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Resource efficient and erosion preventive integrated high- and lowland aggregate

Jemal Katsitadze, Zaur Phutkaradze, Georgi Kutelia

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Abstract: The article proposes a fundamentally new design of a resource-saving, anti-erosion unit that significantly improves the quality of soil tillage in cultivating agricultural crops, improves the productivity of the plow, significantly eliminates soil erosion and reduces the fuel consumption of the tractor by reducing the traction resistance.

The construction of the unit and the principle of its operation are described in detail. It can be successfully used both in plain and in mountainous terrain.

Characteristic similarity criteria and a criterion equation for studying the traction force of the proposed unit are obtained and their physical meaning is revealed

KEYWORDS: SOIL EROSION, UNIT, PRODUCTIVITY, FUEL CONSUMPTION, MECHANIZATION, SIMILARITY CRITERION, CRITERION EQUATION.

It is known that at basic tillage with common ploughshare is created the dense bottom surface of the soil that can hold water and causes water erosion. As a result, the crop productivity and soil looseness quality are reduced.

Based on the results of the research conducted it is determined that the primary tillage with chisel plow completely or significantly avoids the cultivated soil erosion phenomenon on the slopes. Due to high pressure area on the chisel ploughshare surface, the soil bottom dense layer is completely destroyed and break surface is formed which allows to penetrate in greater depth and to maintain soil humidity that contributes to better development of the root system and sharp increase of crop yield. Due to the received results it is defined that by using the mentioned tillage method the crop yield of the corn is by 35% higher than at tillage by common ploughshare [1,2,3]. It is also known that productivity of smooth tillage plough is 23-43% higher than the mould board-double furrow tillage ploughs, fuel consumption is reduced by 28-39%, and area of cultivated land is higher by 7 - 8% [4].

Problem is rather important and essential as the large part of agriculturally used areas in Georgia are located in small contour areas and slanting slopes that stipulates the advisability of mention areas tillage by chisel plough.

Novelty of the question lies in the fact that there will be developed completely new component insertion construction of resource efficient and erosion preventive integrated high - and lowland agricultural aggregate which is registered with the National Intellectual Property Centre "Sakpatenti"[5, 6]. The basic essence of this aggregate is that it has a frame, chisel poles with attached abutments and ploughshare and plough wings. The chisel poles are installed frontally on the frame crossbar, while the plough wings are symmetric and are installed sequent on rotational beam jointly connected with rear frame of chisel poles. In addition, with the aid of hydro-cylinder, the beam has the possibility of rotating around the connected with the frame juncture (Fig. 1 and 2).

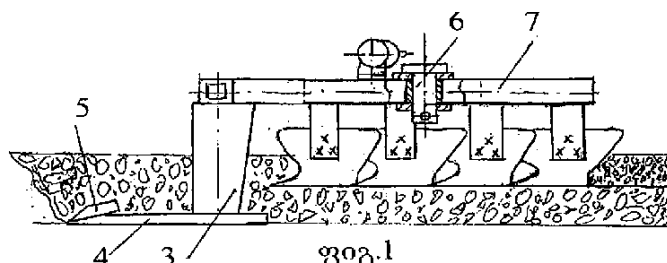


Fig. 1

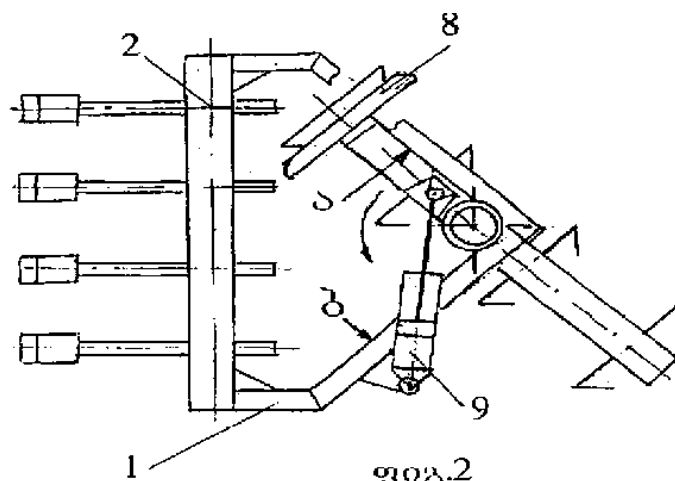


Fig. 2

1. Frame; 2. Crossbar; 3. Chisel pole; 4. Abutment; 5. Plough-share;
6. Joint;
7. Rotational beam; 8. Plough symmetrical wing; 9. Hydro-cylinder.

Constructional novelty of the offered aggregate lies in the fact that chisel poles with abutments and ploughshare are rigidly attached to the frame crossbar, while the chisel plough symmetrical wings are successively located behind chisel poles and are installed on the rotational beam.[5,6]

The plough's symmetric wings are working both in left and in right positions through turning rotational beam with the aid of hydro-cylinder, thus it is carried out the upper productive soil layer turn-over by smooth tillage principle that significantly improves the quality of tillage, increases capacity and reliability of the aggregate, decreases erosive processes and the tillage time, reduces fuel consumption.

Scientific and engineering innovation of the tasks set is the technology concept of functioning of the offered aggregate, its completely new constructional compatibility that stipulates the innovative approaches to execution of works and coping with the challenges stated in, aggregate appropriation, application area, working conditions and determination of stated technical requirements in accordance with its basic parameters and technical performances.

To study the performance of this unit, we used the theory of similarity and variability, which allows you to plan targeted experiments in advance and take into account the simultaneous influence of various factors on the parameter being studied. Based on the analysis of literary sources [7,8,9], we established the main factors that significantly affect the performance of the unit (tab. 1)

Table .1: The list of factors affecting the performance of resource-saving anti-erosion unit

#	Optimization parameter and factors	Designation	Dimension in SI system	Dimension expressed by symbols of values
1	Unit Performance	W	m ² /s	L ² T ⁻¹
2	Working width	B	m	L
3	Processing depth	h	m	L
4	Soil resistivity	K	n/m ²	ML ⁻¹ T ⁻²
5	Plowing speed	V	m·s ⁻¹	LT ⁻¹
6	Traction force	P	n	MLT ⁻²

The functional dependence between the optimization parameter and factors acting on it has the form:

$$W = f(B, h, K, V, P) \dots \quad (.1)$$

This dependence can be expressed in the form of similarity criteria. We use the π – theorem for this:

$$r = N - n = 6 - 3 = 3$$

r - is the number of criteria, N - the number of factors, n – the number of main factors. We choose B, V and P as the main factors. Their dimensions are:

$$[V] = LM^0T^{-1}$$

$$[B] = LM^0T^0$$

$$[P] = LMT^{-2}$$

The determinant of powers of their degrees must not be equal to zero.

$$D = \begin{vmatrix} 1;0;-1 \\ 1;0;0 \\ 1;1;-2 \\ D = -1 = 0 \end{vmatrix}$$

The similarity criteria are equal:

$$\pi = WV^\alpha B^\beta P^\gamma = 1$$

$$\pi_1 = hV^{\alpha_1} B^{\beta_1} P^{\gamma_1} = 1$$

$$\pi_2 = K_1 V^{\alpha_2} B^{\beta_2} P^{\gamma_2} = 1$$

$$WV^\alpha B^\beta P^\gamma = L^2 T^{-1} L^\alpha T^{-\alpha} L^\beta T^\gamma M^\gamma T^{-2\gamma} = L^0 T^0 M^0 = 1$$

We obtain the linear equations:

$$2 + \alpha + \beta + \gamma = 0$$

$$-1 - \alpha - 2\gamma = 0$$

$$\gamma = 0$$

Their solution results in: $\alpha = -1$; $\beta = -1$; $\gamma = 0$

Therefore, the similarity criterion to be determined is equal:

$$\pi = \frac{W}{BV}$$

Similarly, we obtain the other determining criteria:

$$\pi_1 = \frac{h}{B}; \quad \pi_2 = \frac{KB^2}{P};$$

The standard form of the criterion equation has the following mathematical expression:

$$\pi = \varphi(\pi_1, \pi_2, \dots) \quad (2)$$

$$\text{or} \quad \frac{W}{BV} = \varphi\left(\frac{h}{B}, \frac{KB^2}{P}\right) \dots \quad (3)$$

The obtained criterion equation is the basis for the purposeful designing; we have designed trials according to it. The functional dependencies between the similarity criteria have the form

$$\frac{W}{BV} = c\left(\frac{h}{B}\right)^x;$$

$$\frac{W}{BV} = c_1\left(\frac{KB^2}{P}\right)^{x_2};$$

After taking of logarithm of the obtained expression and summing we will obtain:

$$2lg \frac{W}{BV} = lgc + lgc_1 + xlg \frac{h}{B} + x_1 lg \frac{KB^2}{P}$$

We take antilogarithms of the latter expression and obtain:

$$\frac{W}{BV} = A\left(\frac{h}{B}\right)^a \left(\frac{KB^2}{P}\right)^b \dots (4)$$

$$\text{where} \quad A = \sqrt{c \cdot c_1 \cdot c_2};$$

$$a = \frac{x}{2}; \quad b = \frac{x_1}{2};$$

Constant coefficients c, c_1 and exponents x, x_1 characterize the simultaneous influence of individual factors on the performance of a resource-saving anti-erosion aggregate

Findings

1. A fundamentally new design of a resource-saving, anti-erosion aggregate is proposed, which significantly improves the quality of soil cultivation when cultivating crops, increases the productivity of the plow, significantly eliminates soil erosion and reduces tractor fuel consumption by reducing traction resistance.
2. The unit we offer can be successfully used both on the plain and in mountainous terrain.
3. Characteristic similarity criteria and a criterion equation for the study of the proposed unit are obtained and a technique for targeted experiments is developed.

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The analysis of power expenditure of a wide-cut seeder for the performance of the technological operation

Aduov Mubarak Aduovich, Nukusheva Saule Abaidildinovnacand, Kaspakov Esen Zhaksalikovich, Isenov Kazbek Galimtaevich, Volodya Kadirbek, Tulegenov Talgat Konisbaevich, Uteulov Kanat Tolekbergenovich
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Abstract: During the operation of the tractor unit in field operations, not all the power developed by the tractor engine is effectively spent on useful work.

To use the tractor power effectively, reduce or eliminate its useless losses, the article considers the tractor power balance, showing the distribution of effective power among the individual components for traction and driving their working details.

According to theoretical studies, it was found that the traction resistance of a wide-seeder with clutch openers consists of two components; this is the resistance of the hopper to movement and the resistance of the filling part

It was found that traction resistance will decrease as the hopper empties. The pulling resistance of the embedment is made up of several components, with the maximum permissible working speed of the unit, the maximum embedment depth and the highest seed sowing rate, the required power to perform the sowing process is obtained within 120 kW (163, 155 h.p), excluding the tractor power for raising or lowering the side sections of the sealing part. The total power consumption is distributed as follows: 90,8% to overcome the traction resistance of the wide seed drill, 9,1% for the fan hydraulic drive, and the remaining 0,1% for the electric meter.

To reduce the amount of required power for the sowing process, it is necessary to work in the direction of reducing the seeder mass and improving the design parameters of working coulters.

KEY WORDS: SEEDER, TRACTOR POWER, TRACTION RESISTANCE, SOWING, WORKING BODIES.

The seeders of domestic production currently used in the Republic of Kazakhstan are morally and physically outdated, and today their production has been discontinued. Foreign sowing complexes supplied to Northern and Central Kazakhstan do not fully meet the agro engineering requirements for sowing in our zone. In addition, they are usually metal-intensive, energy-intensive and expensive. In this regard, we developed a wide-spread seeder that would meet the quality indicators of work and meet the needs of farmers in our country, affordability and quality of sowing [1, 2].

Our wide-spreader seeder consists of a sowing and seeding part, Figure 1 [3]. To conduct an energy assessment of a wide-seeder, we determine the power to perform the technological operation of sowing. The effective power of the tractor engine, during the operation of the tractor unit, is spent on overcoming various resistances. The equation showing the dependence of the required effective engine power on the resistance overcome by the tractor is called the power balance equation [4]. When using a tractor in field operations, not all the power developed by the engine, which is called effective, is spent on useful work.

To use the tractor power effectively, to reduce or eliminate its useless losses, we consider the tractor power balance, showing

the distribution of effective power among the individual components. In order to assess and determine correctly the fraction of power that can be used to pull the machine and drive their working bodies [5].

It should be noted that with the tractor moving uniformly, the following power losses occur:

- in a power transmission - to overcome the frictional forces in bearings, gear teeth of gearboxes and other components of the power transmission, as well as to shake the oil;
- to drive mechanisms that ensure the normal operation of the tractor, in particular power steering, etc.;
- on self-movement of the tractor;
- on slipping of a running gear;
- in the presence of lifting of tractors and losses to overcome it.

All of the above power losses are expended for the operation of tractor components. The remainder of the effective power is used to complete the sowing process.

Figure 1 shows a wide- cut seeder and its working bodies.

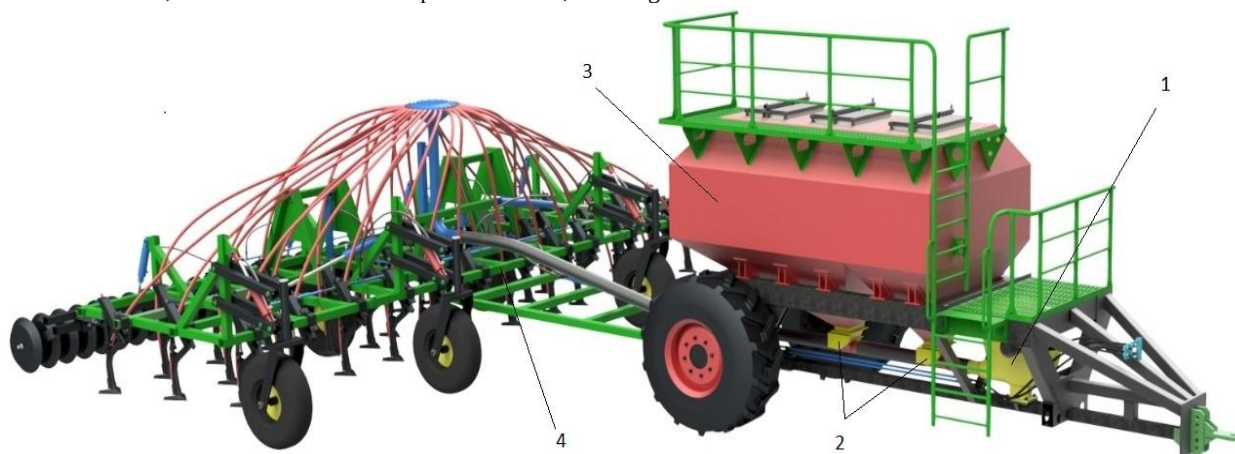


Figure - 1. Wide-cut seeder: 1 - hydraulic drive of the air system, 2 - electric drive of sowing devices, 3 - hopper for seeds and fertilizers, 4 - close-up part of the seeder.

The power balance equation of the backfill part of the wide- cut seeder, which will perform the technological operation, is presented in the following form:

$$N_{total} = N_{tract} + N_{fan} + N_{seeding} \quad (1)$$

kW; where, N_{total} - is the total power required to carry out the technological operation, kW;

N_{tract} - is the power spent on overcoming the traction resistance of the wide-cut seeder, kW;

N_{fan} - is the power required for hydraulic drive of the wide-cut seeder fan, kW;

$N_{seeding}$ - is the power required for the electric drive of the sowing apparatus of the wide-spread seeder, kW.

According to theoretical studies, the traction resistance of a wide-seeder with clutch openers consists of two components; this is the resistance of the hopper to movement and the resistance of the filling part, which is calculated by the following formula [6]:

$$R_{ws} = R_{tank} + R_{embed}$$

- traction resistance of the hopper to movement; R_{embed} - traction resistance of the embedding part.

The traction resistance of the drill hopper can be found by the formula below:

$$R_t = G_b * f \quad (3)$$

Where, G_b - is gravity of the full hopper; f - is coefficient of resistance to movement on the soil prepared for sowing (0,12).

Note: traction resistance will decrease as the hopper empties.

The traction resistance of the embedding part consists of several components, and is solved by the following formula:

$$R_{embed} = R_{roller} + R_{coulter} + R_r \quad (4)$$

Where R_{roller} - is the traction resistance of the roller, kN; $R_{coulter}$ - is the traction resistance of the coulter section, kN; R_r - is the traction resistance of the seeder for rolling, kN.

If you substitute all the components in the formula, the final formula can be obtained in the following form [6]:

$$R_{ws} = G_{\delta} * f + \sqrt[3]{\frac{D^4}{B * q * d^2}} + ab(0.5 * m_v * A_{\chi} * A_1 * \gamma * a * g + m_v * A_{\chi} * A_1 * C * \cos \varphi + A_{\theta} * \gamma_p * v^2)n + G_c * f \quad (5)$$

The power consumed to overcome the traction resistance of the wide-cut seeder is defined as the sum of the traction resistance, kN, to the operating speed, v_p , m / s:

$$N_{tr} = R_{ws} * v_p \quad (6)$$

The power required for the hydraulic drive of the wide-cut seeder fan depends on the working pressure P_p , Pa created by it, the displacement of air Q_{air} , m^3 / s , and the efficiency η . The efficiency of radial fans: 0,4 ... 0,7 [7].

According to aerodynamic calculations, the total pressure of the acquired radial fan at the outlet is about 2500 Pa, the maximum air flow rate developed by the fans is 41 m / s, and the transported air volume is about 2,2 m^3 / s .

To calculate the power required for the hydraulic drive of the fan, the following formula is used:

$$N_{fan} = P_p * \frac{Q_{air}}{\eta} \quad (7)$$

The use of an electric drive for sowing devices reduces the cost of maintaining the machine due to the lack of drive chains and shafts. An optional electric drive contributes to an even distribution of seeds in the soil and maximizes yield when sowing on various field surface reliefs.

To calculate the drive power of the sowing apparatus, we experimentally determined the torque on the shaft of the sowing apparatus at the maximum seed rate of grain crops. Then the required power is determined from the following expression:

$$N_{seed} = M_{seed} * \omega_{freq} \quad (8)$$

Where M_{seed} - the maximum torque on the shaft of the sowing apparatus, n * m; ω_{freq} - is rotational speed of the metering unit shaft, s^{-1} .

The drive power of the metering unit can also be determined by the formula

$$M_{seed} = U_r * I \quad (9)$$

Where U_r - is the operating voltage in the electric drive network, V;

I - is the magnitude of the current consumed by the electric motor, A.

From expressions (8) and (9) at the maximum sowing rate of seeds of grain crops and the rotational speed of the shaft of the sowing apparatus, we determine the largest amount of the consumed current.

The final equation of the power balance of the seeding part of the wide-seeder will be as follows:

$$N_{tot} = (G_{\delta} * f + \sqrt[3]{\frac{D^4}{B * q * d^2}} + ab(0.5 * m_v * A_{\chi} * A_1 * \gamma * a * g + m_v * A_{\chi} * A_1 * C * \cos \varphi + A_{\theta} * \gamma_p * v^2)n + G_c * f)v_p + P_p * \frac{Q_a}{\eta} + U_p * I \quad (10)$$

This equation does not take into account the tractor power, which is used to raise or lower the side sections of the filling part, that is, the power that brings the wide- cut seeder to the transport or working position.

From equation (10) at the maximum permissible operating speed of the unit, the maximum depth of seeding and the highest rate of sowing seeds, the necessary power to perform the technological process, the sowing is obtained within 120 kW (163, 155 h.p).

Of the total power, 90,8% is accounted for by the power that is used to overcome the traction resistance of the wide- cut seeder, and 9,1% by the hydraulic drive of the fan, and the remaining 0,1% by the electric drive of the sowing device.

To reduce the amount of required power for the sowing process, it is necessary to work in the direction of reducing the seeder mass and improving the design parameters of working coulters.

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Assessment of negative impact of agricultural mobile energy means and euro-5 standard

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Abstract: Environmental problems today are one of the most important and global indicators of human development. One of the consequences of the impact of agricultural machinery on natural resources is their pollution due to loss of fuel and lubricants and engine waste. The purpose of the research is to develop scientific and methodological bases for the selection of criteria for assessing the environmental safety of the diesel engine of an energy vehicle with the creation of an environmental safety management system. The scientific and methodological basis for assessing these factors is a systematic approach to solving environmental problems that arise during the operation of machine-tractor units and other agricultural energy resources. Estimation of the level of emissions of the main pollutants and toxic substances in exhaust gases can be defined by means of the regulatory characteristic of the engine depending on an operating mode of this engine. The optimal mode of operation of the engine YaMZ-236M2, from an environmental point of view, adopted 1450...1850 rpm. In this case, fuel consumption does not increase in this mode. It is possible to reduce the emissions of the most significant NOx exhaust element by limiting the engine speed to 90% of the nominal. CO and CH emissions at a given engine speed have not reached their maximum value.

KEY WORDS: MACHINE-TRACTOR UNIT, EXHAUST GASES, POLLUTION, ENGINE, OPTIMUM, TRACTION CHARACTERISTICS, ECOLOGICAL SAFETY

1. Introduction

Environmental problems today are one of the most important and global indicators of human development. Modern scientists and practitioners note that human impact on the ecosystem has reached such a scale that natural regulatory mechanisms are no longer able to independently neutralize this negative impact.

Objects of agricultural production have a negative chemical, biological, physical and mechanical impact on all major components of the environment: soil, water and air.

Thus, agricultural production in ecological terms causes the manifestation of some processes, which are expressed in the pollution of surface and groundwater, soil erosion and degradation of natural landscapes. Agricultural facilities are livestock farms, agricultural lands, technologies, technical means used in the production and processing of products, transport, warehouses, storage facilities, energy facilities, repair and storage sites. The cause of environmental pollution is emissions of harmful substances from mobile sources and stationary facilities of the agro-industrial complex, including livestock, processing and repair and maintenance enterprises.

Intensive technologies are increasingly used in agricultural production, which include multiple passes through the field of powerful and heavy machine-tractor units (MTU), combine harvesters, technological trucks and mobile vehicles. All this leads to an imbalance of the natural environment.

At the same time, the negative impact of MTU occurs in the following areas: exhaust emissions of internal combustion engines, soil compaction and destruction of its structure as a result of the impact of the running systems of mobile energy resources and tillage implements.

