ground biomass of plants, chlorophyll, density, grain yield

INTRODUCTION

The main task of modern agriculture in Ukraine is to increase the productivity of grain crops, which will contribute to the formation of plant resources, providing livestock with complete feed, and the population with food products. An important place in solving this task is occupied by peas. Its grain contains protein, carbohydrates, saturated with essential amino acids, minerals and vitamins, therefore it is widely used in the production of balanced concentrated feeds. A short growing season and the ability to fix atmospheric nitrogen characterize peas as the best predecessor for agricultural crops, in particular winter forms [1].

Peas are characterized by great genetic diversity, according to the morphological composition there are varieties with leaves (ordinary) and leafless (with tendrils of the so-called aphylla type), indeterminate and determinate growth of the stem and very early and late ripening. There are winter and spring varieties. Seeds vary in color, shape and size. Some varieties of peas are used as a vegetable crop; field peas are used

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for the production of dry grain for the food industry, and forage pea varieties are also widely used [2].

Peas are grown in most countries of the world. North America has increased its share of seed pea and lentil production in recent years. Europe, once the largest producer of seed peas, is seeing a sharp decline in total legume production. At the same time, Asian countries remain the main producer of many leguminous crops, including field peas [3].

According to V.V. Kolosovska [4], peas are widely distributed in Ukraine due to their high productivity and feed value. Peas are a potential crop that, under optimal growing conditions, can provide a high yield of green above-ground mass, as well as grain. Significant fluctuations in the yield of peas depend on the influence of weather conditions on the productivity of plant photosynthesis. The yield of peas depends on many factors, in particular, agricultural technology, weather and climate conditions during the growing season of plants, varietal characteristics, etc. [5; 6; 8]. In recent years, small areas of sowing and low yields of pea grain are due to unfavorable weather conditions and the lack of stable demand in the domestic market, as well as the difficult economic situation of agricultural enterprises. All this, as well as the imperfect technology of growing peas, gives preference to agricultural crops whose cultivation costs are lower, and their production volumes are larger [4; 7; 9].

Systematic droughts in the second half of May and in June suppress the pea so much that it grows 15-20 cm tall, forms no more than 2 beans per plant with 1-2 seeds, and thus provides a yield of 0.4-0.6 t/ha, which is a catastrophic phenomenon against the background of other cultures. Therefore, producers, despite the importance of peas in animal diets, refuse this crop and exclude it from their crop rotations.

But in the last 15-20 years, a new form of peas has appeared – winter peas, which are sown in autumn and spring. He manages to form a generative apparatus earlier than during droughts.Such peas under normal conditions provide a yield of 2.0-2.5 t/ha of seeds, and under favorable conditions – 3.5-4.0 t/ha. Currently, breeders are creating wintering varieties, and agricultural technicians are developing a technological model that would correspond to the biology of this pea. It should be noted that the development of winter pea agrotechnology has not yet been completed, and many issues need to be clarified. In particular, the optimal parameters of sowing rates and plant stand density have not been definitively determined. This element of technology was mechanically transferred from spring peas, so the goal of our research was to determine the optimal rate of sowing seeds for modern varieties of winter peas for growing it in the conditions of southern Ukraine.

One of the main elements of the pea growing technology is the rate of sowing seeds, which ensures optimal sowing density. The pea sowing rate ranges from 0.8 to 1.4 million similar seeds per hectare [5]. In conditions of sufficient moisture supply, more seeds should be sown than in dry conditions [6].

N.V. Telekalo [7] in his experiments came to the conclusion that it is the correctly selected sowing rates that provide a high adaptive capacity, which allows metabolic processes to be restored to an optimal level after exposure to stress factors, which is especially important in conditions of climate change. The main characteristics that determine the adaptation of peas include a high harvesting index, the type of stem growth, friendly ripening of grain, resistance to pests and diseases, shedding of grain, high potential yield.

Optimum plant density and nutrient supply are the most important conditions that affect the productivity of agricultural crops. Therefore, studying the impact of different sowing rates on plant density and yield is of great importance for the process of forming the structural elements of the crop. The density of plants before harvesting is an indicator that shows the correct choice of seed sowing rate during sowing. The rate of sowing can significantly affect the realization of the potential yield of peas under different soil and climatic conditions of its cultivation [8]. Thus, the studies of V.V. Lykhochvor and V.M. Andrushko [9] determined that the structural elements and yield of peas were significantly influenced by the norms of seed sowing. Thus, increasing the rate of sowing seeds to 1.4 million/ha contributed to a decrease in the number of beans per plant to 4.5 pcs., the number of grains in a bean – to 6.1 pcs., the number of grains per plant – to 27.6 pcs. Then, at the sowing rate of 0.9 million/ha, the specified indicators amounted to 4.8, respectively; 6.9; 33 pcs. It has been proven that, in addition to the investigated norms of seed sowing, the yield of Madonna pea grains was also influenced by the agrometeorological conditions of the research years.

At the same time, the dependence of the photosynthetic activity of plants on the density of agrophytocenosis is an important and little-studied issue. Absorption of light and its direct effect on the growth of agricultural plants is an important factor in the life of plants [10]. As for many agricultural plants, the amount of incoming photosynthetically active radiation and the efficiency of use of solar radiation by the plant cover are important indicators during the cultivation of leguminous crops [11].

It has been confirmed that the intensity of photosynthesis of cultivated plants is a rather labile feature, prone to significant exogenous influence of environmental factors. Agrometeorological conditions during the growing season of agricultural crops affect the indicators of photosynthesis. In addition, the photosynthetic activity of crops depends on the area of the leaf surface of plants, the area of their nutrition, the content of nutrients in plant leaves, etc. [12; 13]. The leaf surface area of plants is one of the main factors that determines the amount of absorbed solar energy and its use for biomass accumulation, and also affects the indicators of net photosynthetic productivity. In turn, the amount of biomass accumulated by plants and the activity of photosynthetic processes are decisive in the formation of the yield of agricultural crops [14-16].

The increase in the area of the leaf surface of plants is an indicator that characterizes the general growth rate of any agricultural crop, which leads to a significant absorption of solar radiation and, as a result, contributes to the formation of higher productivity [17].

Thus, further deepening of research in this direction is an urgent task of modern plant breeding.

MATERIALS AND METHODS

For the study, the winter pea varieties Moroz, Enduro and Baltrapp were used, which were sown on the experimental field of the Odesa State Agricultural Research Station of the National Academy of Agrarian Sciences of Ukraine for 3 years. The scheme of the experiment provided for the study of the following sowing rates: 0.7; 0.9; 1.1; 1.3 million seeds/ha. The size of the plots and placement: in the massif, the plot is 15 m^2 (10×1.5 m), randomized. Inter-level corridor: 6 m. Number of repetitions: four.

The experimental field is located in the village of Khlibodarske, Bilyaiv district, Odesa region. The soils are represented by northern chernozem with a humus content of 2.0% in a layer of 10-30 cm. The content of macroelements in the soil during the years of research was P_2O – 6.25; N – 2.60; K_2O – 17.4 mg/100 g of soil.

The main experiment had the following arrangement of plots (Table 1).

Table 1. *Scheme of the location of the plots in the experiment*

I repetition			III repetition		
C_1H_1	C_3H_2	C_2H_4	C_1H_3	C_3H_4	C_2H_2
C_2H_1	C_1H_3	C_3H_4	C_2H_3	C_1H_1	C_3H_2
C_3H_1	C_2H_3	C_1H_1	C_3H_3	C_2H_1	C_1H_3
C_1H_2	C_3H_3	C_2H_1	C_1H_4	C_3H_1	C_2H_3
C_2H_2	C_1H_4	C_3H_1	C_2H_4	C_1H_2	C_3H_3
II repetition			**IV repetition**		
C_1H_2	C_3H_3	C_2H_1	C_1H_4	C_3H_1	C_2H_3
C_2H_2	C_1H_4	C_3H_1	C_2H_4	C_1H_2	C_3H_3
C_3H_2	C_2H_4	C_1H_2	C_3H_4	C_2H_2	C_1H_4
C_1H_3	C_3H_4	C_2H_2	C_1H_1	C_3H_2	C_2H_4
C_2H_3	C_1H_1	C_3H_2	C_2H_1	C_1H_3	C_3H_4

Note: *C_1 – Moroz variety; C_2 – Enduro variety; C_3 – Baltrapp variety; H_1 – sowing rate 0.7 million plants/ha; H_2 – sowing rate 0.9 million plants/ha; H_3 – sowing rate 1.1 million people/ha; H_4 – seeding rate of 1.3 million people/ha*

The area of the sheet surface was measured by the weight method with the preparation of standard cutouts with an area of 1 cm^2. 20 cuttings were weighed and all leaves from a sample of plants were weighed. The area of the leaves in the samples was calculated according to the proportion:

20 cm^2–m_{1T}
X cm^2–m_{2T}

$$x = \frac{20 \times m_2}{m_1}; \quad (1)$$

The size of the photosynthetic potential was calculated according to formula 2:

$$PP = \frac{S_1 + S_2}{2} \times T \quad (2)$$

S_1 – leaf area at the beginning of the calculation period, thousand m^2/ha; S_2 – leaf area at the end of the calculation period, thousand m /ha; T – calculation period, days.

The size of the net productivity of photosynthesis was calculated according to formula 3:

$$NPP = \frac{\mathrm{FP}}{U_2 - U_1} \quad (3)$$

FP – photosynthetic potential thousand m^2/ha × days; U_2 – dry biomass harvest at the end of the period; U_1 – dry biomass yield at the beginning of the period, g/ha

RESULTS AND DISCUSSION

The conducted studies showed that winter peas form a rather low level of the leaf surface (Table 2).

Table 2. Leaf surface area of peas under different sowing rates, 2021 (thousand m^2/ha)

Sowing rate. million seeds per hectare	Moroz		Enduro		Baltrapp	
	2-3 leaves	Budonization	2-3 leaves	Budonization	2-3 leaves	Budonization
0.7	1.3	13.5	1.1	11.4	0.8	13.4
0.9	2.2	16.5	0.9	16.0	1.3	16.2
1.1	2.7	18.40	1.2	19.1	1.5	19.1
1.3	3.0	23.9	1.9	22.5	1.5	22.7
HIP_{05}, thousand m^2	–	0.8	–	1.1	–	0.7

Varieties had no significant differences in leaf area. A direct dependence of the size of the leaf area on the sowing rate was found. As you can see, in all cases, crops with the highest seeding rate had the maximum leaf area. This indicates that the result of photosynthetic activity (accumulation of organic phytomass) is primarily determined not by a quantitative indicator (the size of the leaf area), but by a qualitative one (the productivity of the leaves). Such a conclusion can be drawn already from the analysis of data on the harvest of above-ground biomass (Table 3).