In the twentieth century, the degradation of the fertility of the land fund became an objective factor. The amount of humus decreased by 25%. At present, the amount of humus in the soils of Ukraine varies from 3.5% to 3%, which is 1...2% below the optimum. All the above leads to a decrease in crop yields by 15...20%.

There is a real danger of disturbing the natural and ecological balance (ecosystem) from the deterioration of soil structure, wind and water erosion, pollution of water bodies (water sources) with toxic substances, residues of mineral fertilizers and pesticides.

High density leads to deterioration of physical and biological properties of the soil, it complicates the penetration of roots into the lower horizons and moisture, nutrients remain inaccessible to plants, deteriorating living conditions of microorganisms.

One of the biggest factors of environmental pollution is the tractor fleet [2].

One of the consequences of the impact of agricultural machinery on natural resources is their pollution due to loss of fuel and lubricants and engine waste.

To prevent this negative impact, it is necessary to equip machine yards with washing machines, oil filters for wastewater treatment from oil impurities; timely and at a high technical level to conduct technical inspections, current and major repairs that would prevent the leakage of oils and fuels; correctly regulate fuel equipment and ignition of technical means, tanks with oil products to be installed underground, which in comparison with ground placement significantly reduces losses due to evaporation. Control over engines and fuel systems should be strengthened by regulating the supply of fuel and lubricants, preventing it from leaking.

Table 1. Exhaust gas components and their content [2]

Component	Chemical formula	Amount, %
Nitrogen	N_2	74
Oxygen	O_2	10
Carbon dioxide	CO_2	7
Water vapor	H_2O	5
Benzopyrene	C_2OH_{12}	1.771
Soot	PM	1
Nitrogen oxides	NO_x	0.5
Carbon oxides	CO	0.4
Hydrocarbons	CH_x	0.3
Sulfur oxide	SO_2	0.02
Aldehyds	R_xCHO	0.009

All this requires a comprehensive consideration and solution of this economic problem [5, 6]. However, its implementation is almost impossible without solving the relevant scientific and technical problem. Its essence is a comprehensive study and assessment of the impact of MTU on the environment and the development of environmental criteria to manage environmental safety in the operation of MTU.

The purpose of the research is to develop scientific and methodological bases for the selection of criteria for assessing the environmental safety of the diesel engine of an energy vehicle with the creation of an environmental safety management system.

2. Preconditions and means for resolving the problem

When performing mechanized technological processes in agricultural production, agricultural units are one of the main objects of negative impact on the environment. At operation of cars distinguish the following indicators of ecological safety:

a) exhaust emissions through the exhaust pipe of a tractor or agricultural machinery. Exhaust gases (or exhaust gases) - the main source of toxic substances in the internal combustion engine - is an

inhomogeneous mixture of various gaseous substances with different chemical and physical properties, consisting of products of complete and incomplete combustion of fuel, excess air, aerosols and various micro-impurities (as gaseous, and in the form of liquid and solid particles) coming from the engine cylinders into its exhaust system. They contain about 300 substances, most of which are toxic. The main normalized toxic components of engine exhaust gases are oxides of carbon, nitrogen and hydrocarbons. In addition, with exhaust gases into the atmosphere enter the limiting and non-limiting hydrocarbons, aldehydes, carcinogens, soot and other components.

b) acoustic effects (external and internal noise (in the driver's cab) generated by the tractor (agricultural machine). High noise load not only causes functional disorders of individual body systems, but also leads to an increase in the incidence of cardiovascular, nervous and other diseases. Prolonged noise adversely affects a person, causing headaches, dizziness, diseases of the nervous and cardiovascular systems, dysfunction of the gastrointestinal tract and metabolic processes in the body.

c) specific pressure on the ground of the machine engines. The problem of soil compaction in recent decades has been put forward as one of the first places in a number of anthropogenic impacts on the environment. Overcompaction leads to the strengthening of the main anthropogenic factor of soil and landscape degradation - water and wind erosion. Soil compactions containing little organic matter are most prone. During irrigation, high-humus chernozems will be compacted. The main reason for soil compaction is the high man-made load on them against the background of intensive degumification of the arable horizon. Agrotechnical, organizational-technological and technological measures are used to reduce the negative consequences of overcompaction [4].

d) vibrations on the steering wheel and on the seat of the tractor operator (machine). In agricultural production, the sources of vibration are mobile units used in the repair of technological equipment, as well as mechanized tools. Prolonged exposure to vibration on the body leads to disorders of the nervous system, changes in blood vessels and the vestibular apparatus. Local vibration affects the neuromuscular and musculoskeletal system, leads to spasms of peripheral blood vessels [7].

e) leakage of engine, transmission and hydraulic oil, diesel fuel, coolant;

f) CO content in the air of the working area of the tractor operator or agricultural machine (cab tightness).

Introduction of the environmental safety factor of MTU operation. The scientific and methodological basis for assessing these factors is a systematic approach to solving environmental problems arising from the operation of MTU and other agricultural energy resources.

Currently known [1, 2, 3] studies that consider the impact of technology on soil degradation, as well as work [1] that studies the deterioration of environmental safety from harmful emissions of internal combustion engines.

The generalized environmental safety factor (GF_{es}) [1] from the impact of MTU can be assessed by five categories of environmental safety (ES) of tractors and agricultural machinery:

1) Higher or promising. Environmental safety factor ($GF_{es} < 0.90$). MTU on the basis or on the majority of indicators satisfies values of perspective or international norms. Suitable for use;

2) Good ($GF_{es} < 0.95$). MTU meets all environmental requirements of domestic standards. Promising for internal use;

3) Satisfactory ($GF_{es} < 1.2$). MTU can be used in the production of agricultural products. In the future it is subject to modernization;

4) Unsatisfactory ($GF_{es} = 1.2$). MTU is not to be used. Urgent modernization or its removal from work is required, after emergence of the corresponding replacement for this unit;

5) Inadmissible ($GF_{es} > 1.2$). Urgent exclusion of MTU from production is required.

When designing an MTU, it may be necessary, only for environmental indicators, to determine the possibility of implementing or not new technical solutions for this unit. To do

this, it will be necessary to use a comprehensive environmental assessment for five categories of environmental safety.

Environmental Euro standards for harmful emissions of exhaust gases from internal combustion engines.

In the 1990s, European environmentalists sounded the alarm. In the cities of the old world, the content of harmful substances emitted by cars rose sharply, which became more and more every day. Europeans have become hostages of urbanization, and their futures have become increasingly hazy, as has the air in cities. The UN was forced to act, and set up a commission to assess the situation and find a way out. The results of the commission's assessment were not encouraging: emissions of hydrocarbons, nitrous oxide, carbon dioxide and heavy substances threatened to lead to very sad consequences in the near future.

"Euro" is an environmental standard that regulates the content of harmful substances in the exhaust gases of vehicles with diesel and gasoline engines. After all, car emissions include more than 200 different chemicals (carbon dioxide, sulfur dioxide, aldehydes, soot, lead compounds) that enter the environment. Some of them have a toxic effect.

The development, organization of production and introduction of new automotive fuel have always been the result of a compromise between motorists and refiners. Motorists formulated requirements for fuel performance based on the parameters of work processes developed by engines, and refiners tried to correlate the possibility of meeting these requirements with the technical capabilities of plants, the need to ensure fuel efficiency and complete use of hydrocarbons. To ensure the proper operation of car engines, gasoline and diesel fuels must meet a set of requirements based on their purpose, environmental safety and sustainability. Environmental requirements for the mobile vehicle and its engine are currently a priority. Ecological purity of an exhaust is put in a design of the engine and mobile means as a whole at design. Further in operation, the toxicity characteristics must remain stable. Toxicity regulation in modern car engines is in most cases either not required or severely limited. At the same time, in car engines of previous years of production, especially with carburetors, the toxicity of the exhaust is directly related to the technical condition of the power supply and ignition system and their regulation. Therefore, currently the repair of the engine, no matter how complex it may be, can not be considered qualified and high quality, if the toxicity of the engine exhaust after the repair exceeds the established permissible limits.

Until recently, Ukraine had a Euro-1 system that limited emissions of mobile substances from mobile vehicles. This has significantly strengthened environmental safety, although over time the number of vehicles on state roads has increased, and this has required stricter regulations. Ukraine's transition to the new Euro-2 standards has been implemented since January 1, 2006 in accordance with the Law of Ukraine "On Some Issues of Importing Vehicles into the Customs Territory of Ukraine". Euro-2 standards have tightened the requirements for the quality of fuel consumed by a mobile vehicle and for the content of harmful impurities in exhaust gases. According to the current legislation from 2010, all mobile vehicles at the first registration must comply with the environmental standards of "Euro-3", which will reduce emissions of carbon oxides and nitrogen oxides - by 40%, and carcinogenic solids - by 50%. From January 1, 2012, the requirements for vehicles have intensified, and imported and manufactured in Ukraine vehicles under commodity codes 8701 20, 8702, 8703, 8704, 8705 must comply with environmental standards not lower than the level of "Euro-4".

State Committee for Technical Regulation and Consumer Policy (№ 244 of October 3, 2007) new national standards "Gasoline for high-quality cars" and "High-quality diesel fuel" came into force in Ukraine on January 1, 2008, which fully meet the requirements "Euro-3" and "Euro-4". These standards regulate fuel standards, namely standard fuels contain five times less benzene, which is a strong toxic solvent, half the concentration of actual resins, which causes engine wear, and five times less sulfur, which

causes corrosion of metals. . But only a few domestic refineries are able to produce fuel of appropriate quality, so it is mainly imported.

With the signing of the agreement with the EU, Ukraine has committed itself that from January 1, 2016 in Ukraine will be banned the use of fuels that do not meet Euro-5 environmental standards.

This standard was introduced in Europe in 2009 and it prohibits import of cars that have been in use for more than 5 years.

Euro-4 is an environmental standard that regulates the content of harmful substances in the exhaust gases of cars, introduced in the European Union in 2005.

The Euro-4 certificate confirms the compliance of a car or any other vehicle with European environmental standards, the main indicator of which is the level of emissions of harmful substances - carbon dioxide, nitrogen oxides and hydrocarbons, etc. (Table 2).

Table 2. Toxicity standards for heavy-duty diesel engines, g/m³

Standard	Content in exhaust gases, g/m ³		
	NOx	CH	CO
Euro - 0	15.8	2.6	12.3
Euro - 1	8.0	1.1	4.45
Euro - 2	7.0	1.1	4
Euro - 3	5.0	0.66	2.1
Euro - 4	3.5	0.46	1.5
Euro - 5	2.0	0.46	1.5

In 2018, Euro-6 environmental norms should come into force in our country, which is provided by the latest version of the Law of Ukraine "On some issues of importation into the customs territory of Ukraine and registration of vehicles."

3. Results and discussion

Research of influence of a mode of work of the diesel engine on an example of the regulatory characteristic on indicators of ecological safety.

Ensuring environmental safety in agricultural production becomes especially important in connection with the constant development of the agro-industrial complex and, as a consequence, the strengthening of harmful effects on the environment. The technical condition of the internal combustion engine has an extremely strong influence on the carcinogenic hazard of the exhaust gases of mobile vehicles.

Also, the coefficient of ecological safety of mobile energy means is significantly influenced by the quantitative and qualitative composition of combustion products of the working fuel-air mixture, which is determined by the processes of fuel supply, mixing, evaporation, combustion, compression and expansion, and well-organized workflow. Each of the components of the exhaust gases has its own characteristics of the physical and chemical processes of formation and decomposition. Knowing the composition of exhaust gases, you can with a high degree of probability to analyze the nature of the combustion process. At the same time, CH emission characterizes the size of the flame extinguishing zones and the amount of fuel not involved in combustion, CO emission - the amount that did not fully react due to lack of oxygen in the oxidation zone, NOx emission - the volume of the combustion products zone with high temperatures. It should take into account not only the absolute values of the concentration of harmful substances in the exhaust gases, but also the nature of their changes depending on the mode of operation or regulation. For example, a decrease in NOx emissions with increasing load characterizes the moment of a sharp improvement in the mixture, which leads to a decrease in temperature in the combustion zone due to the intensification of the soot formation process, and to a lack of oxygen in the combustion products zone.

As we have defined earlier, the main pollutants and toxic substances that are subject to the strictest control include:

- Carbon monoxide (CO);
- Nitric oxide (NOx);
- Carbohydrates (CH).

To determine the amount of harmful substances in the environment, we accepted for analysis one of the most common in the south of Ukraine tractor series HTZ-170 with YaMZ-236M2 engine.

Estimation of the level of emissions of the main pollutants and toxic substances in exhaust gases can be defined by means of the regulatory characteristic of the engine depending on an operating mode of this engine. For clarity, you need to build a regulatory characteristic of the engine YaMZ-236M2. The corresponding required calculation parameters are presented in table. 3.

Table 3. Parameters for construction of the regulatory characteristic

n_d / n_n	1.06	1.03	1	0.9	0.8	0.7	0.6	0.5
Engine speed n_d , rpm	2226	2163	2100	1890	1680	1470	1260	1050
Engine power N_e , kW	0	60.75	121.5	124.74	116.75	105.4	91.7	76.25
Torque moment M , N·m	0	276.2	552.5	630.3	663.70	685.3	695.3	693.5
Fuel consumption G , kg/h	6.38	13.8	21.26	21.06	19.41	17.63	15.73	13.67
Specific fuel consumption g_e , g/kWh	455	227.5	175.00	168.87	166.25	167.125	171.5	179.37

Since we in the second section by approximation found the theoretical dependences of the change in the amount of CO, NOx and CH depending on the engine load, the total emissions are presented in table 4.

Table 4. Dependence of diesel engine emissions on its power

Engine power, kW	0	47.2	94.4	96.9	90.7	82.0	71.3	59.3
CO, g/m ³	1.110	1.288	1.823	1.862	1.768	1.648	1.516	1.391
CH, g/m ³	0.523	0.620	1.230	1.272	1.171	1.036	0.885	0.738
NOx, g/m ³	0.250	2.539	2.278	2.103	2.496	2.852	3.014	2.898

Using a computer and Excel, you can present the control characteristics of the diesel engine with graphs of CO, NOx and CH emissions (Fig. 3.1 - 3.4).

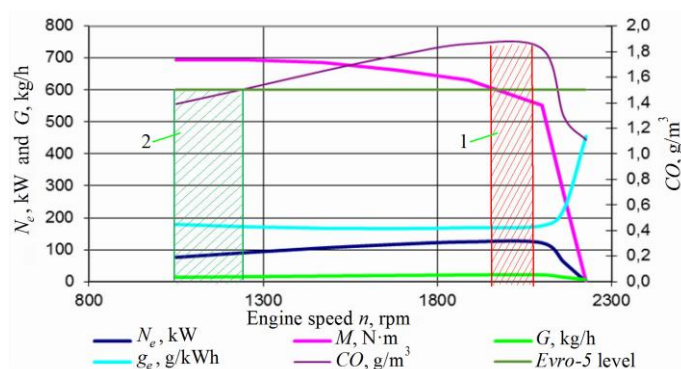


Fig.1. Dependence of CO emissions on engine operation mode: 1 - the range of maximum CO emissions; 2 - the range of permissible CO emissions according to the environmental safety standards of Euro-5

In fig. 1 shows the area in which the engine operation mode is shown: its power, speed, fuel consumption, which meets the environmental standard Euro-5 for CO, also shows the range of maximum carbon monoxide emissions. Received a mode of operation of the tractor engine up to 1250 rpm, where its carbon monoxide emissions meet the standard of environmental safety.

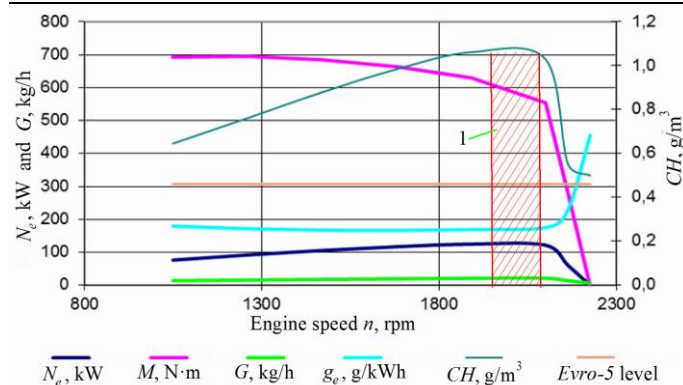


Fig. 2. Dependence of CH emissions on the engine operation mode: 1 - range of maximum CH emissions

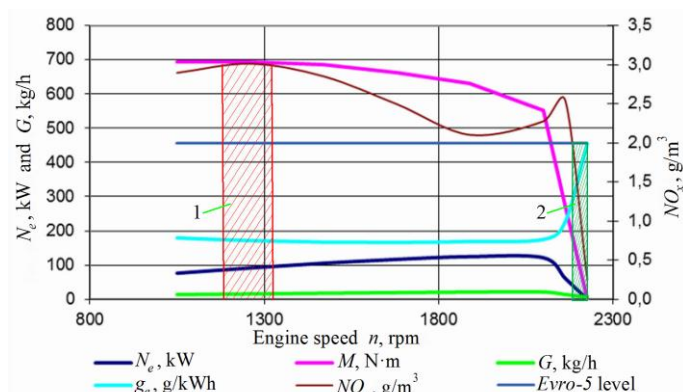


Fig. 3. Dependence of NOx emissions on the engine operation mode: 1 - the range of maximum emissions; 2 - range of permissible NOx emissions according to Euro - 5 environmental safety standards

In fig. 2 - 3 we see that the standards of Euro-5 CH and NOx are quite high, and we can not meet them in those modes of operation of mobile vehicles that are acceptable for environmental safety.

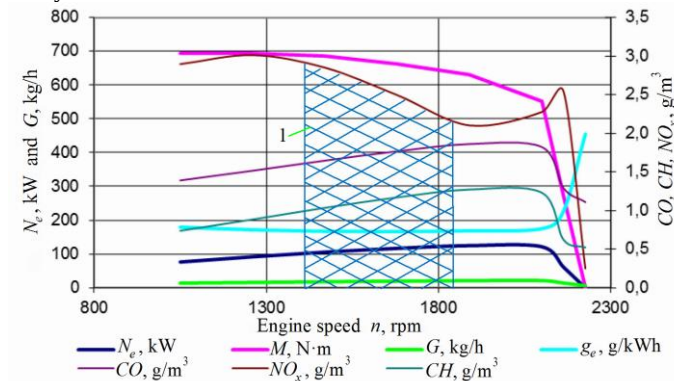


Fig. 4. The general dependence of CO, CH, NOx emissions on the engine operation mode: 1 - the range of optimal operation of the mobile vehicle in terms of the amount of CO, CH, NOx emissions

In fig. 4 shows the area that we accept as optimal for the operation of the tractor from an environmental point of view. As the indicators of carbon monoxide and hydrocarbons begin to increase, while slightly exceeding their parameters, and the rate of nitric oxide decreases, thereby compensating for the growth of other components of exhaust gases.

It follows that the accepted mode of operation of the engine in terms of speed can be considered 1450...1850 rpm, at average power and average load of the mobile vehicle, while fuel consumption does not increase in this mode.

Analysis of the dependence of CO, CH, NOx emissions on the traction characteristic of the tractor.

The main indicators of the tractor in gears are usually presented in the form of traction characteristics.

Traction characteristic is a set of dependences of traction power, speed, fuel consumption, engine shaft speed, and others. characteristics of the traction or transport machine from the traction force. Traction characteristics allow you to assess the dynamic, economic, etc. performance of machines and is determined by calculation or traction tests. It depends on the engine power, the type of engine, the weight of the vehicle and the physical and mechanical properties of the surface on which the movement takes place. Based on the characteristics, calculations are also made on the rational combination of traction machines with various agricultural and industrial implements.

Analyzing the obtained graphs (Fig. 1-3) in the light of the current implementation of new standards for emissions of harmful gases CO, NOx and CH, we can see that with increasing load and speed of the engine YaMZ-236M2 there is an increase in CO and CH emissions, up to nominal mode engine. At the same time, the content of NOx compounds in the exhaust gases, under the same conditions, decreases to 1890 rpm, in this mode the engine can develop a maximum power of 124.7 kW (Fig. 5), which is 96.93% of the nominal value of 128.7 kW (Fig. 5).

Since the use of a tractor at a certain optimum involves a corresponding reduction in engine power, it will change the traction properties of the tractor. To compare the obtained new characteristics of the tractor with the nominal operating mode N_e , respectively, we will build a traction characteristic for the nominal and new operating modes.

Since the limitation of engine power will also change the performance of the tractor, it is advisable to compare them at different levels of power developed by the engine.

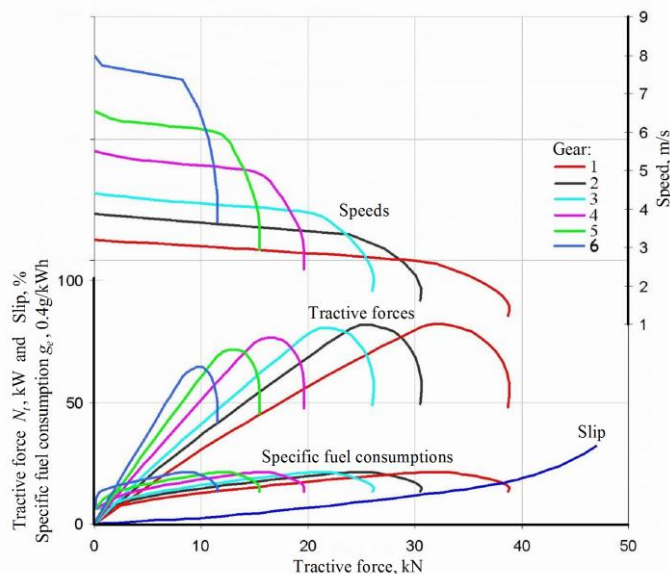


Fig. 5. Traction characteristics of the engine at rated power $N_e = 124.7$ kW

Thus, there is a possibility of a significant reduction in emissions of the most significant volume and weight of the NOx exhaust element, if you limit the engine speed to 90% of the nominal. There will also be a reduction in CO and CH emissions, because at this value their volumetric amount has not reached its maximum value..

4. Conclusions

1. It is proved that the assessment of the level of emissions of major pollutants and toxic substances in exhaust gases can be performed using the regulatory characteristics of the engine depending on the mode of operation.

2. To comply with the Euro-5 standard, the mode of operation of the YaMZ-236M2 engine for CO emissions should not exceed 1250 rpm.

3. Euro-5 standards for CH and NO_x emissions are quite high, so the engine YaMZ-236M2 can not meet them in any mode of operation of mobile vehicles.

4. The optimal mode of operation of the engine YaMZ-236M2, from an environmental point of view, adopted 1450...1850 rpm. In this case, fuel consumption does not increase in this mode.

5. With increasing load and speed of the engine YaMZ-236M2 there is an increase in emissions of CO and CH, up to the nominal mode of operation of the engine. The amount of NO_x compounds in the exhaust gases, under the same conditions, decreases to 1890 rpm. At such speeds, the engine can develop a maximum power of 124.7 kW, which is 96.93% of the nominal value of 128.7 kW.

6. It is possible to reduce the emissions of the most significant NO_x exhaust element in terms of volume and weight by limiting the engine speed to 90% of the nominal. CO and CH emissions at a given engine speed have not reached their maximum value.

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Experimental study results of the grinding process in a hammer-type shredder with side separating sieves

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Abstract: The technical implementation of air-product flow control in the working chamber of a hammer mill for timely separation of conditioned particles from the main stream and their lateralization (removal to the side zones) for the purpose of evacuation from the working chamber is considered. The energy and quality indicators of the grinding process in a hammer mill with side separating sieves are determined. The obtained experimental dependences are necessary for the manufacture of hammer crushers for farms and the development of recommendations for the operation of hammer crushers with side separating sieves. Improving the conditions of the grain material separation process and timely unloading of the finished product from the grinding chamber makes it possible to achieve economic efficiency by reducing the content of the dust fraction in the finished product and reducing the specific energy costs of the grinding process.

KEYWORDS: GRINDING, SIEVE, SEPARATOR, GRAIN.

1. Introduction

High requirements for the manufacturability of equipment, as well as the quality of processing feed material that meets the physiological needs of farm animals, lead to the need to expand research in the field of grinding feed grain. The most important technical and economic task of grain mass grinding is to obtain a final product with uniform grain size composition with the required particle size and minimum energy costs.

Theoretical studies have established the possibility of correcting the trajectories of conditioned particles of crushed raw materials to the optimal location zone of the separating sieves [1]. Further experimental studies are needed to determine the adequacy of the obtained structural and geometric parameters of the grinder. The developed methodology for engineering and analytical research of the air-product flow control process (hereinafter referred to as the APF) in the working chamber of the hammer crusher made it possible to form variations of the technical solution schemes ensuring the fulfillment of the designed objective function - unloading the finished product through the side unloading zones under established technical conditions and quality indicators [1, 8].

2. Preconditions and means for resolving the problem

The complexity of mathematical formalization of the process of APF lateralization in the working chamber of the hammer crusher, as well as the presence of accepted assumptions, implies checking the operability of the detected analytical dependencies within the framework of experimental studies [1]. To determine the level of reliability of the proposed technical solution, it is necessary to evaluate the productivity and energy intensity of the grain material grinding process, as well as analysis of quality characteristics of the grinding product. This analysis is necessary to confirm the economic efficiency of the developed laboratory-production equipment and identify promising areas for further improvement of the production and technological base [4, 8].

3. Solution of the problem under consideration

To determine the rational operating parameters of the system of lateralization of conditioned particles during grinding in a hammer shredder with side separating sieves, experimental studies were conducted (Fig. 1). The program of laboratory and production tests provided for determining the productivity of the hammer crusher and the energy consumption of the grinding process, depending on the size of the feed of various components.

The tendency to increase the productivity of the crusher requires matching the energy consumption with the quality of the ground grain. To study the granulometric composition of crushed grain raw materials in production conditions, the analysis of grinding products obtained during grinding on an experimental crusher was carried out

[2]. An indispensable condition for the operation of closed-type crushers is the circulation of grain material in the volume of the working space of the shredder. The energy consumption per unit of finished product, to a greater extent, depends on the amount of circulating material. Therefore, it is advisable to evaluate the energy efficiency of a shredder with a lateral arrangement of unloading zones and the APF lateralization function by an indicator that characterizes the degree of filling the volume of the working chamber with grain material [5, 6].

With an increase in the filling factor of the working volume of the chopper chamber, the load from the circulation of incoming material increases. There is a high probability of occurrence of a mode when the amount of grain material increases uncontrollably.

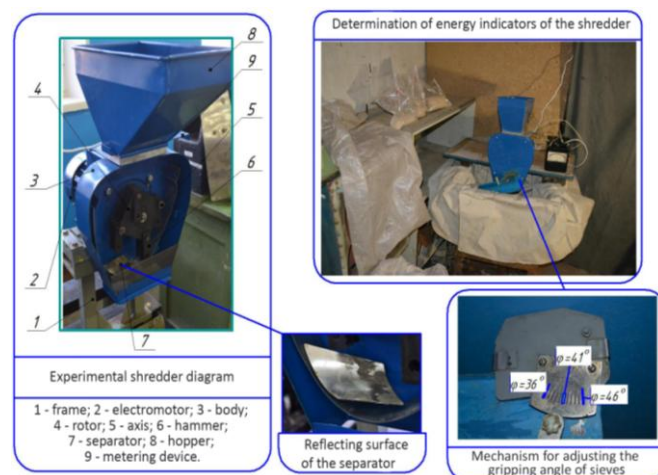


Fig. 1. Experimental hammer-type shredder

As a result, the shredder is overloaded. Such a marginal, non-functional state, when processing of incoming material is technologically impossible, leads to an emergency situation. The elimination of emergency mode is provided by optimizing the feed of grain raw materials to minimize the circulating load [1, 8].

Filling the volume of the working chamber is characterized by the amount of grain material constantly located in the working chamber and is determined by a coefficient that is reliably calculated using the formula:

$$(1) \quad \mu = \frac{q - Q}{V}$$

where:

μ – Fill factor of the volume of the working chamber, kg/(m³·h);

q – Feed rate feedstock, kg/h;

Q – Total output, kg/h;

V – Working volume of the grinding chamber, m³.

The method of optimization of elements of the working chamber of the hammer shredder was to create anomalous modes of evacuation of the conditionative product from the working chamber of the shredder. The anomalous operating mode of the unloading system was implemented by setting the capture angles of the separating sieves, which contradict the calculated results, with other adequate geometrical parameters of the separator. We varied the gripping angle of the sieves φ , in the range from 36 to 46 degrees, and recorded the specific energy consumption per unit of production and the value of the filling coefficient of the working chamber volume.

4. Results and Discussion

Rational mode of grinding is determined by dependence of capacity of experimental grinder with side separating sieves on volume of loading of ground raw material into working chamber and on degree of grinding determined by diameter of through hole of classification sieve. The dependences of productivity on the feed rate for various sieves and grain materials are shown in the figure (Fig. 2). These dependencies allow you to select the optimal values of feed volumes, which provide the highest throughput of the experimental shredder with side separating sieves.

The optimal operating modes of the experimental hammer mill (the sieve diameter is 3 mm, the crushed material is wheat) are determined by the maximum capacity of 206.5 kg/h with a supply value of 260.76 kg/h. When grinding barley, the maximum capacity of 190.3 kg/h is provided by a supply of 226.9 kg/h. When using a sieve with a cell diameter of 5 mm, the maximum capacity for barley is 217.8 kg/h, and for wheat 230 kg/h.

The quality of the finished product was evaluated using variational grinding characteristics (Fig. 3) for various grinding modules. The results show that in steady state operation the grinder produces the same particle size composition.

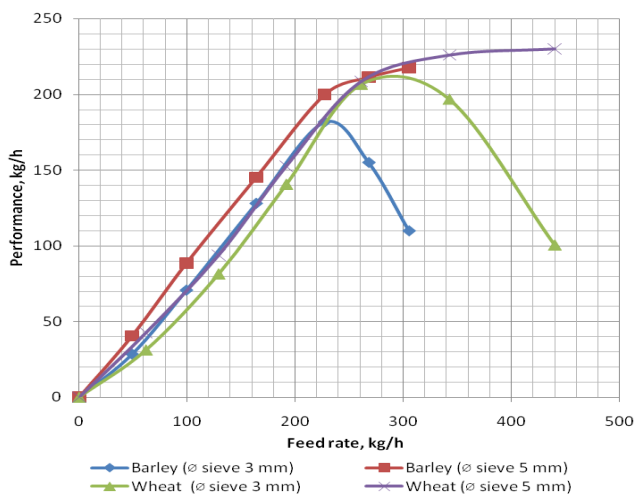


Fig. 2. Dependence of the productivity Q of the hammer shredder on a supply value q of the crushed material

The characteristics of barley groats obtained using a sieve with a diameter of 5 mm have a linear relationship. This indicates that their sizes are distributed fairly evenly across classes. The average particle size for a 5 mm sieve corresponds to a diameter $d = 1.75$ mm. When using a sieve with a diameter of 3 mm, the average particle size is $d = 1.32$ mm. Analysis of the total grinding characteristics (Fig. 3) showed a tendency to a downward trajectory, which indicates the uniformity of the particle size distribution. Studies have shown that increasing the diameter of the sieves holes in the crusher leads to an increase in particle size in the ground product and a decrease in the amount of fine particles [3].

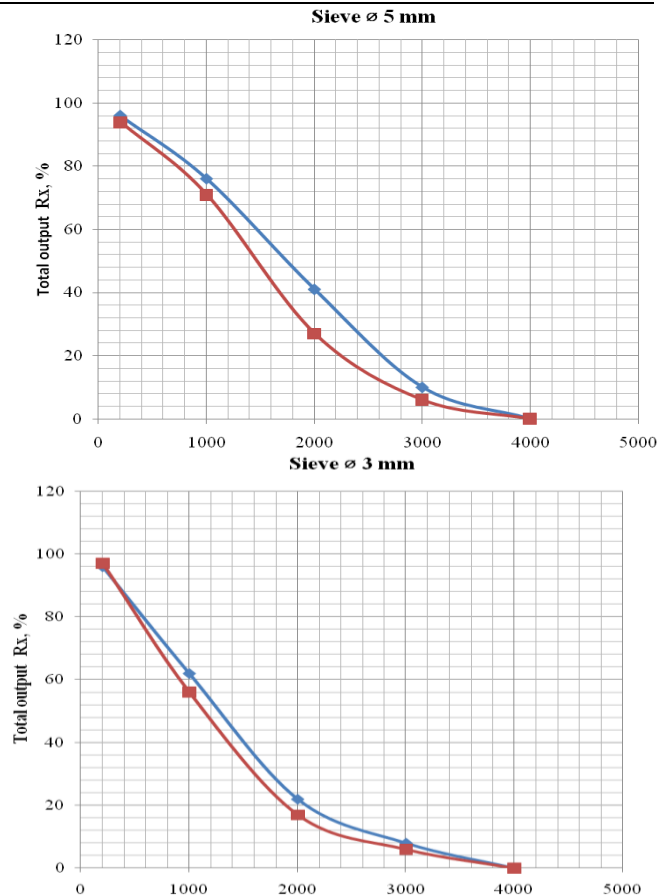
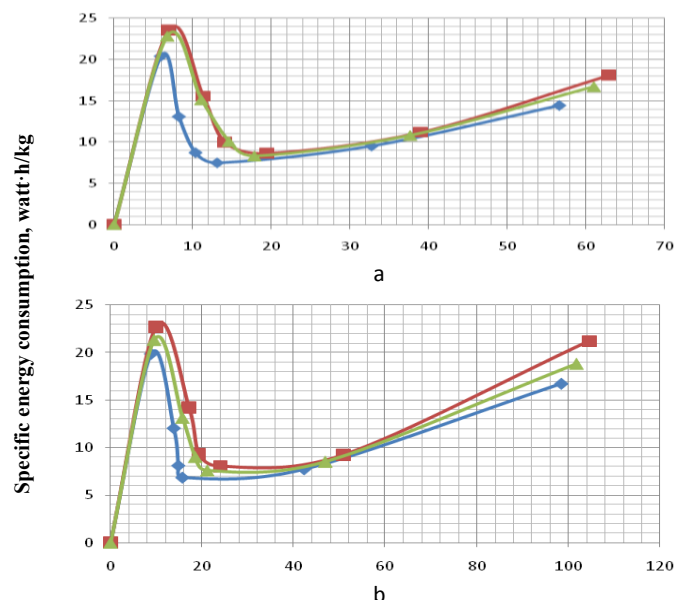


Fig. 3. Variational grinding characteristics for various grinding modules and grain crops

It should be noted that it is possible to obtain a ground product meeting the requirements of medium grinding (for young livestock ducks, chickens, turkeys and fattening of cattle at the age of 76 to 100 days, of early young cattle and pigs, sucked sows) when installing in a hammer crusher a sieves with a diameter of 3.0 mm. To obtain feed for calves, young cattle, young chickens, broilers, ducks, geese, meat and bacon fattings pigs, young sheep, it is necessary to install a sieve with a hole diameter of 5.0 mm [9].

The dynamics of the change in specific energy consumption from the change in the amount of grain material in the working chamber of the hammer grinder are represented by the graphs in Figure (Fig. 4).



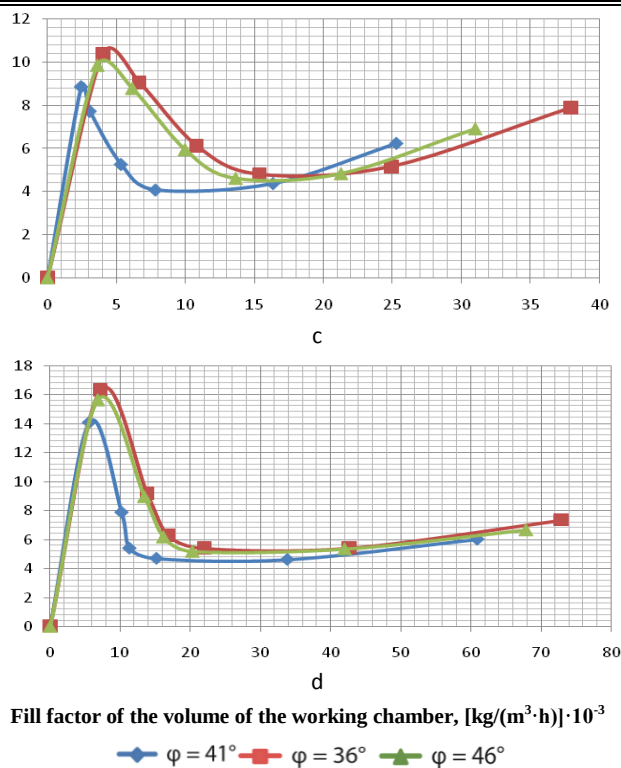


Fig. 4. Dependencies of specific consumption of energy per unit of product from the fill factor of the volume of the working chamber: a – the grinding of barley, sieve diameter 3 mm; b – the grinding of wheat, sieve diameter 3 mm; c – milling the barley, the diameter of the sieve 5 mm; d – milling of wheat, the diameter of the sieve 5 mm

It follows from the graphs that the specific energy consumption of grinding significantly depends on the degree of grinding controlled by the size of the sieve cell. It was found that the energy consumption of grinding barley and wheat to the degree of grinding corresponding to the caliber of the sieve with a cell $\varnothing 3$ mm is in the range of 7.48 to 20.39 watt-h/kg, and from 6.85 to 19.87 watt-h/kg, respectively. The lower limit is reached when the feed of the crushed material is 226.9 kg/h for barley and 260.76 kg/h for wheat. When using a sieve with a cell of $\varnothing 5$ mm indicators of energy consumption change slightly, in case of finding of coefficient of filling of volume of the working camera in the range of values, for barley from 7.83 to 16.35 and for wheat from 15.17 to 33.82 it testify to the nominal mode of operation of the grinder.

A comparison of the results of theoretical calculations with experimental data indicates an increase in the circulating load, which leads to an increase in specific energy costs.

The analysis of the provided schedules shows that with reduction of an angle of capture of a sieve to 36 degrees the specific power consumption of crushing of barley and wheat (to the degree of a grinding corresponding to sieve caliber with a cell of $\varnothing 3$ mm) is ranging from 8.63 up to 23.57 watt-h/kg for barley and from 8.03 to 22.76 watt-h/kg for wheat. In case of application of a sieve with a cell of $\varnothing 5$ mm specific costs of energy of crushing of barley are in range from 4.8 to 10.40 watt-h/kg. For wheat, the interval boundaries are slightly wider - from 5.40 to 16.32 watt-h/kg. The average increase in energy intensity of the process due to reduction of the capture angle is 18%.

Energy parameters in case of increase of the capture angle of the sieves to 46 degrees have similar dynamics of change. The boundaries of the interval values indicate a less critical nature of the effect of increasing the angle of capture of sieves on technical and economic indicators. For example, when using a sieve with a hole

diameter of 3 mm, the energy consumption of grinding barley is in the range of 8.31 to 22.85 watt-h/kg, and for wheat from 7.6 to 21.36 watt-h/kg. At the same time, the energy consumption of grinding when using a sieve with a hole diameter of 5 mm for barley is from 4.61 to 9.86 watt-h/kg, and for wheat from 5.19 to 15.64 watt-h/kg. The average increase in the energy intensity of the process for the second anomalous mode is 12 %.

5. Conclusion

The proposed methodology of laboratory production studies allowed us to determine the main operational indicators of the designed hammer grinder with side separating sieves.

For the unloading system (a separator with an initial curvature of the reflecting surface $\alpha = 40^\circ$ and a sieve capture angle $\varphi = 41^\circ$), economically feasible operating modes of the hammer grinder with side separating sieves have been established.

The values of the throughput capacity of the shredder have been reached, ensuring satisfactory quality indicators of the resulting product. When grinding wheat on a sieve with a diameter of 3 mm, the productivity was 206.5 kg/h., For barley, the productivity was 190.3 kg/h. When using a sieve with a mesh diameter of 5 mm, the productivity for barley is 217.8 kg/h, and for wheat - 230 kg/h.

The experimental dependence of the specific power consumption of grinding on the filling factor of the volume of the working chamber showed an increase in power consumption, both in case of deviation in the direction of increase and in case of deviation in the direction of decrease of the value of the grip angle of the sieves from the optimal value (41 degrees). Reducing the screen grip angle to 36 degrees increases the power consumption by 18%. Increasing the screen grip angle to 46 degrees increases the energy consumption of 12%. The results are fair for barley and wheat when ground on sieves with diameters of 3 mm and 5 mm.

Sufficient convergence of theoretical and experimental results confirms the prospects of creating a technical product – hammer-type shredder, which technologically provides for the lateralization of APF and lateral evacuation of the conditioned product.

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Study of specialized wide-rail agriculture unit for rail farming

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Abstract. A promising direction for further sustainable development of agriculture not only in Ukraine but also in the world is the introduction of innovative technologies, which should include the track and bridge systems of agriculture. These systems provide the basis for the automation and robotization of most crop production processes, ensure efficient implementation of "precision" and "digital" farming and provide other significant benefits. Scientists have not sufficiently studied the issue in this regard, and there is currently no effective methodology for implementing the potential technical-operational and technological properties of specialized broad gauge means of agricultural production mechanization for the rutting system of agriculture. Therefore, from the point of view of solving the food problem in the world, especially during the COVID-19 pandemic, as well as developing resource-saving technologies based on the principles of the rutting system of agriculture, in accordance with the trends of scientific and technological progress in the field of mechanization - improving the level of functioning of technical means through integrated mechanization, electrification, automation and robotization - this direction of research is relevant. The aim of the research is to substantiate the main advantages and effectiveness of the use of a specialized vehicle for rutting agriculture by justifying its main parameters. As a result of these studies, it was found that the energy saturation level of specialized agricultural vehicles moving in the tracks of a permanent technological track should be $23.5 \text{ kW} \cdot \text{t}^{-1}$, in realizing the traction force at the level of 6.37 kN by 1t of their weight. Losses of the field area for the engineering zone when using agricultural equipment with a wheelbase width exceeding 6 m are 5-6%. The economic effect of the use of broad-wheeled agents in wheat cultivation technology is at least 150 € per hectare.

KEY WORDS: TRACK FARMING, BRIDGE AGRICULTURE UNIT, CONSTANT TRAMLINE, ENERGY SATURATION, LAND USE, ECONOMIC EFFECT.

1. Introduction

At present the most actual problem of soil reconsolidation by running systems of energy means and self-propelled machines remains worldwide [1, 2]. One of the ways to solve this problem is the transition to new farming technologies that allow reducing the area of tractor and machine tracks in the field. Thus, the transition to minimum tillage technologies (No-till) reduces the relative area of wheel motor tracks in the field to 46% [3, 4]. An even greater effect in reducing the compaction effect of the wheels of the running gear of the units on the soil is observed in the tramline system of cultivation (Controlled Traffic Farming – CTF). The organization of parallel motion of aggregates along a specially created tramline allows reducing the area of traces from the wheels of machinery in the field to 14% [5, 6].

Farming with a constant tramline is the separation of the zones of movement of agricultural aggregates from the zones of plant processing. In practice, this means that the same transport and technology tracks are used for tillage, planting, spraying and harvesting to move the agricultural aggregates along them. That is, the functional purpose of the field area is divided into fruit-bearing (agricultural) and technological (engineering) zones.

On the basis of duration of use of technological track by scientists of southern branch of National scientific center "Institute of mechanization and electrification of agriculture" (Ukraine) [7] it is offered to classify it on periodic, temporary, constant, long-term and stationary. The practical use of the last three introduces certain difficulties to its implementation by traditional tractor-combine means of mechanization. As in the decision of a problem of optimization of complexes of machines for tramline agriculture there are difficulties in coordination of parameters of running systems of tractors and agricultural machines with parameters of a technological track. On the other hand, the forced coordination of machine units on the parameters of their running systems can lead to an incomplete loading of their engines on various technological operations in the technological cycle of cultivation of agricultural crops, which levels the effect of the implementation of the basic principles of tracked agriculture.

2. Preconditions and means for resolving the problem

For the purpose of practical implementation of the concept of track farming, a number of different technological and technical solutions have been offered worldwide: the use of traditional tractors with extended wheel axles, bridge tractors such as Dohler, Swedish bridge tractor Biotrac with four driving wheels, ASA-Lift WS 9600 WS, etc. [8]. The use of such specialized wide-track agribusinesses to a certain extent solves the problem of reducing soil compaction, because the area from the tracks of their wheels is reduced to 5-10%.