Table 3. *Crop of above-ground pea biomass under different sowing rates, t/ha (2021)*

Sowing rate of million seeds per hectare	Moroz		Enduro		Baltrapp	
	2-3 leaves	Budonization	2-3 leaves	Budonization	2-3 leaves	Budonization
0.7	1.2/0.24	6.6/1.65	1.0/0.21	7.9/1.97	1.3/0.26	6.9/1.79
0.9	1.6/0.32	6.7/1.61	1.2/0.24	6.9/1.72	1.6/0.31	6.1/1.59
1.1	1.9/0.40	6.2/1.55	1.4/0.27	6.5/1.63	1.8/0.36	5.9/1.53
1.3	2.0/0.43	6.5/1.62	1.7/0.33	6.4/1.60	2.1/0.40	5.6/1.51
HIP_{05}, thousand m^2	–	0.03/0.02	–	0.02/0.02	–	0.04/0.03

Note*: green mass is shown in the numerator, and absolute dry mass in the denominator*

As you can see, in most cases, the maximum level of biomass harvest is formed at the minimum density of plants in the budding phase. As the density increases, the biomass gradually decreases, which is a reliable sign of the significant advantage of crops with lower sowing rates in terms of photosynthesis productivity (Table 4).

Table 4. *Net productivity of photosynthesis for the period of 2-3 leaves to the budding phase depending on the pea sowing rate, 2021 (Moroz variety)*

Sowing rate, million seeds per 1 ha	Average leaf area, m^2/ha	Increase in dry biomass per period, t/ha	Duration of the period, days	Photosynthetic potential, thousand m^2/ha *days	Net photosynthetic productivity, g/m^2 per day
0.7	2400	1410000	36	266.4	5.29
0.9	9400	1290000	36	338.4	3.81
1.1	10500	1050000	36	378.0	2.78
1.3	13400	1190000	36	482.0	2.47

Thus, the decisive role in the formation of the phytomass crop belongs to the productivity of photosynthesis, and not to the size of the apparatus. The difference between the extreme options, as we can see, reaches 200%. Such a difference led us to the idea of determining the chlorophyll content in pea leaves. We obtained the following results (Table 5).

Table 5. Chlorophyll content in pea leaves in the budding phase, 2021 (Moroz variety)

Sowing rate, million/ha	Total chlorophyll, mg/100g		
	Total	Including	
		"a"	"c"
0.7	5.9	4.3	1.6
0.9	4.9	3.5	1.4
1.1	3.3	2.4	0.9
1.3	2.7	2.0	0.7

Indeed, the difference in options was very high (more than 2 times). Comparing the fractional composition, it is necessary to note the lack of specificity in this respect. In all cases, the "c" fraction was equal to 35-40% of the "a" fraction, which is a typical ratio for plants with the C4 type of photosynthesis. The main indicator that characterizes the expediency of one or another sowing rate is the yield of the main products. In our experiment, the Baltrapp variety with a sowing rate of 0.7 million seeds/ha was the most productive (Table 6).

Table 6. *Yield of winter peas depending on the sowing rate, t/ha*

Sowing rates million/ha	Moroz			Enduro			Baltrapp		
	2020	2021	Avarage	2020	2021	Avarage	2020	2021	Avarage
0.7 (в)	0.69	1.79	1.20	0.73	3.03	1.88	0.74	3.10	1.92
0.9	0.69	1.78	1.21	0.69	2.60	1.65	0.67	2.48	1.58
1.1	0.68	1.35	1.02	0.68	2.12	1.40	0.66	2.11	1.39
1.3	0.67	1.40	1.04	0.67	1.91	1.30	0.56	1.88	1.22
$HIP_{0.5}$, t/ha	A-0.06 B-0.04 AB-0.08	A-0.11 B-0.13 AB-0.18	–	–	–	–	–	–	–

Other varieties also formed the maximum productivity at the sowing rate of 0.7 million seeds/ha. Only the Moroz variety provided the same level of productivity at the norms of 0.7 and 0.9 million/ha.

Of course, the results of the 2020 crop, when the drought nullified all the efforts of the producers, and the wild pea did not form any crop at all, could negatively affect the final conclusions. But the data of 2021 very convincingly testifies to the expediency of sowing peas at the rate of 0.7 million units/ha.

Research by V.V. Lykhochvor and V.M. Andrushko [18; 19] established that the yield of pea grain also changed under the influence of seed sowing rates. A somewhat lower yield was noted on the variant with a seed sowing rate of 0.9 million/ha – 6.34 t/ha. The highest yield of peas, on average over the years of research, was noted on the variants of the experiment with a seeding rate of 1.0 and 1.1 million/ha – 6.52 and 6.55 t/ha, respectively, which is more by 0.18-0.21 t/ha for the option of seeding rate of 0.9 million/ha. On the variants of the experiment 1.2; 1.3 and 1.4 million/ha observed a natural decrease in the yield of pea grain in all years of research. It should be noted that, regardless of the investigated rate of seed sowing, higher grain yield was formed by plants of the Madonna variety.

CONCLUSIONS

On the basis of two-year data, it can be concluded that wintering peas form a small area of the leaf surface, which is marked by a high level of difference in productivity. Thus, the leaf surface area of winter pea plants at the rate of seed sowing of 0.7 million/ha was the smallest and, depending on the phase of growth and development of the plants, was 1.3-13.5 thousand m^2/ha in the Moroz variety, 1.1-11.4 thousand m^2/ha in the Enduro variety and 0.8-13.4 thousand m^2/ha in the Baltrapp variety. At the same time, the largest leaf surface area was formed by pea plants at the sowing rate of 1.3 million/ha, regardless of the studied variety. Varieties had no significant differences in leaf area. The decisive importance in the formation of the crop belongs to the productivity of photosynthesis. Thus, according to the results of the research, the highest indicators of net productivity of photosynthesis were characterized by the variant of the experiment with the seed sowing rate of 0.7 million/ha.

It was established that the highest winter pea grain yield, on average over the years of research and according to the studied sowing rates, was formed by the Enduro variety – 1.56 t/ha, which exceeded the indicators of the Baltrapp variety by 0.03 t/ha or 1.9%. and for the Moroz variety – by 0.38 t/ha or 24.4%. It should be noted that, regardless of the studied variety, the highest grain yield was obtained for seed sowing norms of 0.7 million/ha – 1.67 t/ha on average for the studied varieties, which exceeded the indicators of other variants of seed sowing norms by 0.19-0.48 t/ha or 11.4-28.7%. It should be noted that an increase in the sowing rate of winter pea seeds to 1.3 million/ha ensured the lowest grain yield regardless of the studied variety in all years of research.The practical aspects and conclusions of our research are aimed at improving the conditions of growth and development of winter pea plants during the growing season, which directly affect the yield of the crop in the conditions of southern Ukraine, in particular, the introduction of the researched elements of crop cultivation technology will ensure a much more efficient use of moisture during the growing season of plants and, as a result, their formation of a higher grain yield.

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Особливості фотосинтетичної діяльності рослин гороху зимуючого залежно від норм висіву

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Анотація. Горох – досить вибаглива до погодних умов культура, тому на тлі погіршення кліматичної ситуації треба звернути увагу на зимуючу форму. Основною перевагою гороху зимуючого є те, що він використовує вологу зимового періоду і завдяки цьому формує надземну і підземну біомасу рослин ще раніше, ніж настає літня посуха. На початку відновлення процесів весняної вегетації рослини мають добре розвинену кореневу систему, яка проникає вглиб ґрунту до 10 см, тоді як горох ярий в цей час тільки починає висівати. Як наслідок, потенційна урожайність гороху зимуючого в 2–3 рази вища, ніж у ярого. Метою досліджень було визначення впливу сортових особливостей рослин, норм висіву насіння на фотосинтетичну діяльність посівів та урожайність зерна гороху зимуючого в умовах півдня України. Методи досліджень: польовий, лабораторний, розрахунковий, статистичний. У результаті досліджень було вивчено особливості наростання надземної маси рослин, фотосинтетичної діяльності посівів та формування урожайності зерна сортів гороху зимуючого. Виявлено оптимальну норму висіву насіння гороху зимуючого, за якої повною мірою реалізується генетичний потенціал сортів. Встановлено норму висіву насіння, за якої рослини гороху зимуючого формували максимальну площу листкової поверхні. Дослідженнями встановлено, що у більшості випадків максимальний рівень урожаю біомаси сформовано за мінімальної густоти рослин у фазі бутонізації. Зі зростанням густоти поступово зменшується біомаса, що є надійною ознакою суттєвої переваги посівів з меншими нормами висіву за показниками продуктивності фотосинтезу. Визначено, що найвищу врожайність зерна гороху зимуючого, в середньому за роки досліджень і за досліджуваними нормам висіву, сформував сорт Ендуро. Дослідженнями встановлено, що зимуючий горох формує невелику площу листової поверхні, яка відзначається високим рівнем відмінності за продуктивності при пониженій нормі висіву. Відображені в статті практичні аспекти та висновки спрямовані на вдосконалення процесів формування продуктивності гороху зимуючого в умовах півдня України, зокрема за значно ефективнішого використання вологи в період вегетації рослин на формування одиниці врожаю

Ключові слова: фотосинтетична активність, листкова поверхня, надземна біомаса рослин, хлорофіл, густота, урожайність зерна

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Evaluation of Productive Qualities of Sheep of Askani Fine-Wool Breed

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Abstract. An important problem of modern breeding is the selection process, the basis of which is based on a comprehensive assessment of the breeding gene pool, which will make it possible to increase the genetic potential of the sheep of the Askanian fine-wool breed. The development of the sheep breeding industry in Ukraine largely depends on the genetic potential of breeding resources, which are used in the selection of pairs for mating. Thanks to such approaches, it is possible to quickly achieve higher breeding rates of progress on the main traits of productivity. Therefore, the intensification of sheep breeding not only increases the role of breeding, but also requires the improvement of breeding methods, while the traditional practice of sheep breeding should accumulate breeding methods based on a comprehensive assessment of the genetic potential. The hereditary potential significantly affects the productive performance of sheep only after 4-5 generations with the targeted use of the best rams descended from highly productive queens. Therefore, the purpose of this work is to conduct a comprehensive assessment of the productive qualities of Askanian fine-wool sheep and identify the best sires, the use of which will ensure an increase in wool productivity by increasing the genetic potential, which will make it possible to obtain the next generation of animals more productive than the previous one.The results of the research give grounds to assert that the main indicators of wool productivity, as well as indicators of the live weight of sheep of different sex and age groups of the Askanian fine-fleeced breed, depend on the origin, that is, the ram-producer and indicate sufficient opportunities regarding the hereditary potential of this herd, which will make it possible to maintain compliance with the breed type and realize their genetic features. At the same time, the analysis of the obtained research results allows for a comprehensive assessment and identification of the best rams, providing an opportunity to increase productivity, improve the quality of wool and reduce the cost of sheep products

Keywords: live weight, wool shearing, wool productivity, growth, development, economically useful traits, sires

INTRODUCTION

It has been established that highly productive parents have a significant impact on the level of wool productivity not only of individual herds, but also of the breed as a whole. Their genotype is one of the key points to speed up the integration and improve lines, intrabreed types and breeds. And the practice of world and domestic selection and breeding work in sheep breeding shows that in order to improve the productive qualities of sheep, it is necessary to apply their comprehensive assessment. At the same time, it is important to pay significant attention to the assessment of sires that have high breeding and productive qualities and can be the ancestors of new family groups and lines. The works of many scientists, both domestic and foreign, have established that the genotype of the parents is one of the key points that makes it possible to accelerate the integration and improve lines, intrabreed types and breeds [1; 2].