According to scientist V.A. Uleksin [9], the drive of specialized wide-track agricultural units can be fully electric or hybrid. In his opinion, in order to automate driving, these wide-track agricultural units should be four-wheel drive with kinematic-power control, independent for its front and rear wheels.

Scientists have not sufficiently studied the issue in this regard, and there is currently no effective methodology for implementing the potential technical-operational and technological properties of specialized broad gauge means of agricultural production mechanization for the tracked agricultural system. Therefore, from the point of view of solving the food problem in the world, especially during the COVID-19 pandemic, as well as developing resource-saving technologies based on the principles of the rutting system of agriculture, in accordance with the trends of scientific and technological progress in the field of mechanization – improving the level of functioning of technical means through integrated mechanization, electrification, automation and robotization - this direction of research is relevant.

Justification of the main advantages and effectiveness of the use of a specialized vehicle for rutting agriculture, by justifying its main parameters.

3. Results and discussion

In our opinion, the layout scheme of a specialized wide-track agricultural unit for its use in the tramline system of agriculture should contain an electrified chassis 1 with engines 2, driving the wheels of its left and right sides, a set of electrical equipment 3, attaching mechanism 4, retractable supports (jacks) 5, which are attached to the chassis for lifting one of its sides, agricultural implements 6.

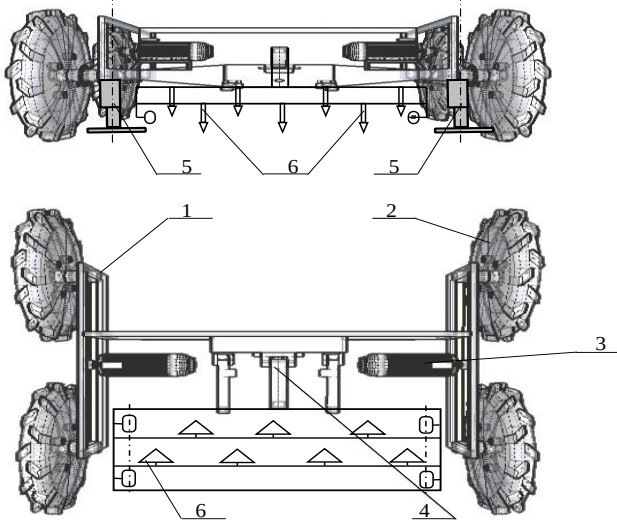


Fig. 1. Specialized wide-track agricultural unit for agricultural work: 1 – chassis; 2 – electric motors; 3 – electrical equipment; 4 – mounted mechanism; 5 – retractable supports (jacks); 6 – agricultural implements

Fig. 1 shows the layout scheme of wide-track agricultural unit is implemented in the construction agricultural unit [10].

For practical realization of the wide-track agricultural unit within the field directly on agricultural operations the issue of realization of its turn, in our opinion, is possible by its rotation on the spot around the center of the turn, which is located in the center of the track on which the agricultural unit itself moves [11, 12]. For this purpose, the is additionally equipped with mechanical retractable supports (Fig. 2) attached to its chassis from left and right side to lift one of them at headland, with respect to the axis coinciding with the longitudinal axis of the support. Such a principle of wide-track agricultural unit turning makes it possible to move it to the next position in a minimum period of time, which increases productivity and requires less area for the engineering field zone.



Fig. 2. Specialised Broad Track Agricultural Unit with hydraulic support for the implementation of on-board turning

In solving the problem of determining the energy content of a specialized wide glue agricultural unit, the power balance equation has been compiled, according to which the power of its energy installation (or power units) is distributed to the drive of its wheels on both its sides and, in certain cases, additional power take-off is possible:

$$N_e = \frac{f \cdot g \cdot V}{\eta_t} \left[\frac{M_l}{1 - \delta_l} + \frac{M_r}{1 - \delta_r} \right] + \frac{\lambda \cdot \varphi \cdot g \cdot V}{\eta_t} \left[\frac{M_l \cdot \delta_l}{1 - \delta_l} + \frac{M_r \cdot \delta_r}{1 - \delta_r} \right] + \frac{g \cdot V (\lambda \cdot \varphi - f)}{\eta_t} \left[\frac{M_l}{1 - \delta_l} + \frac{M_r}{1 - \delta_r} \right] + \frac{N_{PTO}}{\eta_{PTO}}, \quad (1)$$

where V – speed of the wide-track agricultural unit, $\text{km} \cdot \text{h}^{-1}$; f – rolling resistance coefficient; g – free fall acceleration, $\text{m} \cdot \text{s}^{-2}$; δ – wheel slipping ratio; λ – drive load factor; φ – adhesion coefficient of the wheels of the agricultural unit to the bearing surface of the tramline tracks; δ_l , δ_r – left and right wheel slipping ratios; M_l and M_r – the masses of agricultural unit on his left and right side, kg; η_t – transmission efficiency.

By numerical calculations it is proved that for full realization of traction and power properties of specialized wide-track agricultural units at working speeds of their movement to $5 \text{ km} \cdot \text{h}^{-1}$ their energy saturation should be equal $12.5 \text{ kW} \cdot \text{t}^{-1}$ and within $10 \text{ km} \cdot \text{h}^{-1}$ – equal $23.5 \text{ kW} \cdot \text{t}^{-1}$. In this regard, under real operating conditions, reducing the operating speeds of such agricultural units is a way to reduce energy consumption for technological processes in rutting agriculture. In conditions of sufficient wheel adhesion of the specialized wide-track agricultural unit with the bearing surface of the soil track of a constant technological track allows it to develop a traction force of 6.37 kN for each ton of its operating weight. This is 1.4 times more than a traditional wheeled tractor can develop while driving on a stubble agrophone. The movement of the agricultural unit on the soil tramline in contrast to agricultural agrophones can increase its coefficient of adhesion up to 0.55. Thus the maximum tangential force of the traction developed by its wheels is reached at smaller slipping value equal to 0.15...0.17. Practically it means that movement of wide-track agricultural unit on the leveled compacted soil track allows to increase its traction and coupling properties at least on 30%.

With the purpose of an estimation of influence of the sizes of wide-track agricultural unit and parameters of their wheels on a factor of land tenure at arrangement of a field by transport technological paths we will consider, as variant, a kind and a way of their movement (Fig. 3) which can be attributed: on the organization of territory – paddock; on a direction of working runs – racing; on the scheme of processing of a paddock – shuttle; on a type of rotation – loopless.

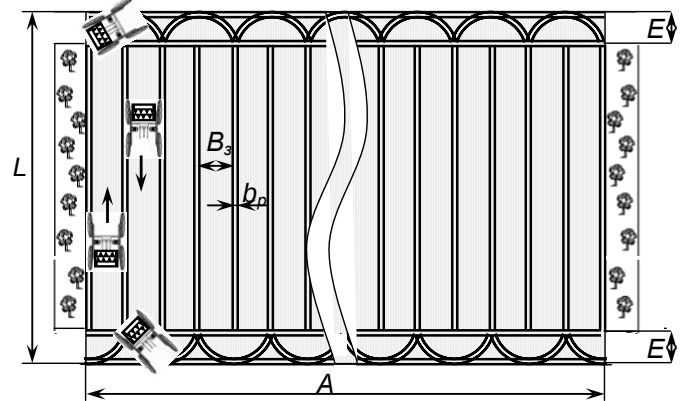


Fig. 3. Field planning scheme for specialized wide-track agricultural equipment: A and L – field width and length; B_s – working width, E_n – swivel lane width; b_p – conveyor belt width

Taking into account the adopted type and method of wide-track agricultural unit movement (see Fig. 3), the conducted researches have established that the influence of its structural parameters on the field area losses under the engineering zone can be estimated by the relative value of the loss factor w_i :

$$w_i = \frac{b_c + c}{L \cdot A} \cdot \left(\left[L - 2(K + b_c + c) \right] \cdot \left[\frac{A - b_c - c}{K} + 1 \right] + 4A + \pi[A - b_c - c] \right), \quad (2)$$

where b_c – tire track width; c – technological tolerance; K – agricultural track gauge; L and A – field length and width.

The analysis of expression (3) has shown that at a rectangular configuration of a field section the use of wide-track agricultural units with track width about 12 m and wheels with profile width 15,5R or 16,9R determines the value of losses of the field area under engineering zone within 7.5-12.5%. For agricultural machinery with a track width greater than 12 m and wide wheels with a tyre profile width of 23.1R - is not more than 5% of the total area.

The width of the transport technological track of the permanent technological track is significantly influenced by the technological tolerance c , which is caused, in particular, by the amplitudes of transverse deviations of the agricultural unit from the straight-line motion, which directly affects the loss of the field area under the engineering zone. Thus, with the increase in technological tolerance up to 0.3 m the losses of the area for the engineering zone increase by 1.5...1.75 times. Therefore, the practical use of wide-track agricultural units in the rutting system of agriculture requires a justification of the principles of their automatic driving, which will minimize the amplitude of deviations from a given straight-line trajectory and, consequently, the value of technological tolerance.

The economic effect E of the introduction of the tramline system of agriculture and the use of specialized wide-track agricultural units is determined, first of all, by three components:

$$E = \Delta e_h + \Delta e_s + \Delta e_e, \quad (3)$$

where Δe_h – economic effect of increasing crop yields, €·ha⁻¹; Δe_s – economic effect of saving seed, €·ha⁻¹; Δe_e – the economic effect of saving energy costs, €·ha⁻¹.

The results of the evaluation of the efficiency of implementation of the rutting system of agriculture and the use of specialized wide-track agricultural units from saving energy costs, sowing material and increasing yields, on the example of wheat cultivation, by (3) are presented in Figure 1. 4.

Analysis of Fig. 4 indicates that if the loss of the field area for the engineering zone in the rutting system of agriculture is more than 6%, and the absolute value of natural soil compaction will be only 0.1 g·sm⁻³, it will be impossible to get positive economic effect only by increasing the yield (curve 1, Fig. 4). According to our estimates, it is still possible to achieve a loss of less than 6% of the field area if specialized wide-track agricultural units with their track width of at least 6 m are used.

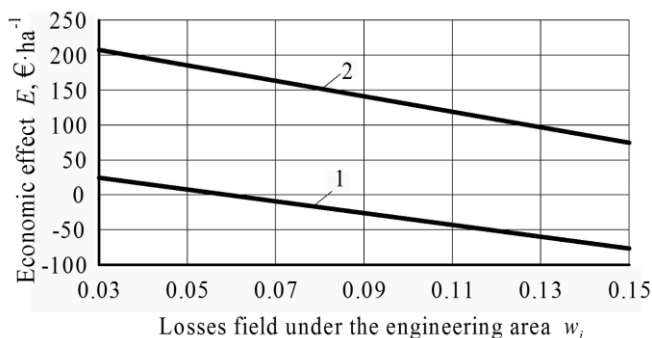


Fig. 4. Results of assessment of efficiency of implementation of tramline system of agriculture and use of specialized wide-track agricultural units from saving energy costs, sowing material and increasing yield of wheat cultivation with different effect of soil compaction: 1 – 0.1 g·sm⁻³; 2 – 0.2 g·sm⁻³

A more tangible economic effect from the use of specialized broad gauge agricultural units in the rutting system will be seen if, with traditional farming technology, soil compaction becomes one of the main obstacles to high yields. And if, with the right soil protection practices, natural soil compaction is achieved in rutting agriculture at the level of 0.2 g·sm⁻³, then, due to a substantial increase in the yield of cultivated plants, the economic effect will be obvious even if the field area under the engineering zone is lost at

the level of 10...15% (curve 2, Fig. 4). The economic effect itself will be greater the less the field area is allocated to the engineering zone. With specialty agricultural, the economic effect of saving energy costs, sowing material and increasing wheat yields will be at least 150 € per ha of wheat.

4. Conclusions

1. Carried out researches it is established that for full realization of traction and power properties of specialized wide-track agricultural units at working speeds of their movement up to 5 km·h⁻¹ their power saturation should be equal. 12.5 kW·t⁻¹, and within 10 km·h⁻¹ – 23.5 kW·t⁻¹. In this regard, under real operating conditions, reducing the operating speeds of such agricultural units is a way to reduce energy consumption for technological processes in rutting agriculture.

2. In conditions of sufficient wheel adhesion of the specialized wide-track agricultural unit with the bearing surface of the soil track of a constant tramline allows it to develop a pulling force of 6.37 kN per each ton of its operating weight. This is 1.4 times more than a traditional wheeled tractor is able to develop when driving on a stubble agrophone.

3. The movement of wide-track agricultural unit on the soil trail in contrast to agricultural agrophones can increase its adhesion coefficient to 0.55. Thus the maximum tangential force of traction, developed by its wheels, is reached at smaller slipping value equal to 0.15...0.17. Practically it means that movement of the agricultural unit on the leveled compacted soil track allows increasing its traction and coupling properties by at least 30%.

4. It is established that losses of the field area under the engineering zone significantly depend on the track width for the movement of specialized wide-track agricultural units, the value of which is directly determined by the width of their wheels. By calculations it is established, that on criterion of the minimum factor of losses of the field area under an engineering zone the rational size of wheel base of the last falls on 7.5 m. In practice, this means that when using tyres of agricultural units with a width of 0.393...0.429 m, the value of losses of the field area under the engineering zone does not exceed 6%. At the same time, at increase of agricultural units track width up to 9 m, that is typical for foreign samples, so-called "bridge" tractors, the amount of area losses decreases up to 5%.

5. The economic effect from the introduction of specialized wide-track agricultural units, which move in the footsteps of a permanent technological track, due to savings in energy costs, sowing material and increasing the yield of cultivated crops is at least 150 € per hectare of wheat cultivation, which allows a return on investment in the development of this promising area of agricultural mechanization.

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Increasing the level of providing service enterprises with spare parts and materials

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Summary: The work of logistical support subsystems of the service enterprise is analyzed, which leads to downtime of cars in repair, which complicates the work of the production area and leads to the necessity of allocation of ever larger premises for the storage of cars waiting for spare parts. The normative planning method for forming the needs of service companies in spare parts was selected, based on the methods of recovery theory. The normative planning method for forming the needs of service companies in spare parts was selected, based on the methods of recovery theory. An exponential Weibull - Gnedenko distribution has been established to describe the demand for the average resources of spare parts and units for cars. It is suggested to manage the stocks of necessary parts by the method of dividing the spare parts into groups A, B, C. The need for spare parts can be calculated using a general characteristic (based on a sample characteristic). Modern dealership service companies have a unified system of spare parts orders, depending on volume and periodicity. The change in the number of consumed parts of the first group, which occur smoothly without sharp fluctuations, is investigated. For the second group of parts, three maximums of spare parts are allocated.

Keywords: SERVICE ENTERPRISE, SPARE PARTS AND MATERIALS PROVIDING LEVEL.

1. Introduction

Formed in the early 90's the spontaneous market of vehicle is becoming more civilized every year, and there are constant links between its participants. Due to the growing purchasing power of the population, there is a steady increase in demand for new and used cars, which in turn leads to an increase in the market for car repair and maintenance services [1].

About 10% of service enterprises (SE) specialize in servicing cars of foreign production only, they also include official dealers of vehicle manufacturers [2].

A necessary condition for the existence of quality service is the effective organization of its logistical support of service enterprises. From a large number of subsystems of logistical support it is necessary to distinguish the following subsystems: maintenance of optimum stocks of spare parts and materials and methods of their replenishment, improvement of processes of ordering, purchase and delivery of component products and materials [3].

Poor work of these subsystems of logistical support of the service enterprise leads to: downtime of cars in repair, which complicates the work of the production area and leads to the need to allocate ever larger premises for the storage of cars waiting for spare parts. The time spent on SE of such cars can reach 3-4 weeks, to increase the queues for service, to increase the number of refusals to customers due to lack of spare parts, to reduce the competitiveness of the enterprise in the market and reduce the popularity of individual brands of cars [4, 5].

In order to solve the problems of providing service companies with spare parts, it is necessary to develop an effective methodology for determining the need for spare parts for service enterprises that are part of the dealer network, as well as to determine the best ways to manage inventories at such enterprises [6, 7].

2. Problem statement

The unsatisfactory operation of the subsystems of logistical support of the service enterprise leads to: downtime of cars in repair, which complicates the work of the production area and leads to the need to allocate ever larger premises for the storage of cars waiting for spare parts. The time spent on SE of such cars can reach 3-4 weeks; to the growth of service queues; to increase the number of refusals to customers due to the lack of spare parts; to reduce the competitiveness of the company in the market and reduce the popularity of individual car brands [8].

3. Research results

In terms of SE, the normative planning method is widespread in calculating spare parts needs. The number of product (element) replacements for any range from 0 to L is determined using recovery theory methods.

Norma spending spare parts:

$$N = \frac{(L_{DP} - L_{NS}) \cdot 100 \cdot n}{t_{DP} \cdot R_{SP}} + 100 \cdot U_Q \cdot \frac{\delta \sqrt{L_{DP}}}{t_{DP} \sqrt{R_{SP}^3}}, \text{ pcs/100aut.per year,}$$

where L_{DP} - mileage of cars during the depreciation period, thousand km;

L_{NP} - the service life of the new part, the car assembly before the first replacement, thousand km;

t_{DP} - the service life of the car by the rate of depreciation, year;

R_{SP} - average spare parts life between replacements, thousand km, taking into account average parts and components times before and between replacements, taking into account the upper confidence limit;

U_Q - the quantile of the normal resource allocation of the initial element;

δ - mean square deviation of the life of the part, thousand km.

The park's annual need for spare parts is determined by the use of the standard:

$$Q = \frac{\alpha \cdot P \cdot N}{100},$$

where α - a correction factor of 0.9-1.0 depending on the category of operating conditions;

P - car park, pc.

The average daily consumption of spare parts for normal distribution is determined by dependence:

$$h_i = \frac{100 \cdot n}{T_i} \left[\frac{V_i}{K_i} Z_G + 0,5q(L) \right], \text{ pcs / 100 aut. per year,}$$

where n - number of parts, units of the same name on the car;

T_i - the life of the car at the rate of depreciation per year;

V_i - the coefficient of variation of the resource between replacements;

T_i - the life of the car at the rate of depreciation per year;

V_i - the coefficient of variation of the resource between replacements;

K_i - factor of reduction of a resource of a workpiece depending on operating conditions;

$$K_i = \frac{R_i}{R_{Z_i}}$$

Z_G - auxiliary value in the calculation of the need for spare parts, which is determined by the table depending on the quantile of the normal distribution of the resource of the initial element;

$G(L)$ - the distribution function of the initial element up to the moment L , which is determined by the table depending on the quantile of the normal distribution of the resource of the initial element

U_Q ;

R_{Z_i} - average spare parts life between replacements;

R_i - the service life of the new part, the node before the first replacement, thousand km.

Formulas for exponential distribution, Weibull - Gnedenko distribution and stationary recovery process are also used in the technique. In the law of distribution laid down by the manufacturers of standards for the average resources of spare parts and units for cars.

You can predict the number of spare parts by using the probability recovery density:

$$Q_a = \sum n_i \cdot h_i \cdot \Delta L_T + U_Q \cdot \sqrt{\sum n_i \cdot h_i \cdot (1 - h_i \cdot \Delta L_T) \cdot \Delta L_T}$$

where n_i - number of cars whose service life is in the i -th interval, pcs.;

h_i - recovery density, rejection / thousand km;

ΔL_T - the average mileage of the car over the analyzed period of time;

U_Q - one-sided quantile of normalized normal distribution;

$h_i \cdot \Delta L_T$ - a product that expresses the probability of failure in the run interval if this interval is very small.

It is proposed to manage inventory in a warehouse by constantly monitoring the availability of the required parts, using, for example, the well-known method of dividing the spare parts into groups A, B, C. This method of separation and is currently applied in practice. Its essence in the following [6]:

- Group A (high demand parts) includes, according to various estimates, up to 10-20% of the total spare parts nomenclature. These details often fail and replacing them with a service company eliminates most of the faults and failures. By cost, these parts make up 75-85% of the total spare parts consumed;

- group B (average demand parts) comprises about 30% of the total nomenclature and the cost of the parts ranges from 10 to 30% of the total nomenclature value;

- Group C (rare demand parts) comprises more than 60% of the total spare parts nomenclature and the cost of parts does not exceed 5-7%.

The need for spare parts can be calculated using known dependencies in mathematical statistics to determine the general characteristic (based on a sample characteristic) [3]:

$$Q_A = \sum_{i=1}^m A_{in} \cdot K_{in} + U_Q \sqrt{\sum_{i=1}^m A_{in} \cdot K_{in}}$$

where A_{in} - planned number of cars of different age composition;

K_{in} - planned specific spare parts need for vehicles of the same age range;

U_Q - the quantile of the normal distribution according to the given confidence probability a .

The block diagram of spare parts orders delivery for the specified orders is presented in Fig.1

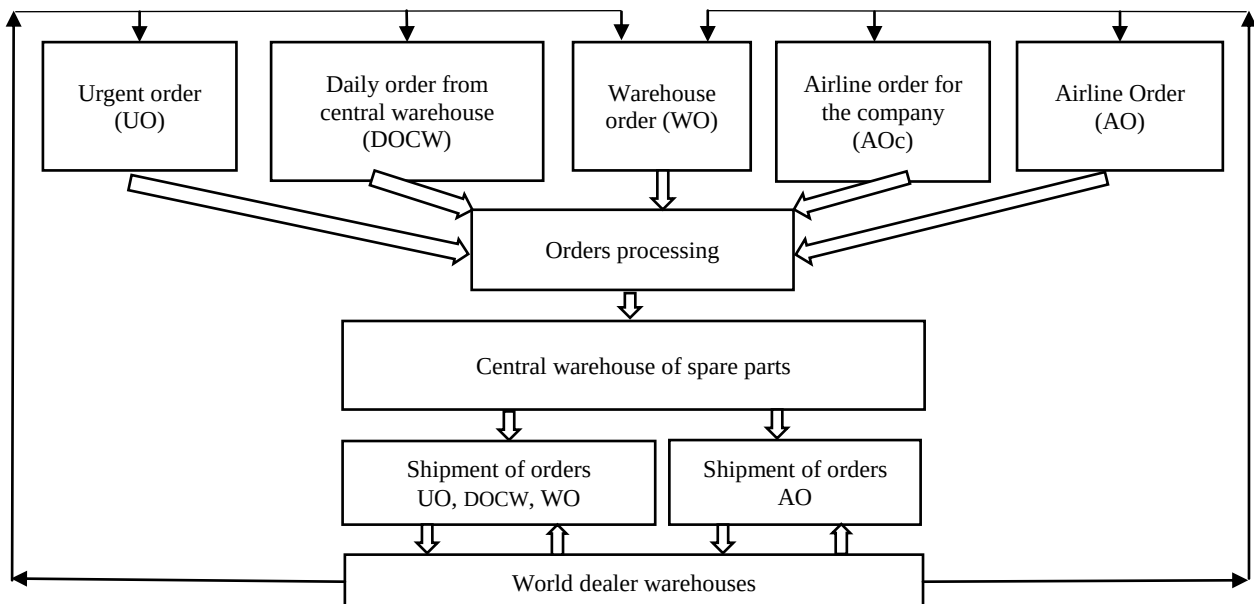


Fig. 1. Ordering system for spare parts of service companies by volume and frequency

For the dealership service companies there is a unified system of spare parts ordering. Depending on volume and frequency, there are several types of orders:

1. «Urgent order» (UO). Ordering spare parts for a specific customer or car under repair. Delivery of spare parts is carried out within several hours from the regional warehouse in accordance with the delivery schedule. The order is created once a day and has a limit on the number of items (no more than 20 names of spare parts).