When using the genetic principles of breeding animals, breeders set tasks that could identify the best genealogical formations and outline the most promising ones for their further improvement, study the genealogical structure, give a genetic explanation for the phenomenon of prepotency of sires and queens, and establish the possibility of using the combination effect when breeding behind lines [3].

The practice of world and domestic selection and

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breeding work in sheep breeding shows that in order to improve the productive qualities of sheep, it is necessary to apply their comprehensive assessment, which consists in ensuring that animals in each subsequent generation surpass their parents in their productive qualities [4]. The success of breeding work largely depends on the ability to most objectively determine the breeding value of animals using various assessment methods [5]. When selecting sheep for further work, it is necessary, on the one hand, to exclude the possibility of the spread of unwanted genes in the herd, for example, causing morphological and physiological defects, and on the other hand, to increase the frequency of desired genes [6]. The most important components of breeding work are the targeted selection and selection of sheep for mating, obtaining and raising strong healthy young animals, full feeding, proper maintenance of adult animals [4-6].

In modern conditions of progressive technologies, scientists are increasingly performing a comprehensive assessment of breeding animals using various methods for analyzing the productive and breeding qualities of animals, using both classical zootechnical methods and more modern ones [9-11].

The breeding methods used in sheep breeding provide an increase in their productivity by only 1-2% from the level achieved in previous generations, however, they do not always involve the use of an integral assessment of rams and queens by genotype and by a set of qualitative and quantitative indicators of their own productivity. The trend in the development of world sheep breeding and the further intensification of breeding work are aimed at increasing the wool productivity of sheep and necessitate a comprehensive assessment of sheep, even in industrial herds, according to the degree of realization of their genetic potential in the context of the main economic and useful indicators of productivity. In Ukraine, this issue does not lose its relevance, which aroused our interest in a comprehensive study of the main economically useful traits of sire rams and their impact on the productivity of offspring.

LITERATURE REVIEW

During the period of early ontogenesis, the growth and development of the organism and future productivity are formed as a result of the "genotype x environment" interaction. The impact of the genotype on the growth and development of animals in the Taurian type of the Ascanian fine-fleece breed depends on the proportion of heredity and economically useful traits of sire rams used in breeding [10; 11].

N. Papakina, T. Oskyrko argue that in the conditions of enterprises, breeding work is carried out according to the available productivity indicators – formed by the individual phenotype of animals, and the confirmation of the valuable genotype of producers is the maintenance of their own high productivity and the manifestation of valuable traits in descendants [12].

V. Yakovchuk and O. Smorochynskyi prove that when selecting sheep for breeding, one of the main indicators is their live weight, which indicates the full development of animals, and it is he who is the leading one during the grading of sheep [13].

In breeding work with sheep, much attention is also paid to their growth indicators. So, according to N.S. Papakina, the growth and development of young animals is an integral part in the formation of the final productivity of farm animals and poultry. Knowledge of the species, breed and sex characteristics of these components makes it possible to introduce optimal methods for managing natural biological processes into production and genetically obtain high productivity of sheep. Within the same enterprise, as a rule, young animals of different sexes are kept, and knowledge about sexual relations and the features of the formation of their productivity is the basis for improving the existing technologies for keeping and caring for young animals [8].

I. Gladij also studied the relationship between animal types and their productivity. This is the scientist, who found that in terms of growth rates, small animals prevailed over large ones, and rams of a knocked-down physique, that is, more compact, with a rounded body, prevailed over stretched ones, with a flatter body [14].

M. Ptáček, J. Ducháček, L. Stádník, and J. Beran studied the characteristics of the growth and development of young sheep of different sexes, which allowed them to establish patterns of sheep formation in different age periods in order to use the data obtained to raise animals of the desired type of constitution and directions of productivity [15].

Particular attention is paid to the study of the relationship between morphofunctional traits and the correlation analysis of economically useful traits, which makes it possible to establish the degree of dominant influence of parental organisms on the manifestation of a similar trait in offspring [9].

A number of Ukrainian and foreign scientists have proved that sheep breeding is a strategic sector in the agricultural sector [3; 5; 10]. According to M. Mihajlova et al. and V. Topikha et al., the Askani fine-fleeced breed of sheep, unique in its direction and level of productivity, constitutional features, is of great value in the breeding gene pool of domestic sheep breeding. J. O. Hampton et al. [10] and M.T. Bastanchury-López et al., proved that it fully meets the world-class requirements [16]. O.I. Karatieieva, claims that their genotype is used both to create new areas of sheep breeding, and for crossing in order to increase the level of meat, milk and wool productivity, accelerate early maturity, improve the quality of meat, wool, skins and fur sheepskins [1]. What is confirmed in the studies of O.P. Krupa, T. Rak [2]. Chikhirov with a group of authors proved that the use of Askanian fine-fleeced rams makes it possible to raise domestic sheep breeding to the world level, and, in turn, refuse to import foreign rams of a similar productivity direction, which will help to avoid loss of funds and eliminate the difficulties of acclimatization of imported representatives, which was confirmed by T.I. Nezhlukchenko and others [2; 4; 11].

MATERIALS AND METHODS

The basis for the research was the private enterprise "Agrofirm" Vasilyevka" of the Mykolaiv region, in the period 2019-2021.

For the study, three groups of sheep were formed, which come from three different rams, which were compared with each other according to the main economic and useful traits.

At the first stage, the live weight of animals of different sex and age groups and their wool productivity were subject to research: clean and washed wool shear, clean wool yield, wool length. Further, within each group, the experimental sheep were divided into sex groups, the rams and lambs of which were compared with each other and their productive qualities were evaluated according to the methods generally accepted in zootechnics (Table 1) [17].

Table 1. *Scheme of the formation of experimental groups in the conditions Private enterprise "Agrofirma "Vasilievka"*

Experienced group					
Ram No. 483		Ram No. 256		Ram No. 628	
Ewe lambs	Lambs	Ewe lambs	Lambs	Ewe lambs	Lambs
16	5	16	5	16	5

Since the assessment by phenotype does not provide complete information about the inheritance of economically useful traits and does not allow us to identify the best carriers of heredity, we used correlation analysis with the calculation of relative variability [17].

Statistical data processing was carried out using the Microsoft Excel and Statistica 6.1 software package according to G.F. Lakin [18].

RESULTS AND DISCUSSION

Characteristics of the productivity of sheep of the Askanian fine-wool breed

According to the results of the research, out of the total number of sheep, which is kept at the enterprise, 3 main rams of the producer are used, and 157 ewes, which together act as a kind of founder of all future generations. These animals have a responsible role, since the genetic potential of all future descendants will depend on the level of productive and breeding qualities. Therefore, in order to maximize their genetic potential, the selection of parents is approached very responsibly, special attention is focused on sires, whose role in this process can be called decisive.

Obtaining high-quality lamb and wool productivity is inextricably linked with the live weight of the sheep. Therefore, in order to maximize the live weight of sheep and, accordingly, the level of meat and wool productivity, rams and ewes with the highest indicators are selected. For sires, on average, it is 118 kg, which is a fairly high indicator for the Askanian fine-wool breed, and 65 kg for a ew, which is also fully consistent with the breed indicator (Table 2). Also, we observed that the live weight indicator is high not only for adult sheep, but also for other sex and age groups. So, at a fairly young age, replacement rams reach 88 kg of live weight, which is a very good indicator, the same can be seen about ewes and overbreds, in which the live weight is at the level of 43 and 50 kg, respectively.

Table 2. *Productivity indicators of sheep of the Askanian fine-wool breed*

Gender and age group	n	Characteristic				
		Live weight, kg	Coat length, cm	Unwashed wool shear, kg	Pure fiber yield, %	Clean wool shear, kg
Rams, total	18	206	19.3	32.4	93.9	14.5
Major ram producers	3	118	11.1	18.1	47.4	8.1
Repair rams	15	88	8.2	14.3	46.5	6.4
Ewe-lambs	87	43	9.5	5.2	45.6	2.2
Yearling	39	50	8.1	6.3	44.5	2.6
Ewes	157	65	10.3	7.4	44.1	3.3

When selecting parents, attention is paid not only to live weight, but also to wool productivity indicators, which for the main sires were within the following limits: wool length – 11.1 cm, unwashed wool shear – 18.1 kg, pure fiber yield – 47.4%, pure wool shearing – 8.1 kg, and for ewes: wool length – 10.3 cm, unwashed wool shearing – 7.4 kg, pure fiber yield – 44.1%, pure wool shearing – 3.3 kg. Both in the case of live weight indicators and wool productivity, full compliance with breed standards was observed.

In the group of replacement rams and ewes, in terms of wool productivity, compliance with the breed standards was also noted.

E. Zonabend König, J.M.K. Ojango, J. Audho, T. Mirkena, E. Strandberg, A.M. Okeyo &J. Philipsson also confirm that meat and wool productivity are the most important traits of sheep breeding and depend on the quality of the breeding material, then there are ewes and rams-producers [19].

I. Suprun, A. Getya, V. Fychak, M. Janíček in their studies speak about the high genetic potential of sheep breeds bred in Ukraine. Observers argue that in the current economic conditions, sheep breeding remains one of the most promising for development in terms of improving land use efficiency, employment, providing the processing industry with raw materials, and for the population – providing food (meat, milk, cheese). When selecting animals for breeding, it is necessary to pay great attention to sires as carriers of the main heredity [20].

Relative variability of the main traits of selection of replacement young stock of the Askanian fine-fleece breed

Many authors point out that in breeding work with individual breeds of sheep, the selection of animals occurs on the basis of their assessment by phenotype. But assessment by phenotype does not always make it possible to determine the hereditarily best individuals, since the quantitative signs of productivity are quite variable and are formed under the influence of the genotype and environmental conditions [2; 18]. Therefore, there is a need to assess the quantitative characteristics of the young Askanian fine-wool breed, which originated from different sires.

In the course of the experiment, 1 study group of offspring was formed from each sire ram: ewes and rams, which were studied in terms of changes in live weight at birth and at the age of 4, 6, 8, 12, 15 months (Table 3).

Table 3. *Changes in the main economically useful traits of young sheep of the Askanian fine-wool breed*

Age, month	Group					
	Ram No. 483		Ram No. 256		Ram No. 628	
	Ewe lambs	Lambs	Ewe lambs	Lambs	Ewe lambs	Lambs
Live weight, kg						
At birth	4.0±0.05	5.1±0.12	4.0±0.03	$4.6 \pm 0.12^{**}$	$3.6 \pm 0.05^{***}$	$4.4 \pm 0.16^{**}$
4	27.4±1.18	38.4±1.46	$26.4 \pm 1.21^{***}$	$36.7 \pm 1.89^{**}$	$25.3 \pm 1.37^{***}$	$35.7 \pm 1.63^{**}$
6	36.1±2.61	52.6±3.42	35.3±1.11	51.1±3.47	33.7±2.85	50.5±4.81
8	40.0±3.17	64.0±5.71	39.0±3.14	62.0±4.51	38.6±4.26	61.0±2.86
12	52.9±2.28	83.6±4.51	50.7±6.22	82.1±5.34	49.2±3.20	80.6±5.51
15	56.7±2.26	91.6±7.51	56.0±3.17	90.1±3.33	54.5±2.26	88.8±4.58
Sheared wool, kg						
12	7.0±0.59	14.1±0.24	$6.4 \pm 0.05^{***}$	$13.2 \pm 0.1^{4**}$	$5.4 \pm 0.0^{4***}$	$12.3 \pm 0.09^{***}$
Wool length, cm						
4	3.9±2.12	5.5±2.14	3.6±1.04	5.0±1.13	3.6±1.64	5.4±1.09
8	6.4±2.13	8.8±3.32	5.4±1.34	8.3±2.30	5.7±2.16	8.4±3.21
12	8.8±4.06	10.8±4.32	7.7±2.12	9.3±3.34	8.2±3.06	10.1±5.29

E.Z. König, T. Mirkena, E. Strandberg, J. Audho, J. Ojango, B. Malmfors, A.M. Okeyo & Jan Philipsson state that animal live weight data and visually assessed size are the most important factors in selecting sires for breeding goals. Large body size is an indicator of good growth rates and is an important feature in breeding [21].

Since wool shearing is directly proportional to the live weight of the animal, when assessing this trait at the age of 12 months, we noted a similar trend. Namely, the young animals of group I were characterized by higher values of wool shearing compared to other groups. The ewes had 7.0±0.59 kg of wool, which is probably more than this indicator in the ewes of II – 6.4±0.05 kg ($P \leq 0.001$) and III groups – 5.4±0.04 ($P \leq 0.001$). A similar trend was noted in terms of the level of manifestation of this trait in rams of group I, which probably turned out to be better than analogues of group II – 13.2±0.14 ($P \leq 0.01$) and group III – 12.3±0.09 ($P \leq 0.001$). Characterization of coat length from 4 months of age to 12 months of age established a similar manifestation of this trait. That is, the young animals of group I have higher values for the length of wool, in comparison with the other two groups.

M.A. Snyman, W.J. Olivier also came to the conclusion that economically important signs of reproduction, growth and wool productivity are in a certain relationship. The better the young growth grows and develops, the faster it reaches a higher live weight and, as a result, will subsequently have better indicators of wool productivity [22].

K.A. Ward, J.D. Murray, C.M. Shanahan, N.W. Rigby & C.D. Nancarrow have used growth hormone to increase wool production in sheep. Phenotypically, such sheep responded to increased levels of growth hormone by increasing their body growth rate and, as a result, were noted by an increase in wool productivity [6].

Correlations between economically useful traits are an important element in breeding work; they represent the interdependence of two or more random variables. Correlative variability is used when improving a certain trait, since the animal organism is a complex interacting system, therefore, improving one trait, it inextricably improves and another, or vice versa, a negative impact on one trait will entail a decrease in others [7; 18].

Therefore, we set a goal to investigate the relative variability between the main breeding traits in sheep breeding: such traits as live weight, wool shear, wool length.

As can be seen from Table 4, the correlations of the main economically useful traits in the context of the experimental groups remain at a high level, however, unlike the previous study, there have been changes in the main economically useful traits. Namely, between the indicators of live weight and wool shearing, high positive relationships were established in all experimental groups, regardless of sexual demorphism – 0.641-0.773 for ewes and 0.823-0.914 for the group of rams. With the highest values in representatives of group II – 0.773±0.0116 (P≤0.001) for ewes and 0.914±0.0427 for rams.

Table 4. *Correlations between the main economically useful traits of young sheep of the Askanian fine-wool breed*

Group	Correlation features			
	Body weight×wool cut		Wool length×wool cut	
	Ewe lambs	Lambs	Ewe lambs	Lambs
Ram No. 483	0.695±0.0284	0.881±0.0342	0.892±0.0111	0.968±0.0031
Ram No. 256	0.773±0.0116***	0.914±0.0427	0.919±0.0232	0.723±0.0118***
Ram No. 628	0.641±0.0542	0.823±0.0132*	0.704±0.0438*	0.971±0.0534

In terms of the length and shearing of wool in the context of the experimental groups, we also found very high correlations for lambs from 0.704 to 0.919, and for rams from 0.723 to 0.971. With the highest values in the group of yolks in the representatives of group II – 0.919±0.0232, and the lowest in group III – 0.704±0.0438 (P≤0.05). For the group of rams, a slightly different trend is noted in terms of the degree of relative variability between the length and wool shearing. Thus, the best were male representatives of group III (0.968±0.0031) with the least manifestation in rams of group II – 0.723±0.0118 (P≤0.001). And among the female representatives, a natural trend was observed, where the higher values of the relative variability were in the representatives of the II group – 0.919±0.0232, with the lowest values in the females of the III group – 0.704±0.0438 (P≤0.05).

A number of scientists from different countries have successfully used correlations when working with sheep in different areas of productivity. So, P.S. Ostapchuk V.S. Pashtetsky, E.N. Usmanova, T.A. Kuevda, E.Yu. Zyablitskaya, T.P. Makalish & J.S. Saenko found a positive correlation between coat fineness and body weight (p≤0.05); between shearing of natural wool and fine wool (p≤0.05); between natural wool shear and live weight (p≤0.05); between washed wool and wool fineness (p≤0.05) and sheared natural wool (p≤0.05). And the greatest thickness of the skin was on the back and lower leg. Scientists also suggest that skin regeneration occurs due to the cells of the basal layer. This is due to the fact that the thickness of the basal layer decreases in the following order: lateral-rear-leg-neck, which correlates with the degree of impact of damaging factors on these areas and the degree of growth of the animal [23].

Assessment of the processes of growth and development of young growth of the Askanian fine-wool breed, depending on their origin

The data of systematic weighing and measurements characterize the growth rate, which is of great economic importance, since intensively growing animals spend less nutrients per unit of growth than slowly growing ones. The growth rate is determined by the absolute and relative growth rates per day, month, year [4; 17].

The study of changes in the live weight of sheep and the assessment of the level of meat productivity we want, as well as the genetic characteristics of sheep only by age intervals, are rather superficial and insufficient. Therefore, live weight is subject to the classical in zootechnics assessment of live weight gain indicators: absolute, average daily and relative [7; 24; 25].

Therefore, we set the task to investigate the indicators of changes in live weight gains at the age of 4-, 6-, 8-, 12-, 15 months (Table 5). When analyzing the age dynamics of the growth in live weight of young animals, it was noted that the highest absolute growth rates were achieved at the age of 0-4 months for representatives of the 1st study group, for rams the value reaches 33.0±1.65 kg, for ewes 23.6±1.18 kg. In turn, the indicators exceeded the value of group II – 32.0±1.6 kg and 22.8±1.14 kg, respectively. And group III, for which these indicators were at the level of 31±1.55 kg for rams, and 21.6±1.1 kg for ewes.

Table 5. Age dynamics of live weight gain in young sheep of the Askanian fine-wool breed

Age, month	Growth					
	Absolute kg		Average daily, g		Relative, %	
	Ewe lambs	Lambs	Ewe lambs	Lambs	Ewe lambs	Lambs
			Ram No. 483			
0-4	23.6±1.18	33.0±1.65	196±0.01	278±0.01	151±7.5	153±7.6
4-6	8.7±0.45	14.1±0.7	145±0.007	237±0.01	27±1.35	31±1.6
6-8	4.4±0.22	11.4±0.57	70±0.004	190±0.01	11±0.5	20±1.0
8-12	12.6±0.63	20.0±1.0	105±0.005	163±0.008	27±1.35	27±1.35
12-15	4.0±0.2	8.1±0.41	41±0.002	89±0.004	7±0.4	9.1±0.5

Table 5, Continued

Age, month	Growth					
	Absolute kg		Average daily, g		Relative, %	
	Ewe lambs	Lambs	Ewe lambs	Lambs	Ewe lambs	Lambs
			Ram No. 256			
0-4	22.8±1.14	32.0±1.6	189±0.01	267±0.01	152±7.6	155±7.6
4-6	8.9±0.44	14.0±0.7	148±0.007***	239±0.01	29±1.45	33±1.7
6-8	4.0±0.2	11.3±0.6	67±0.003	189±0.009	11±0.5	20±1.0
8-12	11.5±0.57	20.0±1.1	96±0.005	164±0.008	25±1.3	27±1.4
12-15	5.2±0.26	8.0±0.4	58±0.003	72±0.003**	10±0.5	9±0.5
			Ram No. 628			
0-4	21.6±1.1	31.0±1.55	180±0.001***	261±0.01	150±7.5	157±7.8
4-6	8.5±0.43	15.0±0.8	141±0.007***	246±0.01	29±1.45	34±1.7
6-8	4.8±0.24	10.3±0.52	81±0.004	172±0.008	14±0.7**	18±0.9
8-12	10.5±0.52	20.0±1.0	88±0.004	165±0.008	24±1.2*	28±1.4
12-15	5±0.25	8.0±0.4	59±0.003	91±0.005	10±0.5***	10±0.5

As in the age of 0-4 months, and in other age periods, the 1st group remained the leader in most age intervals in terms of absolute growth. So, she was noted at 8-12 months, with an increase rate of 12.6±0.63 kg for ewes and 20.0±1.0 kg for rams, where she significantly exceeded others, in addition, she had the highest growth rate in rams 11.4±0.57 kg at 6-8 months, 8.1±0.41 kg at 12-15 months, and generally proved to be the most stable in terms of indicators in each age period.

In terms of studying the indicators of changes in average daily gains, they had a rather undulating and unequal nature of dominance, which began to branch out between all the studied groups, each of which had an advantage in a certain indicator. However, for comparison with the study of absolute growth, the advantage gradually shifted for this trait from group I to III, which showed its dominance in almost every category.

The final stage of the study was the study of indicators of the level of relative growth, which is used to evaluate the economic and biological characteristics of animals, the intensity of dissimilation processes in the body. For the above indicator, there is a similar situation with the growth rates studied earlier, where the advantage of groups I and III continued, which shared leadership in one or another period. However, in this aspect, group I showed absolute dominance in two sex and age groups, remaining the first in terms of relative growth at the age of 8-12 months with an indicator of 27±1.35% for ewes ($P \leq 0.05$), and 28±1.40% for sheep and in the age period of 6-8 months.

The third study group turned out to be the best in a number of relative gains in the age period of 0-4 months – ♂153±7.6%, 4-6 months – ♀29±1.45%, ♂34±1.7%, 6-8 months – ♀14±0.7% and in the age period of 8-12 months – ♂28±1.4% and 12-15 months – ♀10±0.5%, ♂10±0.5%.