2. «Daily order from central warehouse» (DOCW). This order, as well as UO, is carried out when there is a need for specific spare parts. Delivery is made within 24 hours. There is no limit on the number of orders and the number of titles in each order, but for certain items there is a limit on the number of orders for this spare part per day.

3. «Warehouse order» (WO). Spare parts ordering is made to replenish the warehouse, it is created once a day and is formed on the basis of the actual cost of spare parts at the enterprise. Delivery is made within one to two days. The order size is about 150 items on average. The list of ordered parts is analyzed by the department experts on the basis of cost statistics and some additional coefficients.

4. «Airline Order». Ordering items missing at regional warehouse due to low demand, or vice versa, spare parts shortages. It is carried out on a specific request (client account or order-outfit). Delivery is made within 45 days.

5. «Airline order for the company» (AOc). Ordering a large batch of spare parts for wholesale customers. Delivery is made within 30 - 45 days.

If during processing of orders UO, WO and AOc it is found out that spare parts are absent in the central warehouse, the order is shipped from the central warehouse to higher level warehouses (to Europe and Japan). In this case, the order period is increased to 45 days.

The spare parts system of the service company is a queuing system, as it corresponds to the basic features of this system. Spare parts consumed in the service company, form a random flow of requirements, the demand for spare parts in this case, is described by the Poisson distribution:

$$P_{ka} = \frac{a^k}{k!} e^{-a},$$

where P_{ka} - the probability that the number of spare parts required is equal to k at the average number of parts consumed and for the entire time periods analyzed.

The flow of spare parts requirements for existing car service companies, which include the entire complex of departments and services, is divided into several components, depending on the specialization of the company and the amount of spare parts consumed by its departments. As it is noted above, modern service companies (especially those owned by dealership network companies) have, in addition to their own service base, a spare parts sales department where the spare parts are wholesale and retail. In addition to said above departments, the company has its own car fleet for production and economic needs, a department for the sale of new and used cars, and for some there is a car rental service.

General need for spare parts for customer service and repair of customers' cars

$$Q = Q_{MRD} + Q_{PEN} + Q_{CRD} + Q_{CSD} + Q_{SPS}$$

where Q_{MRD} - the need for spare parts for the maintenance and repair department;

Q_{PEN} - the need for spare parts of the car fleet for production and economic needs

Q_{CRD} - the need for spare parts for the car rental department;

Q_{CSD} - the need for spare parts for the car sales department.

Q_{SPS} - the need for spare parts of spare parts shop;

It should be noted that the spare parts sales department may consist of several departments - retail, spare parts wholesale and ordering department, as well as other spare parts departments, such as round-the-clock technical support.

However, to determine the cost of spare parts at the enterprise and the cost of spare parts through the ancillary services of the service company can be combined into one common component of the cost of spare parts, since the repair impacts on the car fleet of the above services are carried out, as a rule, by the customer service, except only a component of the costs attributable to the spare parts sales department.

General need for maintenance and repair of vehicles in spare parts

$$Q = Q_{MS} + Q_{SPS},$$

where Q_{MS} - need for spare parts for maintenance service;

Q_{SPS} - the need for spare parts for the sales (store) of spare parts.

If for calculating the need for spare parts for maintenance service is required the availability of reliable information about the operational factors and the composition of the car fleet, then for calculating need of spare parts for spare parts store, obtaining such information becomes much more difficult.

Account of the fact that at large values of the number of spare parts the Poisson distribution with good approximation can be described by the normal law of distribution. We use this law to determine Q_{SPS} .

For a normal distribution law, the probability Q_{SPS} of will be less than $(M + Z\sigma)$:

$$P(-\infty < Q_{SPS} < M + z\sigma) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^z e^{-\frac{t^2}{2}} dt,$$

where M - mathematical expectation of distribution;

Z - normalized deviation from the mean value;

σ - mean square deviation.

Setting ourself for probability P , we determine the magnitude of such that:

$$\frac{1}{\sqrt{2\pi}} \int_{-\infty}^z e^{-\frac{t^2}{2}} dt = P.$$

Required number of spare parts required nomenclature:

$$Q_{SPS} = M + z\sigma,$$

However, the specifics of service companies predict the need for spare parts at relatively short intervals (usually not more than a month), and if the experimental studies reveal that the consumption of spare parts does not comply with the described dependencies, use this forecasting model will inappropriate.

Factors associated with the organization of logistics support service company, have a strong influence on the need for spare parts according to 67% of specialists. These factors are most manageable at the service enterprise level. According to experts, the complexity of the design, the loss of defects, the unification and the number of complaints give little influence on the need for spare parts (55-60%). Experts also attributed the optimum use of storage facilities to the factors that have little impact. This is due to the fact that the task of efficient use of storage facilities lies mainly with the staff of spare parts who did not participate in the survey.

The survey participants were also asked to name factors that were not included in the list but which, in their opinion, had a significant impact on the need for spare parts.

Summarizing the wording of the experts' answers, we can distinguish the factors not included in the list, namely: the possibility of prolonging the life or restoration of worn parts, as well as the popularity of the car brand and reputation of the service company. These factors should also be explored in future studies.

The randomness check of the levels of a number of residues is performed based on the criterion of peaks (turning points). The sequence level is considered to be the maximum if it is greater than two adjacent levels, is $(\varepsilon_t - 1 < \varepsilon_t > \varepsilon_{t+1})$ or the minimum if it is less than both adjacent levels, that is $(\varepsilon_t - 1 > \varepsilon_t < \varepsilon_{t+1})$. In both cases, it is considered a turning point. The total number of turning points is denoted by R . The randomness criterion with 95% confidence is the inequality:

$$p > \left[\bar{p} - 1,96\sqrt{\sigma_p^2} \right],$$

where $\bar{p}$ - mathematical expectation of turning points number

$$\bar{p} = \frac{2}{3}(n-2),$$

σ_p^2 - number dispersion of turning points:

$$\sigma_p^2 = \frac{16n-29}{90}$$

If the inequality holds, the prediction model is considered adequate.

The number of peak points for both models is six ($p=6$; $\bar{p}=6,67$; $\sigma_p^2=1,81$). Prognostication models the need for spare parts are adequate.

The calculated value of the Fisher criterion for regression models in all cases is more critical. It follows that the regression models are adequate.

In the analysis of the actual cost of spare parts for 2018 - 2019 graphs were drawn of the dependence of the average cost of spare parts by the service company. Changes in the amount of consumed parts of the first group occur smoothly, without sharp fluctuations. For the second group of parts it is necessary to allocate 3 obvious maximum costs of spare parts (Fig. 2).

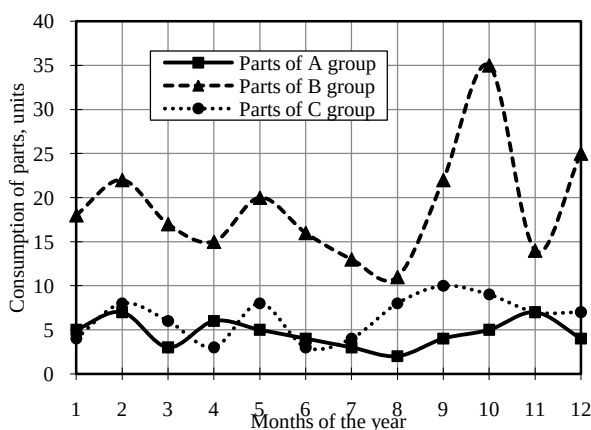


Fig. 2. Distribution of parts costs in the spare parts service by months of the year

The maximum cost of spare parts is in the spring months, when many car owners traditionally prepare their car for the period of summer operation, as well as in the late autumn before the start of the winter period of operation. The minimum outgo of spare parts for the second group is in the second half of summer, which is associated with the period of summer holidays.

The fluctuations in demand for spare parts of the third group are similar to the fluctuations in the second group. In many studies of seasonal variations in outgo of body parts and changes in the number of road traffic accidents (RTA). According to statistics, the increase in the number of accidents begins in August and lasts until November. This confirms the schedule of spare parts for the service. In the period October - November, the queues for body repair increase, and often there is a shortage of body spare parts.

Many owners in this case order spare parts in the spare parts store, and for repair turn to small service companies, where repair is possible in a shorter time. Said above is confirmed by the increase in the outgo of spare parts in the store in the middle of November-December. The situation is the same in April-May due to the increase in the number of used cars. The peak of spare parts in the store falls in April, and the peak of service costs shifts to May.

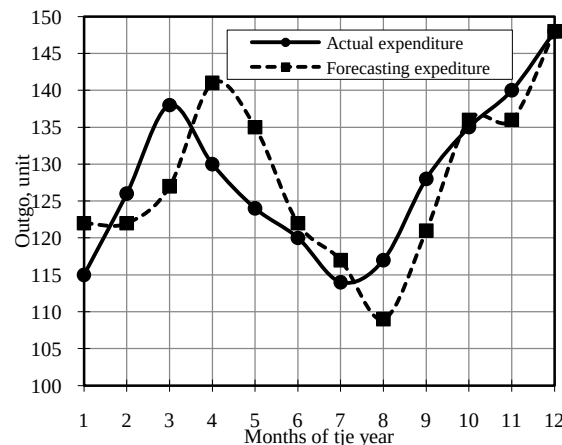
The ABC method is used to determine the nomenclature and the volume of spare parts for storage in warehouses. According to this method, the whole nomenclature of parts of a particular car (in terms of demand) is divided into groups A, B, C:

I group A – high demand parts високого попиту,

II group B – average demand parts,

III group C – exceptional demand parts.

The research results of operational reliability of vehicles show that there is a limited number of parts that more often fail and thus determine the labor and material outgo of maintaining cars in working order.



According to the results of studies, graphs of the distribution of actual and projected injection nozzle consumption by months of the year are being constructed (Fig. 2).

Fig. 2. Distribution costs and the need for the injection nozzles by months of the year

There is a link between the nomenclature of reliability-limiting parts (Detail, Limit, Reliability), defined by different operating methods, and the ABC method used to manage supply and inventory. The single cost criterion provides an opportunity to determine the nomenclature of Group A parts and gives them an upper cost estimate; the comprehensive criterion limits the overall nomenclature of the details of groups A and B and provides a cost estimate. All other details must be in Group C.

Cost index that takes into account all types of costs associated with each spare part:

$$C_i = M_i(CWC_i + C_{LC}_i + C_{DR}_i),$$

where M_i - the number of i parts expended over a period of time (or car mileage), units.;

CWC_i - wholesale cost of i parts;

C_{LCi} - the cost of labor costs to eliminate the failure of i parts;

C_{DRi} - profit loss of the enterprise, connected with the car downtime in repair, in particular, due to the absence of the spare part.

The values obtained are C_i ranked and arranged in descending order:

$$C_a \geq C_b \geq \dots \geq C_i \geq \dots \geq C_m$$

i is assigning new indexes: $a=1, b=2, \dots, m=N$, where N - the total number of item names (nomenclature), that is:

$$C_1 \geq C_2 \geq \dots \geq C_j \geq \dots \geq C_N.$$

For convenience of calculations, relative values of the considered cost indicators (in percent) are introduced, thus normalization of indicators is performed.

$$q_i = \frac{C_i}{\sum_{i=1}^N C_i}.$$

Thus, it is clearly in evidence the method of analytical calculation in considered example.

At experimental studying of change in flow rate of diesel engine nozzles in 2019 it was revealed that spare part changing cost during the year is nonlinear. As the results of the analysis of the dynamics of the cost of spare parts are showed, smooth variations are characterised of engine parts consumption.

To substantiate the choice of the prediction model, depending on the nature of the curve of the cost of spare parts, the need for spare parts on the example of injection nozzles for 2019 is calculated, and then compare the values obtained with the actual cost of these parts.

4. Conclusion

1. The high growth of the car fleet contributes to the increase in the need for service companies in the spare parts and materials necessary for its operation.

2. Service companies have a huge amount of competitors. Deficiencies in the logistics system support lead to a decrease in the competitiveness of the enterprise in all areas of activity.

3. Methods of forecasting the needs of service companies in spare parts have been developed. The proposed method allows to formalize the processes of determining the needs of enterprises in

spare parts, to increase the efficiency of existing systems of logistical support of service enterprises.

4. Methodical principles of the choice of mathematical models for forecasting the needs of car service companies in spare parts were developed, on the basis of which the areas of the most effective use of mathematical models were determined.

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Correlation of light wavelengths on spectral cameras and vegetation indexes in barley crop scouting

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Abstract: *This paper presents a case study of a barley field experiment that was periodically scouted using a drone spectral camera. The camera has 4 bands so barley was scouted using 4 wavelengths of light - Green, Red, Red Edge and Nir Infra Red (NIR). Based on these wavelengths it is possible to calculate different vegetation indexes known in science and practice. In this paper, 15 such indices were used. The research work concerned the observation of correlation between individual wavelengths and corresponding vegetation indexes. This paper seeks to emphasize the importance of particular wavelengths and spectral areas in crop scouting.*

KEYWORDS: CROP SCOUTING, VEGETATIVE INDEX, CORRELATION

1. INTRODUCTION

Sensors are available today which can accurately detect crop nitrogen status during the growing season. Algorithms have been developed which relate crop canopy reflectance in specific wavebands to how much nitrogen fertilizer is needed. Sensors can be either passive (using sunlight) or active (using an internal light source). Sensors can be used on a variety of platforms: handheld, ground or aerial vehicle, satellite. Active sensors can be used around the clock, regardless of cloud cover or sun angle [1]. With the global development of industry and population growth on Earth, there is a growing need for spatial data. They should provide a wide range of information that is useful in different spheres. The Unmanned Aircraft System (UAV) for air crop scouting consists of a multispectral camera and a camera carrier in the form of an unmanned aerial vehicle (UAV) - drone. Such systems are used primarily in agriculture for monitoring plant health, monitoring evapotranspiration and irrigation and for monitoring plant nutrition [2]. Farmers, agencies, agricultural research community and firms require access to tools to analyze and estimate stressed and productive regions to obtain higher yield. At present, this is performed manually using visual interpretation. Recently there has been some development in the detection and mapping of the stressed crop by use of hyperspectral analysis; but, there is an information gap between farmers and information about the location of the crop under stress in the given area [3]. The popularity of UAVs in scientific data gathering and applications, especially the use of small multi-rotor UAVs is quite widespread. These portable multi-rotor UAVs are portable, low-cost, highly maneuverable, and easy to handle. These features make such UAVs attractive to scientists and researchers worldwide. There has been a sudden spurt of UAV use in niche domains such as agriculture. Agriculturalists are choosing UAV-based field operations and remote sensing over the time-tested satellite-based ones, especially for local-scale and high spatiotemporal resolution imagery [1].

Generated maps of vegetation indexes on the basis of taken images of the experimental plot from the drone for different heights and overlaps showed no deviations between them. Therefore, for the further application of these maps as inputs during the first phase of precision agriculture, flight altitude and overlap during recording are not significant factors, especially when recording larger areas [4]. In the past several decades, remote sensing has played a vital role in providing up-to-date and detailed information for monitoring atmospheric and terrestrial environments at the regional, continental, and global scales. Such information is typically generated based on remotely sensed images processed into spectral vegetation indices. Among the various spectral vegetation indices derived from remotely sensed imagery, one of the most widely used vegetation indices is the normalized difference vegetation index (NDVI), which is defined as the difference between the red and near-infrared (NIR) reflectance divided by their sum. Previous studies showed that NDVI is strongly related to the fraction of absorbed photosynthetically active radiation (FPAR), leaf area index (LAI), and net primary production (NPP). NDVI has also been used in a range of applications including the study of vegetation-climate interactions, detection of long-term vegetation

changes, assessment of vegetation functional characteristics and modeling of the global carbon balance. Furthermore, NDVI time series data has been successfully used in a variety of applications, including global change investigations, phenological studies, crop growth monitoring and yield prediction, drought and desertification monitoring, wildfire assessment, and climatic and biogeochemical modeling [5].

2. MATERIALS AND METHODS

2.1. Materials

When planning a UAS flight just before crop scouting, the operator is tasked with specifying the flight altitude and switching of successive shots. Reconnaissance was first performed for an altitude of 70 m with 60% in recording overlap. The weather for field reconnaissance was ideal. During this experiment, a Parrot Bluegrass UAV with propellers equipped with a 4-channel Parrot Sequoia multispectral camera was used. Channel have own wave length: Green (550 nm +/- 40 nm), Red (660 nm +/- 40 nm), RedEdge (735 nm +/- 10 nm) and NearInfraRed - NIR (790 +/- 40 nm). Drone management was performed through an Parrot Fields manufacturer's application installed on the remote computer. Crop for scouting was barley.

2.2. Methods

Correlation describes the intensity and direction of the linear relationship between the two variables. With the IBM SPSS Statistics v.21 software, it is possible to calculate the Spirman's correlation coefficient r_0 . This coefficient is suitable for ordinal quantities or ranked quantities. The correlation value can be between 0 and 1. Various authors give different interpretations, however, Cohen gives the following guidelines for the correlation size: a small correlation of $0,10 < r_0 < 0,29$, a mean correlation of $0,30 < r_0 < 0,49$, a large correlation of $0,50 < r_0 < 1$. These guidelines apply regardless of whether there is a negative sign in front of the coefficient r_0 . A negative sign indicates its direction, not the magnitude [6].

3. RESULTS

Site srop condition of barley on this field per display distribution, is given in Fig. 1 Such groupings vegetation index can be defined organizational zone explored part of the plot. Because the UAV contains a 4-channel camera, it is possible to form 4 different reflection coefficients on 4 different maps. The coefficients are listed simultaneously in a table containing a total of 882904 coordinates and corresponding coefficients.

This table is base for calculation of 15 different vegetation indecis regarding their definition in science papers for each of 882904 coordinates and corresponding coefficients.

SR - Simple Ratio is ratio of NIR and Red reflection. Intensity of red light reaching the canopy is slightly greater than that of near infrared, but on the forest floor the relative intensity of the infrared is many times greater due to the selective absorption of radiation by leaf pigments. The intensities of infrared and red light can be expressed as a ratio, and this ratio can be calibrated with leaf-area index measured directly at several points in a forest. To maximize the ratio as leaf-area index increases

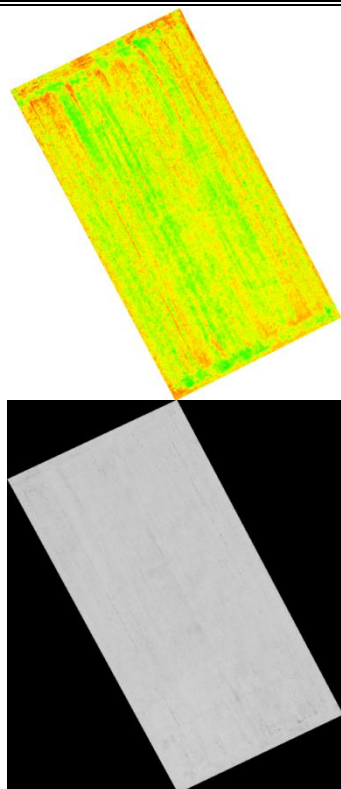


Fig. 1. Map of NDVI index on the experimental field and detail coordinates map

, the ratio should be between light at 800 and 675 nm [7].

A Modified Simple Ratio (MSR) is proposed for retrieving biophysical parameters of boreal forests using remote sensing data. MSR is an improved version of RDVI for the purpose of linearizing their relationships with biophysical parameters [8].

GRVI is calculated as the normalized difference between the visible green and red bands. As green leaves develop, the reflectance of visible green increases and that of red decreases. In contrast, at the time of leaf senescence, the reflectance of green decreases and that of red increases [9].

The DVI is very sensitive to changes in soil background; it can be applied to monitoring the vegetation ecological environment. Thus, DVI is also called Environmental Vegetation Index (EVI) [10].

GDVI - Green Difference Vegetation Index was originally designed with color-infrared photography to predict nitrogen requirements for corn [11].

NDVI is defined as a normalized ratio of reflectance factors in the near infrared (NIR) and red spectral radiation bands where NIR and Red are the surface bidirectional reflectance factors for their respective MODIS bands on the TERRA platform satellite. NDVI exploits the contrast between the red and NIR reflectance of vegetation, as chlorophyll is a strong absorber of the red light, while the internal structure of leaves reflects highly in the NIR. The greater the difference between the reflectance in the red and NIR portions of the spectrum, the more chlorophyll is found in vegetation canopy [12].

The RDVI was proposed to combine the advantages of the Difference Vegetation Index and the NDVI for low and high LAI values, respectively [13].

GNDVI - Green Normalized Difference Vegetation Index is also a modification of NDVI that in turn uses the green band instead of the red one. The response in green reflectance is associated more to the biophysical variables of vegetation and chlorophyll content [14].

TDVI - Transformed Difference Vegetation Index shows the same sensitivity as the Soil Adjusted Vegetation Index (SAVI) to the optical properties of bare soil subjacent to the cover. It does not saturate like NDVI and SAVI and it shows an excellent linearity as a function of the rate of vegetation cover [15].