M.C. Gauvin, S.M. Pillai, S.A. Reed, J.R. Stevens, M.L. Hoffman, A.K. Jones, S.A. Zinn, K.E. Govoni suggest that slow growth and development of young animals can have immediate and lifelong negative consequences for the formation of an animal as a carrier of breeding and productive qualities. And this leads to a decrease in quality and an increase in the cost of production. The authors also argue that limited nutrition or overfeeding slows down muscle growth and changes metabolism during an intensive period of growth, reduces the number of myogenic progenitor cells and leads to changes in the global expression of genes involved not only in the formation of the live weight of the animal, but also in productivity in general [24]. This was also confirmed in the studies of other authors [26].

CONCLUSIONS

The main indicators of wool productivity are represented by the shearing of unwashed wool, the length of wool, the shearing of clean wool and the yield of pure fiber, as well as the live weight indicators of sheep of different sex and age groups of the Askanian fine-fleeced breed are within the breed standard. And they testify to sufficient opportunities regarding the hereditary potential of this herd, which will make it possible to maintain compliance with the breed type and realize their genetic characteristics.

Among the studied groups, according to the change in the main economically useful traits of young sheep, it was found that in terms of the level of development of live weight, indicators of wool productivity, growth and development characteristics, regardless of sexual dimorphism, the sheep of the first group turned out to be the best, which indicates a high genetic potential of ram No. 483 This will allow using it to increase productivity, improve the quality of wool and reduce the cost of sheep products.

Analyzing the work done by us, we can conclude that the characteristics of correlations have established certain patterns depending on the traits of the genotype of the sire. So, according to the majority of correlations between the main features, the young animals of group II, obtained from ram No. 256, turned out to be the best.

According to the level of development of absolute, average daily and relative gains, young animals obtained from representatives of I and III of the study group dominated, showing their absolute advantage, both in terms of sex and age groups, and in certain age periods. The prospect of these studies may be the use of modern techniques in the evaluation of sires to identify the best carriers of the genetic potential.

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Оцінка продуктивних якостей овець асканійської тонкорунної породи

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Анотація. Важливою проблемою сучасної племінної справи виступає селекційний процес, основа якого базується на всебічній оцінці племінного генофонду, що дасть можливість підвищити генетичний потенціал овець асканійської тонкорунної породи. Розвиток галузі вівчарства в Україні значною мірою залежить від генетичного потенціалу племінних ресурсів, які використовуються при підборі пар для спарювання. Завдяки таким підходам можна достатньо швидко досягнути вищих селекційних темпів прогресу за основними ознаками продуктивності. Тому інтенсифікація вівчарства не лише підвищує роль селекції, але і вимагає вдосконалення методів селекційної роботи, при цьому традиційна практика розведення овець повинна акумулювати методи селекції, засновані на всебічній оцінці генетичного потенціалу. Спадковий потенціал відчутно впливає на продуктивні показники овець тільки через 4-5 поколінь за умови цілеспрямованого використання кращих баранів від високопродуктивних маток. Тому метою роботи є проведення комплексної оцінки продуктивних якостей овець асканійської тонкорунної породи і виявлення кращих баранів, використання яких забезпечить ріст показників вовняної продуктивності за рахунок збільшення генетичного потенціалу, що дозволить отримати наступне покоління тварин продуктивніше попереднього. Результати досліджень дають підставу стверджувати, що основні показники вовняної продуктивності, а також показники живої ваги овець різних статево-вікових груп асканійської тонкорунної породи залежать від походження, тобто барана, і свідчать про достатні можливості відносно спадкового потенціалу цього стада, що дасть можливість зберегти відповідність породному типу і реалізувати їх генетичні особливості. При цьому, аналіз отриманих результатів досліджень дозволяє виконати комплексну оцінку і виявити кращих баранів, забезпечуючи можливість підвищити продуктивність, покращити якість вовни і знизити собівартість продукції вівчарства

Ключові слова: жива вага, настриг вовни, вовняна продуктивність, ріст, розвиток, господарсько-корисні ознаки, барани

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Model of the Post-War Development of the Agro-Industrial Complex of Ukraine: Prognostic and Financial Concept

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Abstract. The article is devoted to the formation of the post-war model of development of the agro-industrial complex of Ukraine. The topicality of the topic consists in determining the means of restoration and further development of the agro-industrial complex with appropriate justification of the proposed model, which will contribute to solving the problems of providing food to Ukrainian and foreign consumers. Considering the specifics of the research, the main method was chosen to be systematic, which ensures the complexity of the research. Along with it, the methods of comparisons, formalization, and economic analysis were used, which make it possible to supplement and expand the scope of the research to obtain a scientifically based result. The purpose of the article is to substantiate the prognostic-financial concept of the restoration model of the agricultural industry of Ukraine in the post-war period. The article analyzes the pre-war state of the agro-industrial complex according to the main criteria and reveals the reasons for inefficient use of its potential. A comparison of the efficiency of agricultural production based on the indicator of added value was made in Ukraine with such countries as Poland, Brazil, Germany, France, where Ukraine was found to be significantly behind. It is also emphasized that a small share of Ukrainian agricultural raw materials is sent to industrial processing, which significantly reduces the amount of added value. Taking into account the importance of the influence of external environmental factors on the functioning of the agro-industrial potential at the present time, an analytical justification of this influence in cost calculation is provided. Using the system method, an algorithm for the development of the specified model was proposed, the hierarchy and structure of the development of this complex were substantiated, six principles were determined, scientific approaches were developed for the formation of a prognostic model of the post-war development of the specified complex in experimental and working versions, and the conditions for its implementation were highlighted. The scientific novelty of the article lies in the development of theoretical provisions, which together made it possible to propose a predictive model of the development of the agro-industrial complex of Ukraine in the post-war period, which will contribute to the restoration and further development of the entire specified complex with sustainable provision of national food security

Keywords: agro-food potential, prognostic model, structure of agro-industrial complex, influencing factors

INTRODUCTION

In the difficult war conditions of 2022, which is characterized by catastrophic levels of destruction of the economic and social component of society, it is necessary to start forming the appropriate restoratie schemes, mechanisms, models, etc. already now. In this context, the problem of restoring the agrarian-industrial complex (AIC) is not only to return to the previous state, but also to form a model that would make it possible to use its potential more effectively, in particular, to be competitive on the Ukrainian and foreign commodity markets, to significantly increase the share of processed agricultural raw materials, increase the level of organic production, increase the volume of products of animal origin, etc. In order to solve this extremely important national task, it is necessary, first of all, to develop a well-founded model of the agricultural industry, using a set of scientific approaches, in particular: methods – systematic, comparisons, comparisons, economic analysis; theories of behavioral economics, poles of growth.

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Taking into account the current social situation, it is expedient to divide the publications on the agricultural industry into two periods – the pre-war period and the period that continues from February 24, 2022, when Russia's military invasion of Ukraine was carried out. Such a division is logically justified, since the conditions for the functioning of the agro-industrial complex in these periods are fundamentally different. The pre-war period is important in this study because it is a certain point of reference that captures its pre-war state.Evaluating the works of Ukrainian scientists in the pre-war period regarding strategies, models, mechanisms, etc., we note that they describe the current and future state of the agricultural industry, taking into account the social situation. Thus, in the research work of A. Bosak and L. Mustafaieva, the peculiarities of the production of agricultural products and their export possibilities were investigated, the factors affecting the competitiveness of agricultural sector products were analyzed, the influence of European integration processes on the development of the Ukrainian agro-industrial sector was identified, and the prospects for the further expansion of the free trade zone between Ukraine were substantiated and the EU [1]. O. Novikov, N. Potryvaieva and others substantiated the feasibility of irrigation development in the conditions of Southern Ukraine, as an important condition for the formation of a favorable innovation and investment environment in the region and proved that the development of irrigation requires a systematic approach with mandatory scientific support with the use of public-private partnership. They also determined the economic efficiency of the implementation of the project of the innovative landfill of rainfed agriculture using Smart technologies [2]. Ya. Hadzalo and Yu. Luzan identified shortcomings and substantiated the expediency of significant modernization of the organization of state management of the agrarian sector and proposed an algorithm for building the system of management of the agrarian sphere of Ukraine [3]. P. Izhevskyi carried out an analysis of the export-import balance of the agro-industrial complex of Ukraine, identified its key problems, found that the growth of agricultural holdings encourages small and medium-sized agricultural producers to find new forms of organization, and proposed solutions to key problems of agriculture and food industry with the help of network interaction of enterprises [4].

In the current conditions of the globalized world, the efficiency of agriculture is gaining importance, and it is the subject of research by foreign scientists. Thus, L. Camanzi and S. Troiano emphasized the impact of climate change and natural resource conservation on agricultural production methods, determined the trends of the transition to green economies in the future and justified that the improvement of the multifunctional role of agriculture will occur due to technological transformations and innovations, including the relationship between management environmental resources and agricultural activities, and also determined that the implementation of models of conscious and responsible consumption opens up new opportunities for increasing sustainability both on a local and global scale [5]. M. Miranda and J. Glauber found rapid growth in grain and oilseed production in the Southern Hemisphere during 1980-2019, and argued that production growth is important because it increases supplies to meet global food needs. A semiannual stochastic model of spatio-temporal equilibrium of the general agricultural market with two main exporting regions, the North and the South, which plant and harvest at different times of the year is proposed [6]. M. Abraham et al. at the microeconomic level, reviewed the systematics of aggregation models, assessed the impact of qualitative and quantitative factors, analyzed their advantages and disadvantages, and concluded that aggregation models improved access to credit markets and technology [7]. The list of the works of Ukrainian scientists during the war period, in particular until the first half of May 2022, when active military operations continue in the territories of Zaporizhzhia, Mykolaiv, Kherson, Kharkiv, Donetsk, and Luhansk regions, is not so extensive, because now the situation is being understood with an analysis of possible vectors of further social development, including foreign policy, economic, military and demographic aspects. Thus, A. Vyshnevskyi proposed to create a kind of strategic thinking committee for Ukraine, something like the Global Thinking Committee at Columbia University in New York, which was headed at different times by Joseph Stiglitz and Saskia Sassen [8]. V. Novikov expressed a well-founded assumption that from the point of view of the economic structure, we need to change and not preserve the structure of the economy, or in other words, we need a plan for the transition from an agrarian-raw material to a technological economy [9]. I. Burakovskyi emphasizes the important role of the consolidation of the entire society, noting that the post-war recovery of Ukraine will require colossal efforts from both the government and society. In particular, civil society should facilitate the establishment of a regular, honest and responsible dialogue between citizens and the authorities, as well as offer effective solutions to relevant problems [10].

Analyzing these works, we note that they highlight the views of specialists who have certain scientific and pragmatic experience in the relevant field, and therefore there is an effort to find answers to relevant questions from somewhat personal approaches, in particular from an emotional position and not entirely clear scientific justifications, at the same time these and other works form the components of the theoretical-methodological and pragmatic basis for the development of the agro-industrial complex, which in the future should receive a complete form.

Taking into account the imperative need to find optimal forms, mechanisms, schemes, models of the post-war development of the agricultural industry and the almost absence of scientifically based developments regarding its organization, an appropriate model is proposed.