NDWI - Normalized Difference Water Index was done to: (1) maximize the typical reflectance of water features by using green

light wavelengths; (2) minimize the low reflectance of NIR by water features; and (3) take advantage of the high reflectance of NIR by terrestrial vegetation and soil features [16].

NDRE - Normalized Difference Red Edge Index is a modification of NDVI, which uses red edge band instead of red band. According to the previous studies, NDRE can detect stress in woodlands earlier and is more sensitive to changes in chlorophyll content [14].

WDRVI - Wide Dynamic Range Vegetation Index was invented to achieve better correlation with Leaf Area Index, especially in its high values, where NDVI is not sensitive to LAI changes [14].

SAVI - Soil Adjusted Vegetation Index is independent of factor L. The range of L is from 0 to 1. In practical applications, the values of L are determined according to the specific environmental conditions. When the degree of vegetation coverage is high, L is close to 1, showing that the soil background has no effect on the extraction of vegetation information. This kind of ideal conditions is rarely found in natural environments and can be applicable only in the case of a large canopy density and coverage. The value of L is around 0.5 under most common environmental conditions. When L is close to 0, the value of SAVI is equal to NDVI [10].

MSAVI2 - Modified Secondary Soil Adjusted Vegetation Index does not rely on the soil line principle and has a simpler algorithm; it is mainly used in the analysis of plant growth, desertification research, grassland yield estimation, LAI assessment, analysis of soil organic matter, drought monitoring, and the analysis of soil erosion [10].

OSAVI - Optimized Soil Adjusted Vegetation Index has the following formulation: $OSAVI = (NIR - Red) / (NIR + Red + 0.16)$, where the soil adjustment coefficient (0.16) was selected as the optimal value to minimize variation with soil background [17].

4. DISCUSSION

Table 1 shows a matrix view of the relationship between the individual variables of coefficient reflection (NIR, RedEdge, Red, Green) that were the subject of research in the context of 15 different vegetation indices (VI). These relationships in terms of correlation are shown by means of the Pearson correlation with an appropriate statistical significance for each pair of mutually crossed variables.

Table 1 gives a matrix view of the relationship between the individual variables that were the subject of research in the context of crop scouting. These relationships in terms of correlation are shown using the Pearson coefficient with an appropriate statistical significance for each pair of 15 x 4 mutually crossable variables. The strength of the correlation, or how many percentages of the variance of one variable, explains the other variables, are defined in accordance. In this sense, it is particularly important to highlight those relations between variables where $r_0 > 0.50$, because this suggests a large correlation.

5. CONCLUSIONS

Sensors are available today which can accurately detect crop nitrogen status during the growing season. Algorithms have been developed which relate crop canopy reflectance in specific wavebands to how much nitrogen fertilizer is needed. There are various methods for measuring the vegetative index through the NDRE as well as the different devices for which this is accomplished. Measurement can be done using satellites, using unmanned aircraft equipped with appropriate sensors for spectrometry or using sensors mounted on a work machine or a special platform that is aggregated by a tractor. All measurement methods are characterized by the fact that NDRE and NDVI are the most used indices for crop scouting. They are most commonly applied to commercial sensors. Regarding the values $r_0(NDRE, NIR) = 0.605$, $r_0(NDRE, RedEdge) = -0.613$, Pearson's correlation coefficient has just been shown, for a specific example, that the reason for this is the highest level of correlation between the reflection coefficients obtained during recording and the corresponding indices calculated by a defined algorithm.

	VI	NIR	RedEdge	Red	Green
1	SR (RVI)	.265**	.075**	-.609**	-.097**
2	MSR	.450**	.116**	-.644**	-.089**
3	GRVI	.278**	-.118**	-.100**	-.661**
4	DVI	.241**	.073**	-.219**	-.012**
5	GDVI	.238**	-.017**	-.008**	-.232**
6	NDVI	.572**	.143**	-.588**	-.067**
7	RDVI	.594**	.149**	-.609**	-.070**
8	GNDVI	.585**	-.062**	-.043**	-.609**
9	TDVI	.117**	-.056**	-.180**	-.100**
10	NDWI	-.585**	.062**	.043**	.609**
11	NDRE	.605**	-.613**	.186**	-.044**
12	WDRVI	.213**	.076**	-.611**	-.101**
13	SAVI	.229**	.068**	-.212**	-.012**
14	MSAVI2	.106**	-.052**	-.156**	-.090**
15	OSAVI	.229**	.067**	-.212**	-.012**

** . Correlation is significant at the 0.01 level (2-tailed).

Table 1. Pearson Correlation between VI and coefficient reflection

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On the possibility of conducting fast and reliable soil tests

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Summary: *The current interest in soil awareness is largely due to the increased importance of growing crops in a changing climate. It is characterized by prolonged droughts, followed by short but intense rainfall, often accompanied by strong winds and low temperatures. In a number of situations and due to insufficient information about the condition of the soil and the applied technologies for its treatment, the latter is not able to absorb rainwater, surface water runoff is formed, which exports large amounts of fertile soil and nutrients. An innovative approach is proposed to perform fast and accurate soil tests using its electromagnetic conductivity. A number of physical, chemical and biological properties can be determined by this method.*

Keywords: CLIMATE CHANGE, TILLAGE TECHNOLOGIES, SOIL PROPERTIES, ELECTROMAGNETIC CONDUCTIVITY.

1. Introduction

Preservation and increase of soil fertility is a set of application of modern agricultural practices, expressed in technological activities for tillage, hydro-ameliorative measures, optimal fertilization with mineral and organic fertilizers and use of pesticides, and return to the soil of organic waste processed mechanically or composted, etc., [36].

A significant part of the soils in Bulgaria are affected to varying degrees by degradation processes, which include all types of soil erosion, acidification, salinization, pollution, destruction, etc., which reduces the ability of soils to absorb carbon and increase greenhouse gases from unsuitable agricultural activities. All arable land is characterized by increased mineralization of soil organic matter, which is why it is recommended to apply annual organic materials (by plowing, manure, compost, etc.) in order to enrich the soil with highly active humic substances directly related to plant nutrition.

The reduction of nutrients in the soils of arable lands is associated with the removal of the surface soil layer due to erosion, oxidation of organic carbon from areas with intensive cultivation, improper farming techniques, degradation of soil structure during soil compaction and others. Their rational use is the result of properly applied technologies for growing crops, optimized plant nutrition, efficient use of available water resources and more. To this end, it is necessary to have sufficient and reliable information on the condition of the soil, [2,3,15].

As a result of complex chemical and biochemical processes, a significant part of the organic matter from plant and animal residues that has entered the soil is transformed into specific organic matter with a complex structure, digestible for plants, etc. hummus. Humic substances are concentrated in the one-meter soil layer. The amount and composition of soil organic matter (OM) depends on the climate, microbiological activity and the composition of the humicizing materials.

Current soil health tests and the indicators included in them vary from laboratory to laboratory and there is currently no consensus on which basic biological measures should be included in a comprehensive soil health test, [8].

Finding a widely applicable, relatively inexpensive, convenient, but scientifically stable test for soil health, which is also related to the sustainability of yields, is a challenge for the scientific community, [8,10,11].

On the eve of the fourth industrial revolution and in the conditions of intensively developing digital technologies, agriculture also became an environment for their application. The capabilities of these new technologies provide the farmer with solutions that make it possible to ensure and maintain a balance between conserving natural resources and meeting the needs of the rapidly growing population of the planet for quality food and raw materials for industry, [1].

The system for the application of digital technologies in agriculture must be developed on a top-down basis and implemented 'bottom-up'. In this way, and with their help, farmers could be successful despite their differences in knowledge and experience. Even a novice farmer can quickly become successful in his business, something that his other colleagues have achieved after many years of experience and in which they have often relied on the method of "trial and error", [23, 25].

The basis of the majority of digital technologies in agriculture is the use of proven by science and practice simulation models, describing separately or in combination various physical, mechanical, biological and other processes occurring in the cultivation of crops, [6]. In this way, agricultural technologies can become proactive, i.e. they should react in a timely manner to changes in the conditions of their implementation and to anticipate the expected end result. The sustainability of such technologies largely depends on maintaining a constant connection with the environment of their application. Simulation models, in addition to being the result of this connection, can be adapted to processes and phenomena that appeared at a later stage of their creation as a result of changes in the factors influencing the object of impact, [6, 36,38] .

Proactive technologies provide different opportunities for decision-making at each stage of their implementation, i.e. at any stage of plant development or the state of the resources used. Therefore, a successful solution will depend on the correct application of good practices in the individual stages, [12,14].

EU requirements are for mutual adherence to good agricultural practices. If the requirements are not met, farmers run the risk of losing payments under the various programs. EU rules alone are not enough to solve the problem, as farmers in the region (and not only in the region) do not clearly understand how to apply such technologies.

The main reason for the unclear and partial application of digital technologies stems from the lack of understanding of farmers about how such technologies work and can complement each other so that they are useful in practice. Their misunderstanding is often accompanied by the expression: "This is too complicated, ". Farmers focus mainly on short-term results and do not pay much attention to long-term ones. Current agricultural practices are affected by wrong incentives, lack of sufficient training and modern knowledge.

It is important to note that in Bulgaria consulting services cannot fully provide expert advice on innovations in the application of technologies in agriculture. Usually the advice that Bulgarian farmers receive regarding innovations is based on foreign experience and products, which for the most part have not been proven for the conditions in Bulgaria.

2. Materials and method

There are three main groups of indicators that determine the health of the soil. These are the groups that reflect their physical, chemical and biological properties. Each of them contains several

indicators that interact and each of them affects the properties of the others [9,13,16], Fig.1.



Figure 1. Interaction between the main groups of soil properties

The predominant part of these indicators can be determined with modern means for analysis and digitalization.

Their determination shows the complex condition of the soil, also called "soil health". There is currently no consensus among the scientific community as to which indicators are key in the individual groups and which are their derivatives.

Current soil tests are relatively expensive, vary from laboratory to laboratory, and show inconsistent management results and practices.

Additional research is needed to calibrate and validate all soil health indicators, as well as innovative methods of analysis. This is especially true for biological indicators.

The ideal test for soil condition should be:

- widely applicable to all types of soils and at any time;
- sensitive and adaptive to different cultures management practices;
- reliable in relation to the submitted information;
- adaptable to the methods of digital technologies in order to filter and present the analyzed information for different groups of users.

A good soil health test should be convenient for the farmer to be able to take a sample, perform a measurement and obtain the final result. A number of measurements to determine physical quantities usually have to be made in the field, and some using special equipment.

One of the significant measurements that can be used as an indicator of soil fertility and to digitize it is its electrical conductivity, [19,21,27,29,33].

Soil electrical conductivity (ECa) is a measurement that correlates with soil properties that affect crop productivity, including soil texture, cation exchange capacity (CEC), drainage conditions, organic matter level, salinity, soil characteristics. the individual layers of the soil, the presence of nutrients, etc ..

The current flow in determining the ECa in the soil passes through three media:

- liquid phase medium. It contains dissolved solids contained in groundwater. The liquid medium occupies the large pores;
- solid-liquid phase medium. These are mainly through exchange cations associated with clay minerals, [20,22,24,28,44];
- medium of solid soil particles that are in direct and continuous contact with each other (Rhoades et al., 1999a), [41,42,43].

Due to the presence of the three conduction media, the measurement of ECa is influenced by several physical and

chemical properties of the soil, such as soil salinity, cation saturation rate, water content and bulk density, [13, 29,45].

The percentage of saturation and bulk density are directly influenced by the content of clay and organic matter (OM). In addition, the exchange surfaces on clays and OM provide the medium of the solid-liquid phase mainly by exchange cations. Therefore, the content and type of clay, cation exchange capacity (CEC) and OM are recognized as additional factors influencing ECa measurements. ECa measurements should be interpreted taking into account these influencing factors.

Another factor influencing ECa is temperature. Electrolyte conductivity (EC) increases by approximately 1.9% per 1°C temperature rise. EC is usually expressed at a reference temperature of 25 °C, [16,46].

Studies show that the optimal values of ECa for fertile soils should be in the range of 110 - 570 millisiemens / meter (mS / m), [18,47].

High ECa values indicate the presence of negatively charged particles (of clay and organic matter) and therefore the presence of more cations (which are positively charged) and are retained in the soil. These are the cations of sodium (Na⁺), ammonium (NH₄⁺), potassium (K⁺), calcium (Ca²⁺), magnesium (Mg²⁺), hydrogen (H⁺), iron (Fe²⁺), aluminum (Al³⁺), copper (Cu²⁺), zinc (Zn²⁺) and manganese (Mn²⁺), which are useful for plant growth and development.

ECa of the soil is influenced by a number of its properties. In order to be used as an indicator of soil health and therefore to inform the farmer of the activities to be undertaken, the relationship between ECa and other soil properties must be understood.

A field in which the EU is distributed according to a normal law is considered homogeneous. Deviations from the normal law are an indicator of deviations in their properties, [4,5], fig.2.

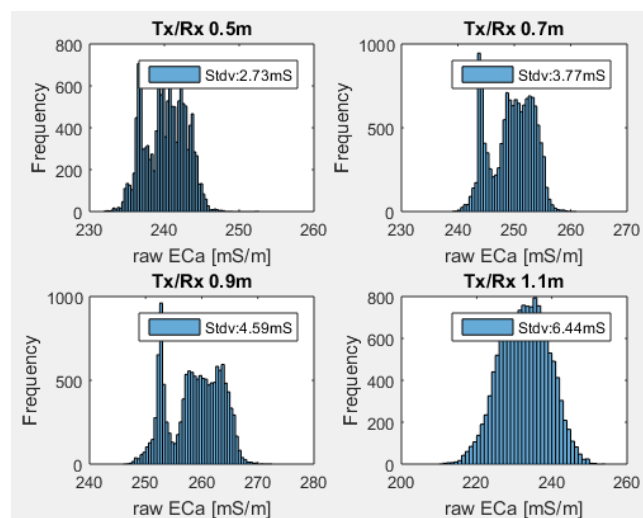


Figure 2. Distribution of EU by depth of the studied horizons

Soil salinization

The first indicator that must be taken into account when determining the condition of agricultural land is their salinity. About 35,000 ha of arable land (6% of agricultural land and 2.4% of irrigated land) are affected by salinization processes. The area of saline soils and the degree of development of the process are constantly increasing. The reasons for this are both global and regional in nature - unfavorable and lasting trends of climate change and hydrological conditions, irrigation with highly mineralized groundwater, natural or man-made deterioration of drainage conditions of intensively irrigated areas and increased fertilization with mineral fertilizers.

The vulnerability of soils to salinization and swamping is manifested in the lowest parts of the valley bottoms as a locally

negative effect of the irrational artificial irrigation carried out in these areas.

Soil ECa is often used to determine salinity. Salinization is an indicator for determining the salt content of the soil. A basic rule for determining salinity is very high ECa values ($> 1600 \text{ mS/m}$). The opposite is also true: very low ECa values ($0-200 \text{ mS/m}$) indicate that the soils are not saline. Salinity is most affected by sodium cations, especially if they exceed 100 mg/kg of soil. Sodium can be extracted from the soil and thus reduce the level of ECa by adding gypsum, [18].

The research and the graphs in Fig. 3 show that from the point of view of salinization, the studied area is good for agricultural use.

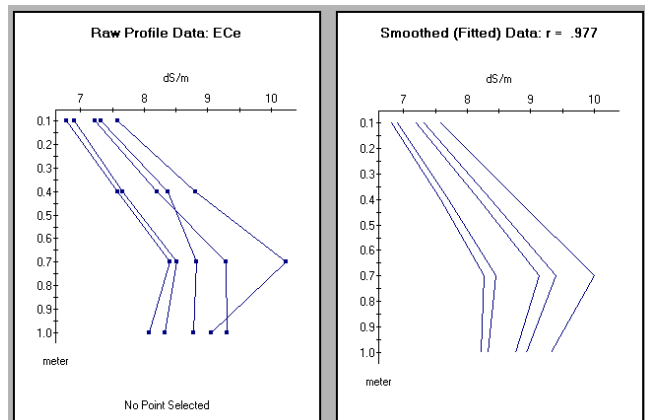


Figure 3. Soil salinity values at the investigated soils

The texture (content of sand, clay and fine particles), salinity, moisture and soil density are the properties that have the greatest impact on ECa.

Although the texture of the soil cannot be changed by its treatments, it is important to note how it interacts with ECa, [19,20,21].

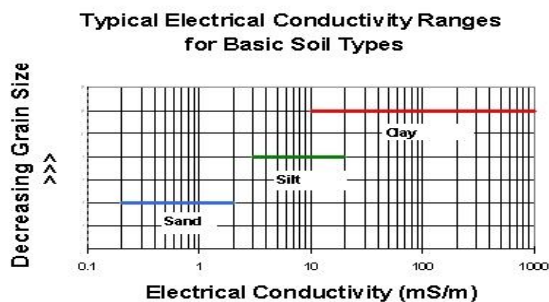


Figure 4. Soil texture (sand, clay and silt content)

The sand has a low ECa ($1-10 \text{ mS/m}$), the fine particles (sludge) have average values ($8-80 \text{ mS/m}$), and the clay - high ECa ($20-800 \text{ mS/m}$).

This means that sandy soils have poor capacity to retain cations and easily lose nutrients compared to clayey and muddy soils.

Clay and muddy soils are much more likely to retain cations and the loss of nutrients will be much less than sandy soils.

Understanding this interaction, it can be considered that for each field with a specific texture at higher values of ECa lower values of mineral fertilization should be applied, as a small part of what is used will be lost by washing in more -lower soil layers.

The addition of organic matter to sandy soils can improve their ability to retain cations and thus improve ECa levels.

Another possibility for analysis of the measurement is that there are still parts of the fields in which the soil texture has not been measured. In such cases, ECa can present a good picture of the sand, clay and / or silt content using the above information.

Another indicator determining the physical properties of the soil is its density. The all-season use of heavy and energy-saturated machines, the annual plowing of the soils at the same depth, as well as other types of treatments at high humidity worsen their physical properties, Fig.5.

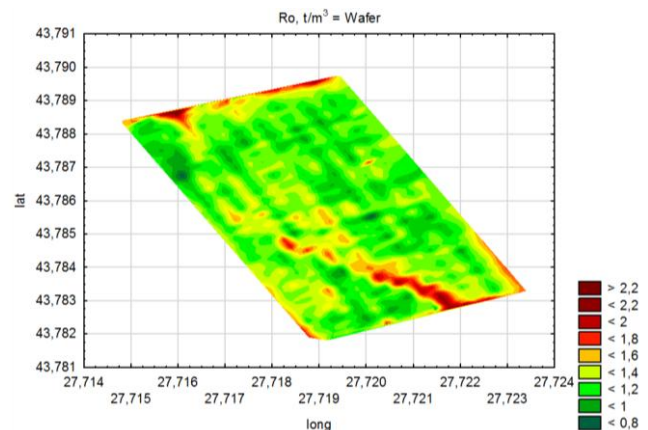


Figure 5. Relationship between ECa and soil density

The graphical dependence of fig. 6 shows a clear dependence that as ECa values decrease, soil density increases.

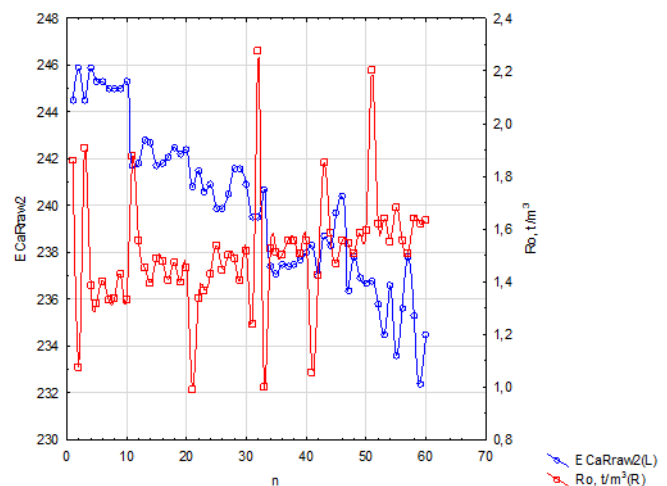


Fig.6. Graphical relationship between ECa and soil density

Soil moisture

The level of soil moisture plays a decisive role in the absorption of nutrients. Only water-soluble forms of these elements can be assimilated by plants. In case of shortage, the nutrients can be imported as fertilizers, but again the degree of their absorption is directly dependent on the presence of water in the root zone.

The indicator for the water content in the soils in the layer $0-100 \text{ cm}$ is the percentage of the maximum field moisture content (PPV) at the beginning and the end of the vegetation period. The relative and absolute soil moisture can be determined.

Maps for spatial distribution of the water content in the layer $0-100 \text{ cm}$ as a percentage of the maximum field moisture content (PPV) are widely used. It is more important to determine the soil moisture for each field and on this basis to calculate the norms for the introduction of nutrients into the soil.

It is important to note that when measuring ECa in the field, the higher the ECa, the more moisture the soil has. The explanation is in most cations in the soil solution. In general, water is a good conductor of electricity, and therefore, the more water there is in the soil, the better the soil conducts electrical impulses. In FIG. 7 shows the soil moisture for each point of the studied field. In the studied case the water content in the soil is in low limits.

For the conditions in the Republic of Bulgaria it is necessary to take urgent measures to improve the conditions for maintaining optimal

soil moisture for a long period of time. It is best for the soil moisture to be in the optimal range throughout the growing season. This can be achieved by implementing results-based scientific solutions to tackle the effects of climate change.

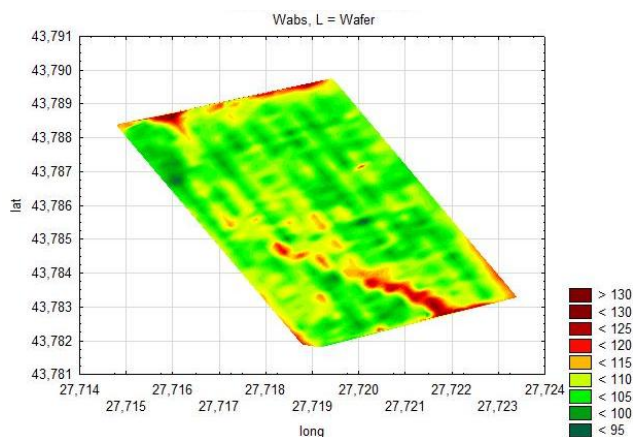


Fig.7. Soil moisture determined by the ECA

Relationship between ECA and soil chemical properties

In the cultivation of agricultural crops, in practice, a biological change of the soil in a given field occurs. This is due to the addition (introduction) of nutrients and organic matter into the soil and through their removal through plants or some degradation processes. The ratio of organic (active) carbon: nitrogen (C:N) shows the ratio of organic carbon to total nitrogen in the analyzed material. For agricultural purposes, such information can be obtained after soil analysis. The stock of soils with nutrients is determined by the content of total nitrogen, organic (active) carbon and total phosphorus, as well as the ratio between organic carbon and total nitrogen.

The C/N ratio is an indication of the conditions for the existence and development of soil biodiversity and for the stability of the soil structure. This attitude varies widely. In 2017 - 2018, the information about the presence of values of organic carbon in the soil 100-120 mg / kg of soil prevails. In some cases it reaches values up to 280 mg / kg soil. These values are not high.

The content and ratio of nutrients in the soil are directly related to soil fertility and plant nutrition.

Organic materials consist of carbohydrates, lignins, tannins, fats, oils, waxes, resins, proteins, minerals and other components.

With the exception of the mineral fraction, organic compounds are composed of different ratios of carbon and nitrogen. This is usually reduced to the C:N ratio.

Carbohydrates are composed of carbon (C), hydrogen (H₂) oxygen (O₂) decompose relatively easily to carbon dioxide (CO₂) and water (H₂O), plus a small amount of other by-products.

Protein-like materials are the main source of nitrogen compounds, as well as sources of carbon, hydrogen and oxygen, and are important for the development of the C:N ratio and the possible degree (rate) of decomposition of organic materials.

Aerobic heterotrophic bacteria are mainly responsible for the breakdown of large amounts of organic compounds generated on the earth's surface. These organisms usually have a C:N ratio of about 8: 1.

When organic residues are attacked by bacteria under suitable habitat conditions, some of the carbon and nitrogen are assimilated into the new and rapidly growing microbial population and a large amount of carbon dioxide is released into the atmosphere.

The number of bacteria is strongly controlled by the C:N ratio of the organic substrate.

As a rule, when organic residues have a C:N ratio of <30: 1 and are added to the soil, there is very little noticeable reduction in the amount of mineral nitrogen available for higher plant forms.

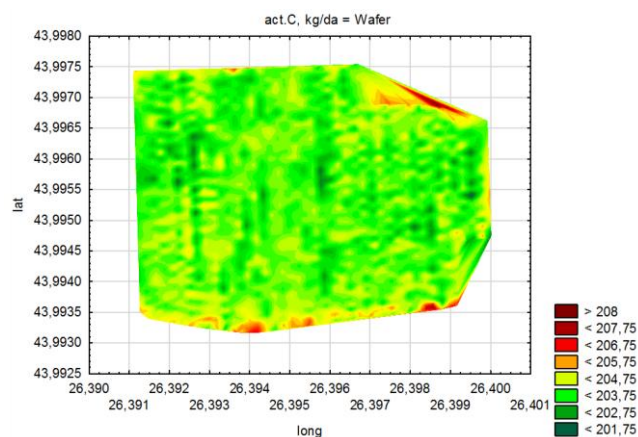


Figure 8. Spectral map for the presence of organic carbon in the soil

However, as the C:N ratio begins to increase to values greater than 30:1, there may be competition for mineral nitrogen forms.

The C:N ratio of plant material can well reflect the type and stage of plant growth. The younger plant usually contains more carbohydrates and less lignin, while the older plant of the same species will contain more lignin and less carbohydrates. The lignin tissue found in trees can have a C: N ratio of up to 1000:1.

The relative importance of the C: N ratio refers to two problems:

- the first is the rate of decomposition of organic matter to the low ratio C: N (formation of humus with an approximate ratio C: N = 10: 1);
- the second is the immediate presence of mineral nitrogen (NH₄ + 4) to meet the demand for higher plant needs.

In cases where a C: N ratio of 30: 1 occurs (ie where there is a large amount of organic residue), the addition of mineral nitrogen to the organic residues is applied. This is a common practice to increase the rate of mineralization (rot) and to reduce the potential for nitrogen deficiency in higher plants.

Composting organic residues allows the decomposition of residues to take place without competition from higher plants for mineral nitrogen and also reduces the C: N ratio of the resulting mass to a C: N value of less than 20:1.

When this material is added to soil, it is unlikely to increase the potential for nitrogen competition between microorganisms and higher plants.

The largest CO₂ emissions from soils are due to tillage and amount to 20-40 t CO₂ / ha per year.

Nitrogen is a food source for microorganisms that break down carbon material. When the process is complete, soil microorganisms die and mineralize. In this way, the microbial nitrogen returns to the soil and becomes available to the plants.

The assessment of soil stock is made on a 5-point scale according to the content of organic carbon C, total nitrogen (N), phosphorus (P) and the ratio between organic carbon and total nitrogen in soils (C / N), which is regulated in Ordinance № 4 for soil monitoring (Table 1).

Table 1. Scale for assessment of the content of nutrients in the soil. . Source: EEA, Report on the State of the Environment, MoEW, 2018

Parameters	opr. C mg/kg	o6m N mg/kg	o6m P mg/kg	C/ N
Very low	< 50	<0,98	< 398	< 8
Low	50 -100	98-133	398 - 553	8 -10

Average	100 -150	133-195	553 - 924	10-12
High	150 -250	195-286	924 - 1599	>12
Very high	> 250	>286	>1599	> 30

By determining the electromagnetic conductivity of the soil and the developed methodology, it is possible to develop models for determining the amount of nutrients in the soil, fig. 9.

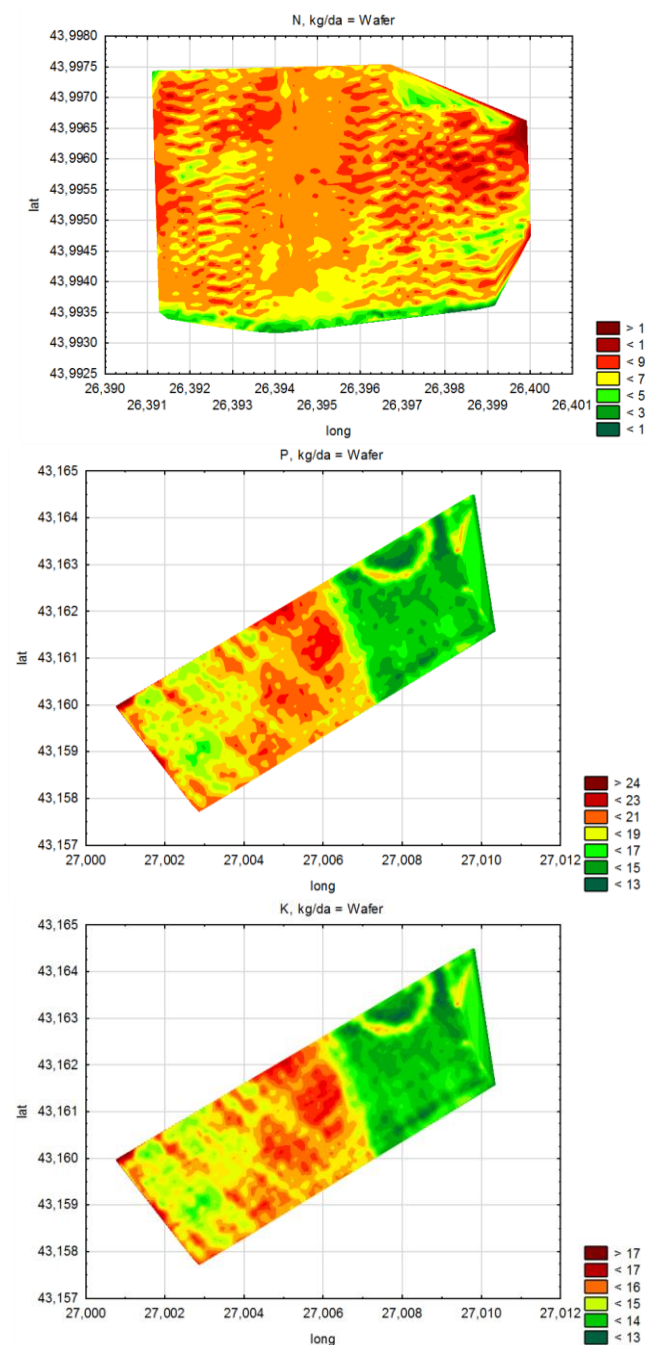


Figure 9. Spectral map for determining the content of nutrients in the soil.

In modern conditions, the development of fast and reliable tests for soil analysis requires working with a large database, processing a large amount of information and knowledge of the methods of mathematical statistics.

Conclusions

1. Soil electrical conductivity (ECa) is a measurement that correlates with soil properties that affect crop productivity, including soil texture, cation exchange capacity (CEC), soil hydraulic conductivity conditions, organic matter content, salinity, characteristics of individual soil layers, etc.

2. The ECa of soils varies depending on the amount of moisture retained by the soil particles.
3. ECa strongly correlates with the size and structure of soil particles.
4. The apparent electrical conductivity of the soil is affected by a combination of physicochemical properties, including soluble salts, sand, clay and silt content, resp. soil water content, bulk density, organic matter and soil temperature.
5. Precision agriculture uses rapidly evolving electronic information technologies that change soil management in a site-specific way, with conditions changing spatially and temporally.
6. It is possible by measuring the electromagnetic conductivity of the soil to determine a number of indicators, the physical, chemical and biological properties of soils.

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Modelling Fe, Zn and Mn availability in soils of eastern Croatia

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Abstract: Iron (Fe), zinc (Zn) and manganese (Mn) are essential microelements with plant available fraction in soil, depending significantly on soil pH and soil organic matter (SOM), which is important for crop growth. The aim of this paper is to present the potential of mathematical models in order to predict the availability of microelements (Fe, Zn, Mn) in acidic and alkaline soils of eastern Croatia. The fundamental database for availability prediction contains results of 22,616 soil samples from eastern Croatia representing an area of 88,714.46 ha of arable land. The mandatory results include soil pH, SOM, available P and K, hydrolytic acidity, and carbonate content. Additional data sets, including supplementary results of total (extracted by aqua regia, AR) and available (extracted by ethylenediaminetetraacetate, EDTA) micronutrient fraction, were used for modelling of micronutrient availability and for final model validation. The modelling micronutrient available fraction was created in 3 steps: (1) regression models of total (AR) and available (EDTA) micronutrients (Fe, Zn, Mn) concentration based on analytical results of soil pH, SOM, AR and EDTA micronutrients fractions; (2) prediction of the available micronutrients fraction (EDTA) based on the soil pH and SOM; (3) model validation using new data set with analytical results of soil pH, SOM, AR and EDTA. The model predicts that moderate micronutrients availability could be expected on 48.45 % (42,972.25 out of 88,714.46 ha) of arable land on average for Fe, Zn and Mn. A high availability could be on 29.32 % (25,982 ha) of arable land on average, but a very significant difference was found among Fe (47.37 %), Mn (39.01 %) and Zn (1.57 %) arable land with high availability. The most important prediction is the one that claims insufficient availability of micronutrient could be expected on 19,579.87 ha in average, what is 22.26 % of arable land. But low Fe availability was predicted on only 2.79 % (2,479.3 ha), significantly more land (22.60 %, 20,035.40 ha) with low Mn availability and the highest percentage (41.4 %) of soil with insufficient Zn availability (36,764.91 out of 88,714.46 ha). The validation shows the highest model accuracy for Zn and the lowest for Fe availability prediction.

Keywords: REGRESSION MODELS, AVAILABLE MICRONUTRIENTS, TOTAL MICRONUTRIENTS CONTENT, EDTA EXTRACTION, SOIL PH, SOM, IRON, ZINC, MANGANESE

1. Introduction

Although different growing media are used to grow plants today, the soil is still considered to be the most important and irreplaceable natural source, while the yields to a large extent depend on the supply of soil with macro and micronutrients. Soil fertility testing is a legal obligation with precisely prescribed mandatory monitoring parameters which help to obtain quantitative and easily measurable results of basic macronutrients [1, 2]. By establishing a database of properties and a manner of use of agricultural land (by means of mathematical-computer modelling) and predicting models for interpretation of availability of readily available micronutrients on the basis of direct analytical data the assumptions were made for obtaining derived data (analysis results obtained by soil fertility testing). The area of five Slavonian counties is the main agricultural area of the Republic of Croatia with 536,123.16 ha of arable land available for production and entered in the ARKOD system of Republic of Croatia, making care of soil quality extremely important. However, as the legislation in conventional agriculture did not impose obligatory monitoring of the concentration of trace elements, very little attention has been paid to them regardless of the significant role they play as essential elements necessary for plant growth and development. Micronutrients deficiency in general can significantly reduce performance as well as profitability of an agro-ecosystem [3]. On the other hand, due to intense agricultural production and increased fertilization some negative effects in the availability of micronutrients [4] may occur. Heavy metals iron (Fe), zinc (Zn) and manganese (Mn) are essential trace elements in soil, and their fractions in the soil are available for plants, depending on the pH value and soil organic matter (SOM). Soil extraction techniques for measuring the status of available micronutrients for plants are important in the diagnosis of deficiency or excess trace elements [5]. Furthermore, soil acidity and toxicity, or the lack of individual elements associated with it, affect crop growth and limit yields in the world [6]. In the soils of eastern Croatia the ratio of available and total concentrations of trace elements are strongly influenced by the soil pH [7], and all analysed elements had a higher available fraction in acidic soils when compared to calcareous soils. In addition, the ratio of the content of total and easily accessible heavy metals in Croatian soils has not been sufficiently researched, although some results and differences in fractions obtained by using

different methods [7] have been published. Strong correlation of soil pH value and micronutrient availability were also concluded in uncontaminated soils in Croatia under different land uses [8] and extracted by water [9] or other extractants [7, 10, 11, 12].

In addition, the distribution of essential and harmful heavy metals of agricultural soils in Croatia [13, 14, 15] and the impact of heavy metals and other soil properties on yields and micronutrient status in crops [10, 16, 17, 18] were analyzed. Plant available fraction of microelements could be represented as a fraction extracted by different solutions and using different methods [19], and therefore these solutions, extracted fractions and methods were compared worldwide [19, 20, 21, 22, 23] and to a certain extent in Croatia [7, 11, 24].

The soil data, regardless of the extraction or measuring methods, could be used for mathematical modelling for analyses or prediction of unmeasured soil properties [8, 12, 20] or for evaluating soil quality [19, 24].

The aim of this paper is to present the potential of mathematical models in order to predict the availability of microelements (Fe, Zn, Mn) in acidic and alkaline soils of eastern Croatia.

2. Materials and Methods

The obligatory soil analysis for agricultural producers in Croatia [1, 2] includes a few agrochemical analyses:

1. Determination of the soil pH (soil suspension in water and in 1 M KCl) according to ISO 10390 [25]
2. Determination of humus or soil organic matter (SOM) according to ISO 11466 [26]
3. Determination of plant available phosphorus and potassium (ammonium acetate-lactate extraction) according to AL-method [27]

Other chemical analyses are not obligatory but are used for determination of total [28] or plant available [29] microelements content in the soil.

The mathematical model could be used for prediction of some unmeasured properties in soil samples, and in this research the mathematical model for prediction of available micronutrient fraction in the soil was created in 3 steps:

- (1) regression model for prediction of total (extracted by aqua regia, AR) and available (extracted by ethylenediaminetetraacetate,

EDTA) micronutrients (Fe, Zn, Mn) fractions in the soil based on analyses of 229 soil samples (preliminary soil data set);

(2) prediction of the available micronutrients fraction (EDTA) using just mentioned regression model and based on the soil pH and SOM analyses of 22,616 soil samples (basic soil data set);

(3) model validation using new data set (validation data set) with analytical results of soil pH, SOM, AR and EDTA analyses of 30 soil samples.

The basic soil data set contains results of 22,616 topsoil (0-30 cm) samples from eastern Croatia representing an area of 88,714.46 ha of arable land. The data set includes results of basic soil properties like soil pH, SOM, available P and K. Preliminary and validation data sets also include results of mentioned basic soil properties as well as the results of the total (extracted by aqua regia, AR) and available (extracted by ethylenediaminetetraacetate, EDTA) micronutrient (Fe, Mn, Zn) fraction.

The soil samples were collected during 14 seasons (2003-2016) from arable land to the 30 cm depth. The soil samples were prepared for chemical analyses according to ISO procedures [30]. The soil samples in basic data set are originally from all 5 eastern Croatian counties (Osijek-Baranja, Vukovar-Srijem, Brod-Posavina, Požega-Slavonia and Virovitica-Podravina), but Požega-Slavonia County and Virovitica-Podravina County are represented by a smaller number of samples (143 and 70). Therefore, soil maps are made for three counties (Osijek-Baranja, Vukovar-Srijem, Brod-Posavina) with results of 22,403 samples using ArcGis desktop version 9.2. [31] and ordinary kriging method [32].

3. Results

The results of analyses in the preliminary data set were used for creation of regression models for available fraction of Fe, Mn and Zn (and total fraction of Zn). The soil pH in water suspension was on average 6.83 with minimum 4.39 and maximum value 8.67. The values in potassium chloride suspension were significantly lower (3.74-8.33 and 5.92 on average). Soil reaction for basic data set (Table 1) was some lower on average (6.53 in water and 5.73 in 1 M KCl suspension) but with wider range of acidity and alkalinity (from pH 3.41 and 3.91 up to 8.25 and 8.91 in potassium chloride and water suspension, respectively). The content of SOM was on average 2.02 % in preliminary and 2.10 % in basic data set. The lowest SOM content was 0.32 % and the highest 10.80 % but only 0.1 % of soil have the SOM content higher than 5 % and only 3 samples have the SOM content lower than 0.5 %.

Table 1: Results of chemical soil analyses for the preliminary and basic data set and data calculated by models for basic data set

mg/kg	Preliminary data set			Basic data set		
	Min	Max	Avg	Min	Max	Avg
Soil pH _{H2O}	4.39	8.67	6.83	3.94	8.91	6.53
Soil pH _{KCl}	3.74	8.33	5.92	3.41	8.25	5.73
SOM (%)	0.79	4.51	2.02	0.32	10.80	2.10
Fe _{AR}	20,210.0	38,880.0	28,446.0	-	-	-
Mn _{AR}	228.40	1,024.00	657.03	-	-	-
Zn _{AR}	40.83	114.90	62.41	35.77 ¹⁾	211.08 ¹⁾	61.46 ¹⁾
Fe _{EDTA}	17.39	4,478.00	615.65	0.78 ¹⁾	1,285.47 ¹⁾	464.85 ¹⁾
Mn _{EDTA}	5.38	131.40	34.31	15.58 ¹⁾	70.59 ¹⁾	37.44 ¹⁾
Zn _{EDTA}	0.48	7.97	1.63	0.45 ¹⁾	9.79 ¹⁾	0.71 ¹⁾

¹⁾Data predicted by mathematical models (not results of analyses)

The total concentration of Fe in the preliminary data set was 20.21 – 38.88 g/kg (Table 1), Mn 228.40-1,024.0 mg/kg and Zn 40.83-114.90 mg/kg with the highest concentration on average of Fe (28,446 g/kg), then Mn (657.03 mg/kg) and the lowest average concentration of Zn (62.41 mg/kg). In the same samples the highest concentration of plant available fraction extracted by EDTA solution was also for Fe (615.65 mg/kg on average), followed by Mn (34.31 mg/kg) and the lowest average concentration of Zn (1.63 mg/kg). The measured plant available fraction (17.39-4,478 mg/kg Fe, 5.38-

131.40 mg/kg Mn and 0.48-7.97 mg/kg Zn) are the ranges of values that regression models are created for.

The regression models made using preliminary data set and used for prediction of available micronutrients content in the basic data set were different for each microelement.

Iron model is simple, using two pH values and SOM value:

$$\text{Fe}_{\text{EDTA}} (\text{mg/kg}) = 760.35 \times \text{pH}_{\text{H}_2\text{O}} - 753.64 \times \text{pH}_{\text{KCl}} - 86.93 \times \text{SOM}$$

Zinc model has two steps: first step is for modelling total zinc in the soil and second for plant available zinc:

$$(1) \text{Zn}_{\text{AR}} = 6.345 \times \text{pH}_{\text{H}_2\text{O}} + 0.172 \times \text{pH}_{\text{KCl}} + 9.059 \times \text{SOM}$$

$$(2) \text{Zn}_{\text{EDTA}} = 0.0634 \times \text{Zn}_{\text{AR}} - 1.012 \times \text{pH}_{\text{H}_2\text{O}} + 0.807 \times \text{pH}_{\text{KCl}} - 0.095 \times \text{SOM}$$

Manganese model is simple, using pH values and SOM value:

$$\text{Mn}_{\text{EDTA}} = 85.824 - 13.432 \times \text{pH}_{\text{H}_2\text{O}} + 6.044 \times \text{pH}_{\text{KCl}} + 2.2315 \times \text{SOM}$$

In analyzed soils of eastern Croatia the pH value was in wide range (Table 1) and a higher pH value was measured in most eastern parts and in a lower extend in southern parts (yellowish area on Fig.1), and acid soils were mainly in the central and western area of Osijek-Baranja County (red area on Fig.1). In total, pH_{H2O} > 7.0 was found in 40.62 % samples of the analyzed areas and a pH_{KCl} > 6.0 in 44.61 %.