The purpose of the article is to develop a model of the post-war development of the agricultural industry of Ukraine with the corresponding theoretical justification and feasibility of implementation.

MATERIALS AND METHODS

For the theoretical substantiation of the specified model, the system method was used as the main one. The peculiarity of this method is that its application makes it possible to study complex, unbalanced, open systems, which is the agro-industrial complex of Ukraine. Considering the serious problems of the specified complex, the universality of the approaches of this method determines the forms and schemes of the research, which ensures the formation of the stipulated model. The application of the method of comparisons helps to identify differences in the dynamics of the development of the agro-industrial complex of Ukraine and other countries and to shape development directions. The method of formalization was used in the substantiation of the specified model. A. Konverskyi presents its essence as follows: "Formalization is a type of sign modeling, by means of which the essence of the studied object or phenomenon is fixed, transmitted by a sign or a combination of signs and, most importantly, this combination of signs is treated as the object or phenomenon itself. Thus, it is not about the fact that as a result of formalization we abstract from the content of the studied objects, but about the fact that, with the help of symbols, the essential aspects of the content are expressed through the form, and then the study of the content is carried out on the basis of a symbolic model, according to formal rules [11, p. 54-55]. Economic analysis was used in the study of the state of the agro-industrial complex of Ukraine in the pre-war and post-war periods, which made it possible to identify specific problems, determine characteristics, and form development vectors of the specified model.

For the logical construction of the research order, a corresponding algorithm was formed (Fig. 1).

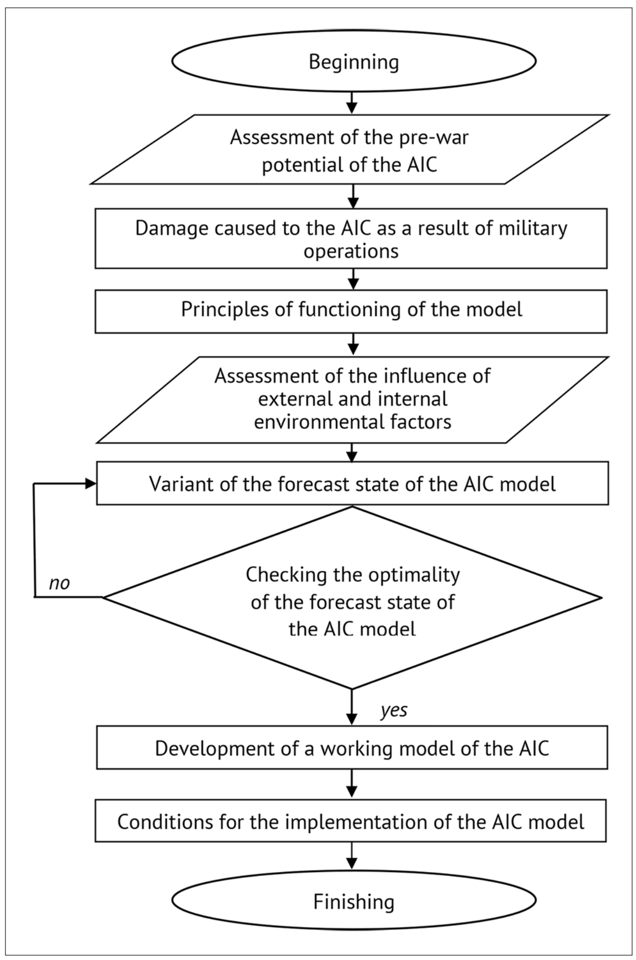

Figure 1. *Algorithm for the development of the APC model*

Source*: developed by the authors*

The information base of the research was: works of foreign and domestic scientists, branch specialists; statistical and analytical materials of the Ministry of Agrarian Policy and Food of Ukraine, Ministry of Agriculture and Rural Development of Poland; specialized public organizations, scientific institutions; regulatory and legal documents that reflect the current and strategic aspects of the functioning of the agro-food complex.

RESULTS AND DISCUSSION

In the process of carrying out the research, the algorithm for developing the APC model was substantiated. A prognostic model of the agricultural industry was built, which includes elements of the external and internal environment, as well as the structure of the agricultural industry and its components. An assessment of the current problems of the specified complex is presented and the main characteristics of its functioning are determined.

The stages of the research are reasonably determined. Separate characteristics of the pre-war potential of the agro-industrial complex by individual components are presented. It is worth noting, according to the UN (Food and Agriculture Organization, FAO), Ukraine is one of the most important producers of agricultural products in the world and plays a leading role in the supply of food products to world markets. According to the results of 2021, Ukraine is the world's largest exporter of sunflower oil (35% of world exports), ranks second in the export of barley (14% of world exports), third in the export of corn (11%) and rapeseed (over 10%), 1st place in terms of wheat exports (about 10% of world exports). Agricultural exports in general are the largest source of foreign exchange earnings for Ukraine. At the same time, the export structure of Ukrainian agricultural products indicates its mainly raw material nature and the need for development in the direction of deeper processing and production of products with higher added value [12, p. 93].

At the moment, the structure of crop production is dominated by crops of low-margin crops (89% by area of crops), which leads to a lower profit compared to the possible profit obtained from the sale of high-margin crops. For comparison, developed countries mainly grow high-margin crops (80% in the crop production structure in Spain, Italy and the Netherlands). The structure of animal husbandry is weakly diversified with a predominance of poultry farming. Animal husbandry occupies 21% of the agricultural sector. During the last five years, a downward trend has been observed – the number of cattle and pigs is decreasing, and the number of poultry is increasing. "The reasons for the decrease in the number of cattle are unprofitability" [14]. Despite the permanent increase in the export of agri-food products during 2014-2021, growing import volumes, in particular those products that can be manufactured in Ukraine, cause great concern (Fig. 2).

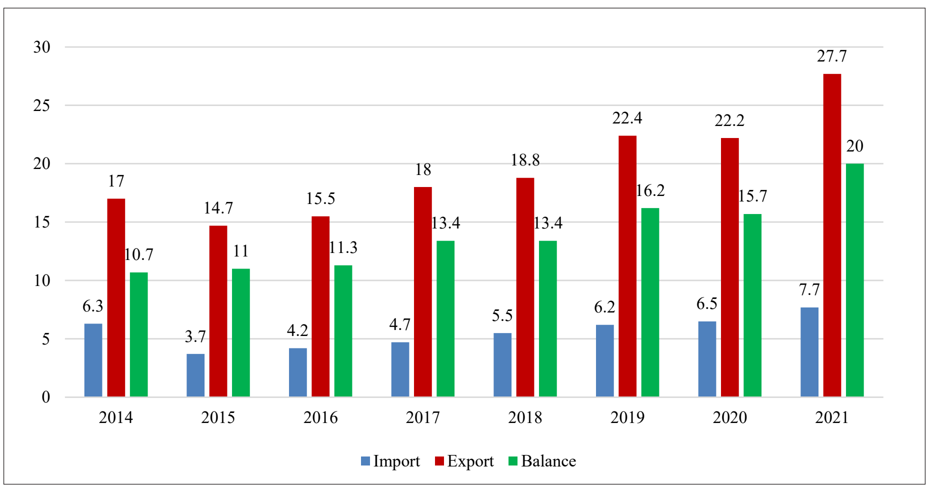

Figure 2. *Dynamics of export and import volumes of agro-food products, billion dollars. USA*
Source: *compiled according to [15-17]*

For an objective assessment of the agro-food potential of Ukraine, we will compare the relevant main criteria of Ukraine and Poland and draw conclusions (Table 1).

Table 1. Criteria for agricultural production in Ukraine and Poland in 2020

Indicators	Poland	Ukraine	
		Total	% to Poland
Territory, thousand square meters km	312.7	603.5	193
Population, million people	37.9	42.2	111.3
Nominal GDP of the country, billion dollars USA	594	156	26.2
GDP of the agricultural sector, billion dollars USA	14.9	14.6	98.0
% of the GDP of the agricultural sector in the GDP of the country	2.5	9.4	3.76 times
Area of agricultural land, million hectares	18.7	42.2	2.26 times
Area plowed, %	36.5	53.9	147
Export of agricultural products, billion euros	34	19	55.9
State support for farmers, billion euros	4.1	0.39	9.5

Source: *[18-20]*

Evaluating these criteria, we determine that Ukraine is larger: the area of agricultural land is 2.26 times, the plowed area is 1.47 times, but it is smaller: the export of agricultural products is 55.9%, and the state support for farmers is only 9.5%. Therefore, the level of intensity of land use in Ukraine is much higher, but the efficiency of management is much lower, therefore it is expedient to change the pre-war model of agro-industrial complex with an emphasis on eliminating those problems that were previously inherent.

Forming a new model of the post-war development of the agro-industrial complex of Ukraine, it is worth taking into account the damage caused to the agro-industrial complex as a result of military operations. B. Danylyshyn calculated the possible losses of the economy, in particular the agricultural sector: "Similar estimates of losses of the economy based on the "territorial withdrawal" of regions of Ukraine from the normal process of economic reproduction show that the economic losses of Ukraine on an annual basis can reach: GDP production – 46%; export revenues – 48%; capital investment – 45%" [21]. Specialists of the Financial Club performed calculations according to two options by 52%, agriculture by 45%, export – by 52%. According to this scenario, the fall in the GDP of Ukraine may amount to 31% [22]. In this context, it is worth noting that now the war in Ukraine continues and the damages will be specified after its end.

It should be noted that the insignificant efficiency of using the potential of the agro-industrial complex was due to many reasons, in particular: low productivity of agriculture in comparison with Poland, Brazil, and Germany; predominant nature of raw material production; the growing trend of food imports; negative factors of influence, first of all, of the external environment, which are caused by the permanent increase in the prices of energy carriers, mineral fertilizers, the significant limitation of supplies to EU countries due to insignificant quotas, as well as the imperfect theoretical and methodological justification of its current functioning and development in the direction of European integration processes, which should include the intensification of agricultural production, an increase in the volume of organic production, and an increase in the share of processing of agricultural raw materials [23; 19; 20]. Without defining the entire complex of this rationale, let's focus on only one of the components – the principles of the model's functioning. Justifying the principles, we will determine that the observance of such scientific approaches as systematicity and synergistics presupposes the use of the main method, and in this case the systemic method will be the most receptive, as it allows to study open complex systems, which is the agricultural industry of Ukraine.

Let's argue these principles.

1. Hierarchy of construction. Taking into account the postulates of the system method, the economic system is structured into appropriate hierarchical levels, subsystems and elements. Depending on the purpose and tasks of the research, the methodology is determined and the structure of the research object is substantiated. In the context of this study, the subsystem is defined as the APC, which in turn has a corresponding hierarchy. Regarding the hierarchy, in general, there are no significant differences of opinion among scientists, in particular V. Kopytko, O. Kopytko [24], G. Sytnyk [25], I. Bila, N. Nasikan [26], so we will define it as follows (Fig. 3).

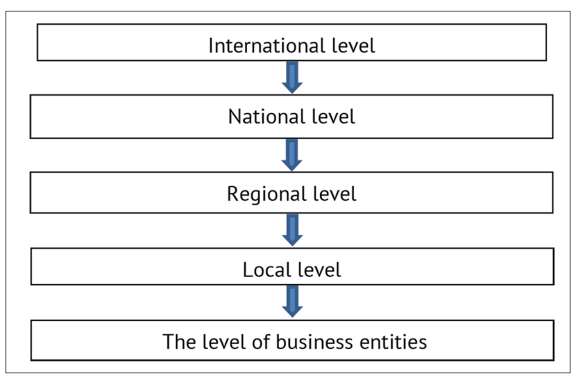

Figure 3. *Hierarchy of agro-industrial complex of Ukraine*

Source*: summarized by the authors*

2. Structural integrity. Note that, regarding the structure of the agro-industrial complex, scientists present a different composition of subsystems and elements. Taking into account the purpose of this study, it is expedient to apply the following provisions when justifying the elements of the agro-industrial complex subsystem:

– an element, as a component of a subsystem, must have compatible features with the subsystem, namely, the relevant governing body, organizational certainty, rules of functioning and development (normative and legal framework), resource composition, connections with other elements of the subsystem and the external and internal environment;

– the ability to generate and spend the appropriate type of energy (labour, financial, raw materials, etc.);

– play an inherent role, according to its purpose, in the structure of the subsystem and influence the functioning of other elements;

– to have a certain autonomy, which, however, does not contradict the strategy and tactics of functioning and development of the subsystem.

Taking into account the specified provisions, the composition of the elements of the agricultural industry as a defined subsystem of the economic system is presented as follows (Fig. 4).

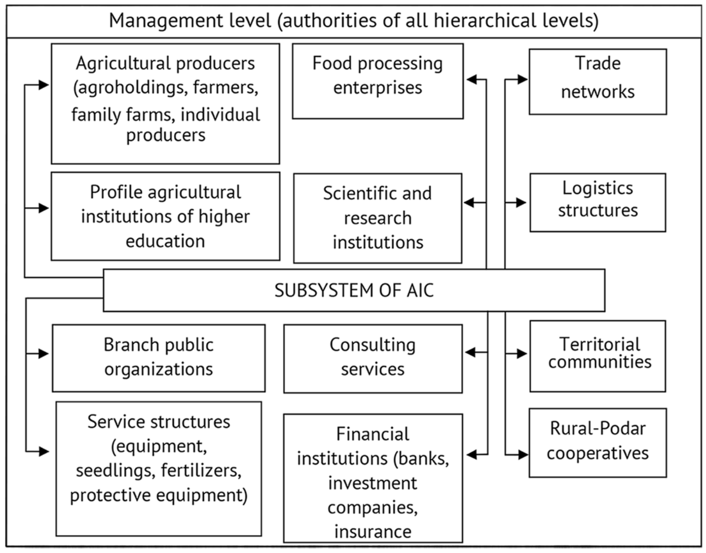

Figure 4. *Functional component structures of the agro-industrial complex of Ukraine*
Source*: developed by the authors*

Determination of criteria for current functioning and strategic guidelines for development. The criteria are the defining characteristics of the state of the object under study, and therefore their selection must be approached carefully. A comparison of individual criteria for the state of the agro-industrial complex in Poland and Ukraine makes it possible to assess the comparative efficiency across countries. Such estimates serve as the basis of economic analysis and allow choosing the most optimal vectors of development of the agro-industrial complex of Ukraine in the post-war period. Pragmatics of Ukraine in the pre-war period operated, for the most part, with statistical characteristics, including sown areas, gross harvests, volumes of export deliveries, and, at the same time, characteristics regarding economic efficiency, including comparative content, somewhat receded into the background. The criteria should be formed taking into account: optimizing the interests of the state as a whole, regions, territorial communities and commodity producers. In this context, a well-known proverb is mentioned, the authorship of which is attributed to Cicero (106-43 BC) and which in an approximate version of the Ukrainian language is interpreted as follows: "Heavenly grace is needed to reconcile the benefits of the redeemers and the population, so as not to bring one into sacrifice to others and make sure that the sheep are whole and the wolves are fed" [27, p. 29]. This issue remains relevant at the present time, but in connection with the improvement of the legislation and a clearer definition of the property, land, and financial rights of the participants of the agro-industrial complex, it must be resolved. Also, the production of agricultural products from 1 ha of land area should be a significant criterion. Ukraine has quite significant areas of agricultural land, however, the predominant raw material nature of export supplies significantly reduces the real capabilities of the agro-industrial complex, which does not contribute to obtaining additional income, does not create new jobs and does not contribute to replenishment budgets of all levels [15-17]. Within the scope of the purpose and defined scope of the study, it is not possible to submit other criteria with the appropriate analytical apparatus, however, such an approach to the specified criteria should be followed.

4. Emergencies. It provides for the formation of progressive qualities in the agro-industrial complex, in particular, the intensification of agricultural production, an increase in the volume of added value, an increase in the area of organic production, which until now were not inherent to its individual elements. Such progressive qualities should be foreseen based on the real efforts of the participants of the agricultural industry.

5. Synergetics. This principle has a rather broad interpretation, but it is one of the basic ones for the development of complex systems. As for the agro-industrial complex, transforming to the current reality, which is characterized by military operations in large areas of Ukraine, logistical problems, insufficient budgetary support for agricultural producers, it conditions the emergence of new qualities, the elimination of obstacles on the way to development, energy accumulation, etc.

6. Consolidation of the efforts of agro-industrial complex participants to restore destroyed agricultural areas, production facilities, warehouses, infrastructure, as well as the creation of new management mechanisms.

The implementation of these criteria is a strong theoretical and methodological basis and should contribute not only to the restoration of the pre-war state of the agricultural industry, but also to determine the vectors of recovery and be the basis of a new model of the agricultural industry.

Like any complex structure, the agro-industrial complex subsystem is affected by factors of the external and internal environment in the process of functioning. which can be positive or negative. According to the system method, a factor is formed by a corresponding element of the environment and its influence is determined by the energy of this element, taking into account the preventive actions taken against the negative reaction of another element or elements on which this influence is directed. Since the composition of the elements of the social system is much wider than the elements of the agro-industrial complex, they can be influenced by elements of other systems [28]. Thus, a convincing example is when the elements of the military subsystem of Russia have a significant negative impact on all elements of the agro-industrial complex subsystem. Since factors by their nature can be military, political, economic, demographic, etc., we will limit ourselves to economic ones. In the external environment, positive factors are the favorable situation of agri-food Ukrainian products, the removal of quotas for Ukraine by the European Union, and negative factors are logistics networks that are blocked by Russia, delays in payment for delivered products. The positive factors of the internal environment are the quality of Ukrainian chernozems, favorable climatic conditions, and the professionalism of product manufacturers, while the negative ones are insufficient budget funding and a lack of labor. In an analytical form, the power of influence on the components of the potential of the agricultural industry at the national level from the negative factors of the external environment is defined as follows (eq. 1).

$$\sum_{i=1}^{n} P = -(\Delta F + \Delta M + \Delta S + \Delta L + \Delta N + \Delta T) \times K \quad (1)$$

where: P is the specified impact force; F – loss of financial resources; M – loss of material resources; S – loss of land resources; L – loss of labor resources; N – losses from damaged infrastructure; T – other losses depending on the specifics of the object; K is a generalizing correction factor that takes into account the level of damage.

Applying this approach, it is possible to calculate the corresponding strength of influence of the selected factors. When developing the specified model, the main provisions of the prognostic-financial concept were substantiated. Forming the methodological toolkit, the determined system method was used as the basis of the research. One of his postulates suggests that in order to study a complex open system, it is necessary to go beyond its boundaries. Regarding this study, it involves the use of the latest theoretical constructions from various fields of science, in particular the theory of behavioral economics and the theory of growth poles, the identification of specific signs of the functioning of the object of resource, financial, and legal content, the relationship with the surrounding environment, and the prediction of its forecast state. Also, the use of: the method of comparisons involves the analysis of the agricultural sector in comparing its previous and future state with other countries; analytical methods – enables assessment with obtaining specific parameters; prognostics – the possibility of forming scientifically based components of the object with the definition of development vectors; sociological methods – to take into account the mental component of the Ukrainian people, which is a defining characteristic of the development of the social system, in particular the agricultural sector.

Using these approaches, we will form a prognostic model of agriculture (Fig. 5).

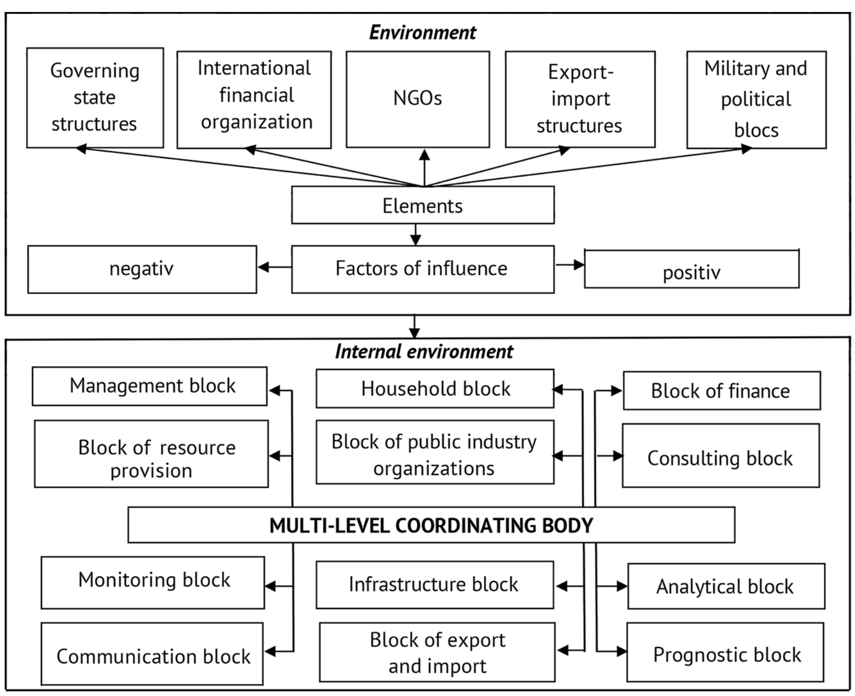

Figure 5. *Predictive model of AIC*

Source*: developed by the authors*

When developing the model, the shortcomings of the functioning of the pre-war model were taken into account, in particular:

– lack of state support. Thus, budget expenditures in individual European countries in 2019 amounted to (million euros): Turkey – 7,034, Poland – 2,693, Italy – 2,486, Denmark – 610, Bulgaria – 578, which compared to 540 in Ukraine, are significantly larger. therefore, it is expedient to increase it [29];

– incompleteness of strategic documents regarding development vectors [30-32]. Evaluating the acts that regulate the functioning of the agro-industrial complex, we note that they do not have defined timelines, guidelines for strategic development, permanent monitoring, scientific support, and sufficient budget funding [33; 34]; insufficient pragmatic justification, which does not contribute to the effective management of agribusiness structures [35; 36]. We also note that in these and other legal acts there is a vague demarcation by hierarchy and meaning: strategic – (relevant long-term strategies); basic – national level of agro-industrial complex (Codes); regarding the development of certain industries – Concepts; operational response – Resolutions of the CMU; current functioning – Decisions of ministries, departments, local authorities. As one of the examples, we note that in direction 9. "Agro-industrial sector and food industry" of the National Economic Strategy for the period until 2030 [37] certain problems are highlighted, certain wishes are expressed regarding the development of the agro-industrial complex industries, but without a clear responsibility of officials due to deadlines, adequate budgetary support, etc. This situation regarding the legal support of the domestic agricultural industry in general, and its branches in particular, is due to organizational problems, in particular, the lack of involvement of relevant scientific institutions, specialized public organizations, and analytical agencies, therefore further improvement of this base is proposed;

– the lack of permanent fruitful cooperation between the structures of the agricultural industry, therefore, in accordance with the principle of consolidation, the creation of a multi-level coordination body with appropriate powers, budget funding with the involvement of representatives of all participants of the agricultural industry is foreseen. The functions of this body should not be duplicated with the powers of relevant ministries, but in war and post-war conditions, such a need is relevant for the preparation and further implementation of current and strategic decisions. Note that the presence of coordinating, controlling, consulting independent bodies is inherent in developed agricultural countries. Thus, in Italy, an independent performance evaluation body functions and in monochrome form performs the functions of evaluating the activities of the Ministry of Agriculture, Food and Forest Policy (Organismo indipendente di evaluation della performance in forma monocratica) [38].

To determine the optimality of the forecast state of the agricultural industry model, we will use the following approaches:

– compliance of such a model with the main development vectors of the corresponding models in the leading agricultural countries. In this context, we note that the models in the mentioned countries have their own characteristics, but the problems of proper budget financing, food security, support of the domestic producer, basic resource provision, and organic production are solved much more effectively;

– the creation of powerful clusters at the local level, with basic administrative formations at the level of territorial communities, including agricultural commodity producers, a united agricultural cooperative, processing enterprises, logistics structures, trade networks, consulting services, financial structures, and an effectively functioning coordinating body based on the administration of territorial communities;

– dynamic growth of the GDP of agriculture and the corresponding volumes at hierarchical levels;

– overcoming the identified negative trends.

In the conditions of the current military aggression of Russia, it is difficult to make a predictive assessment of the state of the agricultural industry of Ukraine, however, certain adjustments are made after it ends.

Taking into account the identified shortcomings in the proposed model, if appropriate, appropriate adjustments are made and a working model of the agro-industrial complex is formed. Considering that Ukraine is now in a state of future uncertainty due to significant economic, military, political, demographic, etc. factors, it is necessary to take this into account when forming the working model of the agricultural industry. It should be noted that modern economic and mathematical methods, with a certain degree of probability, make it possible to determine this, in particular, using the theory of decision-making under conditions of uncertainty and applying known approaches, in particular – Chebyshev's inequalities or the criteria of Laplace, Wald, Savage, Hurwitz, Hodges-Lyman, etc. [39; 40].

In order to ensure the effectiveness of the proposed working model of agriculture, the conditions of its implementation play a significant role. In this context, we will present relevant proposals at the level of state management and the views of individual specialists.

One of the areas of implementation of this model is the Decree of the President of Ukraine No. 266/2022. dated April 21, 2022, "Questions of the National Council for the Recovery of Ukraine from the Consequences of the War", which provides for the creation of such a body [41]. The authors note that the intended functioning of such a body correlates with proposals for a multi-level coordinating body of the agricultural sector.

His own vision of the post-war recovery process, which is also related to the agricultural sector, was presented by the chairman of the board of the Institute of Economic Research and Political Consultations I. Burakovsky during the conference in Warsaw on April 28, 2022 "After the war. Rethinking the future of civil society", where he noted; "The war took more than 50% of Ukraine's GDP, and in order to compensate for these losses, the economy must grow by 15% annually for 5 years, by 7% for 10 years. Today, the question of recovery is considered from the point of view of terms (time), funds (financial needs) and sources of financing (aid from the international community, reparations, etc.). The post-war recovery of Ukraine will require enormous efforts from both the authorities and society. In particular, civil society should promote the establishment of regular, honest and responsible dialogue between citizens and the authorities, as well as offer effective solutions to relevant problems. The effectiveness of post-war recovery directly depends on how effectively the state will work as a manager of the recovery project" [10].

Determining the future of the post-war model of Ukraine, in particular its structural component of the agricultural sector, economic consultant V. Novikov expressed the following assumption: "If we look at the Ukrainian situation from the perspective of the Marshall Plan, then the restoration of its economy in its pre-war form will mean the preservation of its agrarian raw materials, which makes Ukraine the poorest country in Europe. Therefore, from the point of view of the economic structure, we do not need the Marshall Plan, we need to change, not preserve, the structure of the economy. In other words, we need an "Anti-Morgenthau Plan", that is, a plan for the transition from an agrarian-raw material to a technological economy" [9].

Regarding the intellectual support of the recovery process, the Chairman of the Board of Transparency International Ukraine, A. Vyshnevsky, expressed his opinion in a reasoned way: "Today is a unique historical moment, when the President of Ukraine has the moral right and objective reasons to turn to such people as Gregory Mankiw for intellectual help. Saskia Sassen, Edward Glaser and many other outstanding thinkers of the world scale" [8].

The role of economic scientists in individual countries had a positive effect, which consisted in the rapid recovery of the country from military destruction, the transition to an innovative path of development, it is enough to mention their role in the formation of new economic models. This is L. Erhard – the author of the "German miracle" in post-war Germany [42], V. Leontiev in the 70-80s ("Asian tigers" – Hong Kong, South Korea, Singapore, Taiwan) [43], who advised the governments of these countries, L. Baltserovych – who in the late 1990s formed a market model of the economy in Poland [44].

Evaluating these views, it is determined that it is worth listening to the advice of foreign consultants, taking into account their experience, but Ukrainian scientists should develop their own model, since they are the bearers of the national mentality, feel the importance of the problem and are able to develop appropriate projects. In this context, we will present the opinion of the well-known Ukrainian scientist I. Lukinov, expressed at the beginning of the present century: "To bring the country's national economy out of a state of crisis, the formation of a scientifically based Ukrainian doctrine and the concept of its economic development, which belongs to our scientists together with practical workers, is of great importance to develop as soon as possible by own efforts, without waiting for Western advisers and consultants to do it" [45, p. 10].

CONCLUSIONS

Revival of the agricultural industry destroyed by the war is a complex and long-term process, given the extent of the destruction, the departure of workers outside of Ukraine, financial problems, etc., and that is why it requires the efforts of the entire society. The task of Ukrainian scientists is to propose theoretical constructions and practical mechanisms for such recovery, and in this context, the development of a model of the post-war development of Ukraine's agricultural industry is an important national task.

Using the developed research algorithm with the application of systemic and synergistic approaches and methods of comparisons, formalization, economic analysis, a prognostic model of the agricultural industry of Ukraine was formed. In the process of developing this model, a thorough analysis of the potential of the agro-industrial complex was carried out, with an assessment based on the criteria of the area of agricultural land, the productivity of the specified complex, and export-import operations. For the theoretical and pragmatic formation of the model: the hierarchy of the agricultural industry of Ukraine was clarified; the functional component structures of the agro-industrial complex are substantiated; the expediency of applying six principles is emphasized; the strength of the influence of negative factors on the potential of the agro-industrial complex in the cost calculation is analytically determined. Considerable importance was attached to the comparison of the state of the agricultural industry of Ukraine with other countries. Thus, the comparison of the percentage ratio of the Ukrainian crop and livestock industries, where it is 79% and 21%, respectively, is unproductive, compared to the weighted average in the EU countries, where this ratio is 57% to 43%. Significant differences were revealed in the comparative analysis of the main agro-food indicators of Ukraine and Poland for 2020, where, with the area of agricultural land in Ukraine 2.26 times larger, the plowed land – 1.47 times, we have almost comparable GDP volumes of this complex, and the export of agro-food production is only 55.9%.

The scientific result of the research has theoretical and practical significance. The theoretical part consists in the development of the theoretical and methodological basis of the prognostic model of the agricultural industry of Ukraine, and the practical part – in the possibility of applying the components of this model at the regional and local levels. We should also note that the prognostic and financial concept of this model is a significant contribution to the solution of an important task at the national level and should contribute to the processes of revitalization of the agricultural industry of Ukraine in new social conditions, taking into account the European choice of Ukraine.

Taking into account the relevance of this issue for the near future of the agricultural industry, it is expedient to continue research highlighting the specifics of the development of industries, financial support, and increasing the level of processing of agricultural raw materials.

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Модель післявоєнного розвитку агропромислового комплексу України: прогностично-фінансовий концепт

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Анотація. Стаття присвячена формуванню післявоєнної моделі розвитку агропромислового комплексу України. Актуальність теми полягає у визначенні засобів відновлення та подальшого розвитку агропромислового комплексу з відповідним обґрунтуванням пропонованої моделі, що сприятиме вирішенню проблем забезпечення продовольством українських та зарубіжних споживачів. Зважаючи на специфіку дослідження, основним методом вибрано системний, що забезпечує комплексність виконання дослідження. Поряд із ним використано методи порівнянь, формалізації, економічного аналізу, які дають змогу доповнити та розширити обсяги дослідження для отримання науково обґрунтованого результату. Метою статті є обґрунтування прогностично-фінансового концепту відновлювальної моделі АПК України у післявоєнний період. У статті проаналізовано передвоєнний стан агропромислового комплексу за основними критеріями та виявлено причини неефективного використання його потенціалу. Здійснено порівняння ефективності сільськогосподарського виробництва за показником доданої вартості в Україні із такими країнами як Польща, Бразилія, Німеччина, Франція, де було виявлено суттєве відставання України. Також наголошено на незначній частці української сільськогосподарської сировини, яка направляється на промислову переробку, що значно знижує обсяги добавленої вартості. Зважаючи на важливість впливу чинників зовнішнього середовища у теперішній час на функціонування агропромислового потенціалу, подано аналітичне обґрунтування цього впливу у вартісному обчисленні. Використовуючи системний метод, запропоновано алгоритм розробки зазначеної моделі, обґрунтовано ієрархію та структуру розвитку цього комплексу, визначено шість принципів, розроблено наукові підходи щодо формування прогностичної моделі післявоєнного розвитку зазначеного комплексу у експериментальному і робочих варіантах та висвітлено умови її впровадження. Наукова новизна статті полягає у розробці теоретичних положень, які в сукупності дали змогу запропонувати прогностичну модель розвитку агропромислового комплексу України у післявоєнний період, що буде сприяти відновленню та подальшому розвиткові всього зазначеного комплексу із стійким забезпеченням національної продовольчої безпеки

Ключові слова: агропродовольчий потенціал, прогностична модель, структура АПК, чинники впливу

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