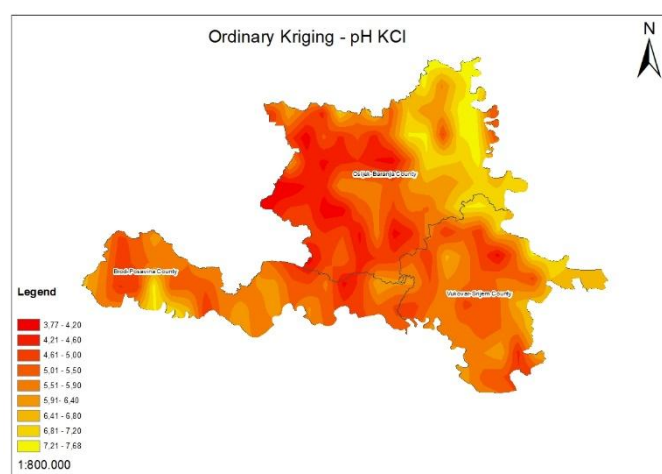


Fig. 1 Soil pH in eastern Croatia counties using ordinary kriging

The average SOM content in analyzed soils was 2.02 % but 51.90 % of area (46,038.86 ha) has SOM content in range 1-2 % and 0.33 % less than 1 % SOM. SOM content in range 2-3 % was in 38.58 % of area (34,229.91 ha), 7.3 % of area (6,509.12 ha) with 3-4 % SOM and only 1,641.40 ha (1.85 %) with SOM content higher than 4 %. The distribution shows that soils with lower SOM content were mainly in the central and western part of Osijek-Baranja County (brighter area on Fig. 2), since higher SOM content was in the most eastern parts of presented region.

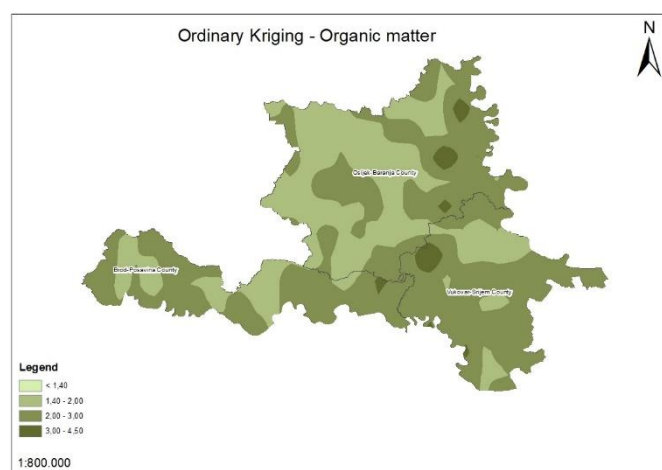


Fig. 2 SOM content in eastern Croatia counties using ordinary kriging

Modelling available Fe in the basic data set with 22,616 samples predicted very low concentration of available Fe on only 1.35 % of analyzed area which are still considerable 1,199.3 ha of arable land. Low Fe availability was predicted on 1,280 ha (1.44 % of analyzed area), medium availability on 7,443 ha (8.39 % of analyzed area) and high availability on 36,764.36 ha (41.44 % of analyzed area). Very high concentration of available Fe fraction was predicted on 47.37 % analyzed area, i.e., on 42,027.66 ha.

The highest correlation among soil properties and predicted available Fe was determined for pH value of soil suspension in potassium chloride ($r^2 = -0,5407$). The correlation was negative meaning that lower soil pH (i.e., more acidic soil) will result in higher concentration of available Fe.

The geographical distribution of predicted available Fe (Fig. 3) shows exactly the same pattern since the darker shade on Fig. 3 (representing higher available Fe concentration) is in the same western part of Osijek-Baranja County like red colour on Fig. 1 representing acid soils (i.e., low pH value). There are also some similar shadings when comparing Fig. 3 and Fig. 2 (representing SOM content), but there was a rather weak negative correlation ($r^2 = -0,3438$) among predicted available Fe and SOM. Still, this fact could be important since very low soil pH can imply stressful conditions for the plant due to toxic effects on the root, especially if the humus content is low [6, 12, 19].

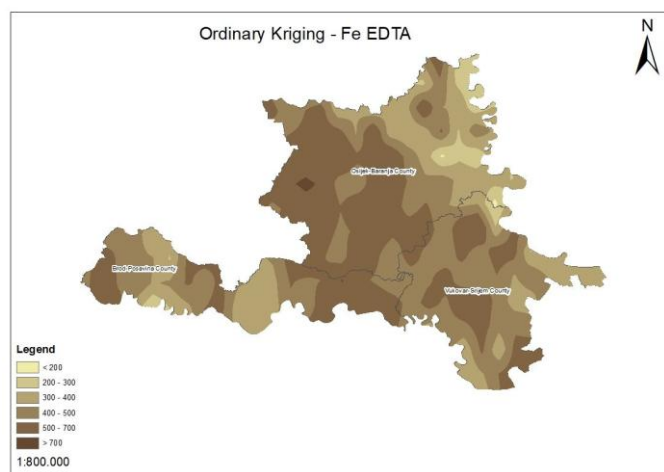


Fig. 3 Predicted available Fe fraction using linear regression model and ordinary kriging

Predicting the availability of Mn based on the basic data set in eastern Croatia, the average availability of Mn was found to be 37.44 mg/kg, which is in the range of medium soil supply (30-40 mg/kg).

Insufficient Mn availability (<30 mg/kg) was predicted for 4,735 samples representing 20,035.40 ha (22.6 % of analyzed areas), and mean Mn availability for 8,819 samples (34,073.19 ha; 38.41% area). High Mn availability with more than 40 mg/kg of plant available Mn was predicted for 9,063 samples representing 34,605.88 ha (39.01% area).

The highest correlation with predicted available Mn was determined as very strong negative correlation for pH value of soil suspension in potassium chloride ($r^2 = -0,91445$). The strong negative correlation means that acid soil (i.e., low pH value) will result in much higher concentration of available Mn. The modelling can result in very useful Mn predicted availability data, since potentially insufficient availability on one quarter of the arable land is predicted.

The geographical distribution of predicted available Mn (Fig. 4) has darker green shade in the same western part of Osijek-Baranja County with red colour on Fig. 1 representing low pH value of acid

soils. Available manganese in soil have also important impact on toxic effects on the root [6, 12, 19], and SOM content in acid soils is very important. However, the correlation among available Mn and SOM was even lower ($r^2 = -0,2446$) than among available Fe and SOM.

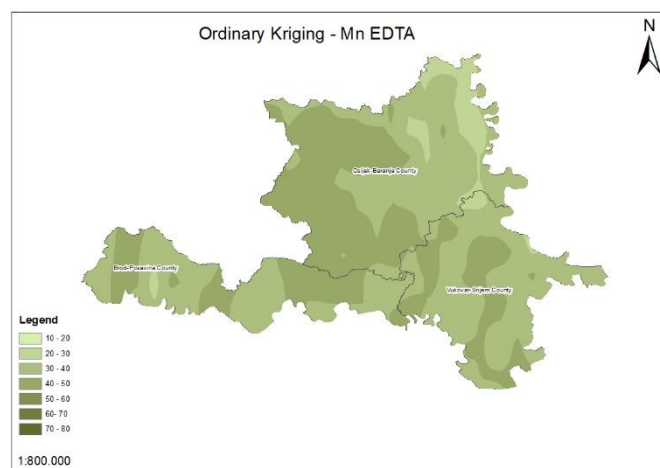


Fig. 4 Predicted available Mn fraction using linear regression model and ordinary kriging

Using linear models for predicting total and available Zn content, average concentrations of total Zn was 61.46 mg/kg (range 35.77-211.08) and available Zn 1.71 mg/kg (range 0.45-9.79) were predicted. According to the model, low Zn availability can be expected at 41.4 % of the area (36.764,91 from 88.714,46 ha), medium availability at 57.1 % (50.636,10 ha) and high availability at only 1.5 % area (1.313, 45 ha).

The highest correlation for available Zn fraction was determined with soil pH in potassium chloride soil suspension ($r^2 = 0,8325$), but also very high positive correlation was among available Zn and SOM content ($r^2 = 0,7892$). Therefore, the geographical distribution of predicted available Zn fraction (Fig. 5) has contours (pattern) very similar to Fig. 2 representing distribution of SOM.

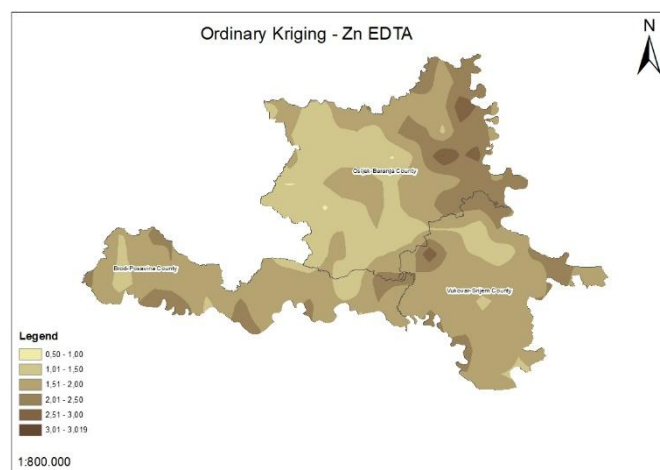


Fig. 5 Predicted available Zn fraction using two steps of regression model and ordinary kriging

Aggregating predicted concentrations of available fractions of all 3 microelements (Fe, Mn and Zn), the model predicts that moderate micronutrients availability could be expected on 48.45 % (42,972.25 out of 88,714.46 ha) of arable land on average for Fe, Zn and Mn. A high availability could be on 29,32 % (25.982 ha) of arable land on average, but a very significant difference was found among Fe (47,37 %), Mn (39,01 %) and Zn (1,57 %) arable land with high availability.

The most important prediction is the one that claims insufficient availability of micronutrient could be expected on 19,579.87 ha on average, what is 22.26 % of arable land. But low Fe availability was predicted on only 2.79 % (2,479.30 ha), significantly more land (22.60 %, 20,035.40 ha) with low Mn availability and the highest percentage (41,4 %) of soil with insufficient Zn availability (36,764.91 out of 88,714.46 ha).

The validation shows the highest model accuracy for Zn and the lowest for Fe availability prediction.

The simple regression models could be very important for planning of soil fertility improvement, either by organic fertilization or application of mineral forms of micronutrient due to avoiding micronutrient deficiency in crop growing.

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Water productivity and the effect of watering on apples grown under conditions of optimal irrigation and water deficit

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Summary: In order to determine the productivity and the effect of irrigation on apples grown under soil and meteorological conditions in the area of the village of Chelopechene - Sofia, research was conducted on drip irrigation of a plantation of the "Florina" variety, and different regimes were tested - from complete satisfaction of the daily needs of water to irrigate the culture with irrigation rates reduced by 20% and 40%. A non-irrigation variant has also been tested.

The productivity of the irrigation rate at optimal irrigation varies by years from 16.3 to 28.0 kg.ha⁻¹.mm⁻¹, and at 40% reduction of the irrigation rate from 19.3 to 26.0 kg.ha⁻¹.mm⁻¹

The highest values of productivity of the irrigation rate are reached at irrigation with a 40% reduction of the irrigation rate, in the dry 2004 high values were obtained and at the variant irrigated with 100% irrigation rate 28,0 kg.ha⁻¹.mm⁻¹

The optimization of moisture in the active soil layer contributes to a significant increase and stabilization of yields, which for the test conditions are from 1266 to 2087 kg / dka. Additional yields ranged from 542 to 821 kg / dka, averaging over the study period.

KEYWORDS: APPLES, YIELDS, DRIP IRRIGATION, IRRIGATION RATE, PRECIPITATION, WATER DEFICIT, ECONOMIC EFFICIENCY, IRRIGATION OPTIONS

Introduction

Good irrigation effect and the most productive use of irrigation water is only possible when applying the optimum irrigation regime that is in accordance with the requirements of the cultivated crops [5,6].

There are a number of studies conducted on the limiting factor - water, in Bulgaria. Their main purpose is to determine the effectiveness of the application of different irrigation regimes for optimal and insufficient water supply. The effect of irrigation is in most cases determined on the basis of the additional yield obtained from irrigation and the productivity of irrigation water [2,3,4,9].

The economic effectiveness of apple production under our climatic conditions is largely determined by the application of rational irrigation regimes and appropriate irrigation techniques. From the conducted researches it is established that from the applied techniques and technologies for irrigation of apples the drip irrigation is most suitable for their biological requirements [1].

The purpose of this development is to determine the productivity of water and the effect of irrigation of apples grown under conditions of optimal irrigation and water deficit for the Sofia region.

Material and method

To determine the productivity and the effect of irrigation of apples grown under soil and meteorological conditions in the area of the village of Chelopechene - Sofia, studies were conducted on drip irrigation of a plantation of "Florina" variety. Different regimes have been tested - from fully satisfying the daily needs of the water culture to irrigation with reduced irrigation rates of 20% and 40%. A non-irrigation variant has also been tested.

The following irrigation options were tested at pre irrigation moisture at 85-90% of WHC / water holding capacity/ maximum field moisture capacity /:

- 1.Option without irrigation;
2. Irrigation with Water application rate 100% M;
2. Irrigation with Water application rate 80% M;
3. Irrigation with Water application rate 60% M.

For soil moisture dynamics, soil samples were taken at variant 2 (100% bp) at a depth of 0-60 cm every 10 cm, which were processed by the weight-thermostatic method. The soil is leached cinnamon forest, slightly sandy - clay in the plow layer, formed on the base of an old deluvial cone of sedimentary materials. It is poorly stocked with nitrogen, medium in phosphorus and well in potassium. The average for the layer 0 - 60 cm the soil has the following water-physical properties: WHC = 22.1%, moisture content - 12.3% by weight of absolutely dry soil, volume weight at WHC - 1.47 g / cm³. For the soil layer 0-100 cm the same indicators have values: WHC - 21.8%, wilt moisture - 12.3% and volume weight - 1.50 cm³. In general, the soil is suitable for growing apples.

The irrigation was carried out by drip, with dropformers KP - 4.6, perforated tube through 0.60 m. With Drip irrigation we do not apply the entire irrigation rate as with other irrigation methods. A reduction is needed at the expense of the unsaturated zone. For this purpose, the equation of [8] was used, taking into account the planting scheme. After calculating the irrigation rate for Option 2, the size of the other variants is reduced relative to its size. For each specific site, the design parameters of the irrigation system and performance are specified.

Results and discussions

The productivity of each crop depends on a complex of factors, the main ones being: the type of crop, its varietal characteristics, the agricultural technology applied, the number of irrigation plants sold, the way they were submitted.

Table 1: Rainfall during apples vegetation period (2001– 2005 г.)

Periods	Total rainfall, mm				
Years	2001	2002	2003	2004	2005
M. IV – IX	358	418	329	258	765
Average multi-annual	365	365	365	365	365
M. VII – VIII	75	158	104	73	400
Average multi-annual	110	110	110	110	110

The amount of rainfall in the 50-year series characterizes the growing season of the culture development (April-September) during the experimental years, as follows: medium humid - 2001, 2002, and 2003; wet -2005 and 2004 very dry. The lowest rainfall occurred in 2004 (258 mm) and the

highest in 2005 (765 mm). During the remaining three years, the rainfall is from 329 to 418 mm, Table 1, and Figures 1 and 2. The fallen rainfall during the growing season of the crop is unevenly distributed, which led to the realization of irritations.

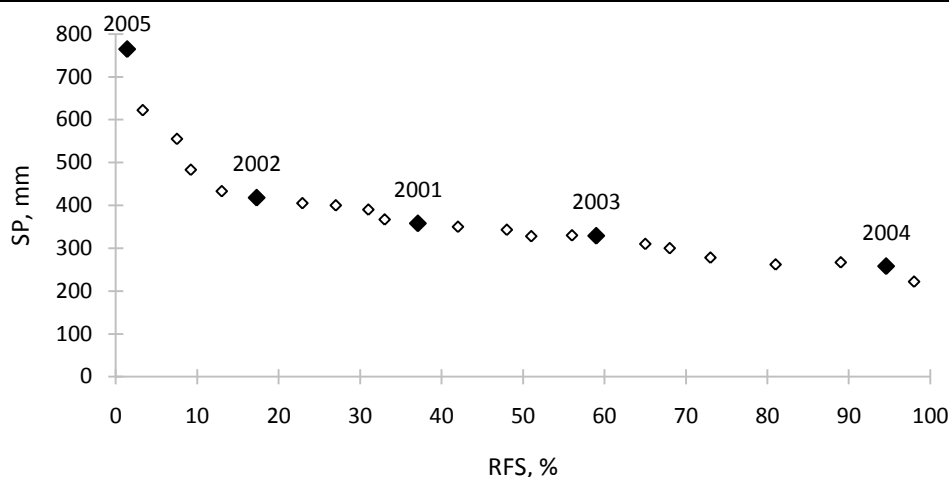


Fig. 1. Sums of precipitations (SP, mm) for the April-September period of 1956-2005 and the relative frequency security (RFS, %) of the amount of rainfall in the Sofia field

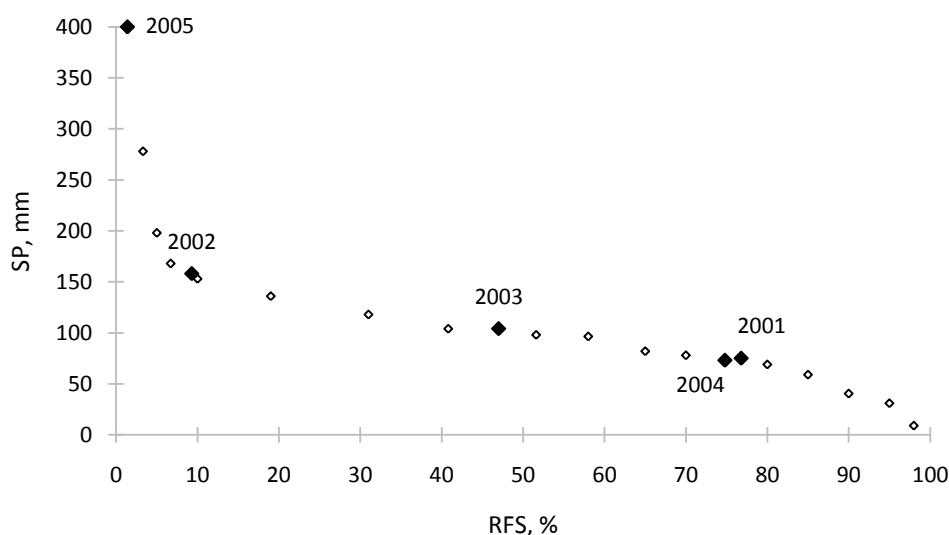


Fig. 2. Sum of precipitations (SP, mm) for the July-August period for 1956-2005 and the relative frequency security (RFS, %) of the amount of rainfall in the Sofia field

When determining the effect of irrigation on apples by the change in the yield obtained from the non-irrigated variant, it was found that for the variant with 100% irrigation rate the increase in apple yield reaches 821 kg / dka, and for the variants irrigated with irrigation rate respectively by 542 up to 686 kg / dka, according to the non-irrigation variant, Table 2.

The optimization of moisture in the active soil layer contributes to a significant increase and stabilization of yields, which for the test conditions are from 1266 to 2087 kg / dka. Additional yields ranged from 542 to 821 kg / dka, averaging over the study period.

Table 2: Efficiency and productivity of water for apples on average for the period (2001-2005) apples

Variant	Irrigation rate m ³ /ha	Total yield (Y) kg/dka	Added yeild (+Y) kg/dka	Compared to v 1, %	Compared to 2, %	Productivity of m ³ water
Non irrigated	-	1266	-	100	40	-
100% M	316	2087	821	164	100	6,6
80% M	261	1952	686	154	7	7,7
60% M	204	1808	542	142	14	8,9

The effect of irrigation is measured by the additional yield as well as the productivity of the irrigation water supplied. The data by years are presented in Table 3. It has been shown that in conditions of regulated water deficit, the yield does not change in

proportion to the change in the size of the irrigation rate. Therefore, water productivity is often higher at a lower irrigation rate. For the test conditions, the values range from 16.3 to 28.0 kg.ha⁻¹.mm⁻¹. In the first and second test years, the highest water

productivity values reach a 40% reduction in the irrigation rate from $19.3 \text{ kg} \cdot \text{ha}^{-1} \cdot \text{mm}^{-1}$ to $26.0 \text{ kg} \cdot \text{ha}^{-1} \cdot \text{mm}^{-1}$ a -low values at 100% M from $16.3 \text{ kg} \cdot \text{ha}^{-1} \cdot \text{mm}^{-1}$ to $21.3 \text{ kg} \cdot \text{ha}^{-1} \cdot \text{mm}^{-1}$. During the dry year, the highest values were obtained with the variant irrigated with 100% irrigation rate : $28.0 \text{ kg} \cdot \text{ha}^{-1} \cdot \text{mm}^{-1}$

Table 3: Productivity of irrigation rate for medium moist and dry year - apples

variant	2001			2003			2004			average		
	+Y	M	PR	+Y	M	PR	+Y	M	PR	+Y	M	PR
100%M	5550	340	16,3	8100	380	21,3	10110	360	28,0	7920	360	22
80%M	4850	272	17,8	6930	304	22,7	8260	300	27,5	6680	292	23
60%M	4370	221	19,3	5770	244	23,7	5960	220	26,0	5366	228	24

Where : +Y is the additional yield , kg/ha; M – irrigation norm , mm; PR – productivity of the irrigation rate $\text{kg} \cdot \text{ha}^{-1} \cdot \text{mm}^{-1}$.

The productivity of the irrigation rate at optimum irrigation varies by years from 16.3 to $28.0 \text{ kg} \cdot \text{ha}^{-1} \cdot \text{mm}^{-1}$ and at a 40% reduction in the irrigation rate from 19.3 to $26.0 \text{ kg} \cdot \text{ha}^{-1} \cdot \text{mm}^{-1}$

The results obtained for apple production during the different humid years indicate the effect of drip irrigation on its size. The largest increase in yield was obtained in 2004 (dry), which

is 55% more than the non-irrigation option (Table 4). The smallest increase of $667 \text{ kg} / \text{ha}$ (25%) was obtained in the wet 2005.

Reduced irrigation rates during the growing season of apples result in losses of yields that are adequate to the percentage reduction in unprovided water. At 20% correction of the irrigation rate the yield decreased by 4% compared to the optimal variant, and at 40% reduction of the irrigation norm - up to 14%, Table 4.

Table 4: Total and relative yield of apples in the Sofia area

Years	2001		2002		2003		2004		2005		average 2001-2005	
Watering norm (share,%)	Y	R	Y	R	Y	R	Y	R	Y	R	Y	R
Noirriga- tion	1567	100	704	100	1135	100	855	100	2070	100	1266	100
100%M	2122	135	1769	251	1945	156	1866	218	2737	132	2087	164
80%M	2053	131	1603	228	1828	143	1681	196	2592	125	1952	154
60%M	2004	128	1421	202	1712	135	1459	170	2444	118	1808	142

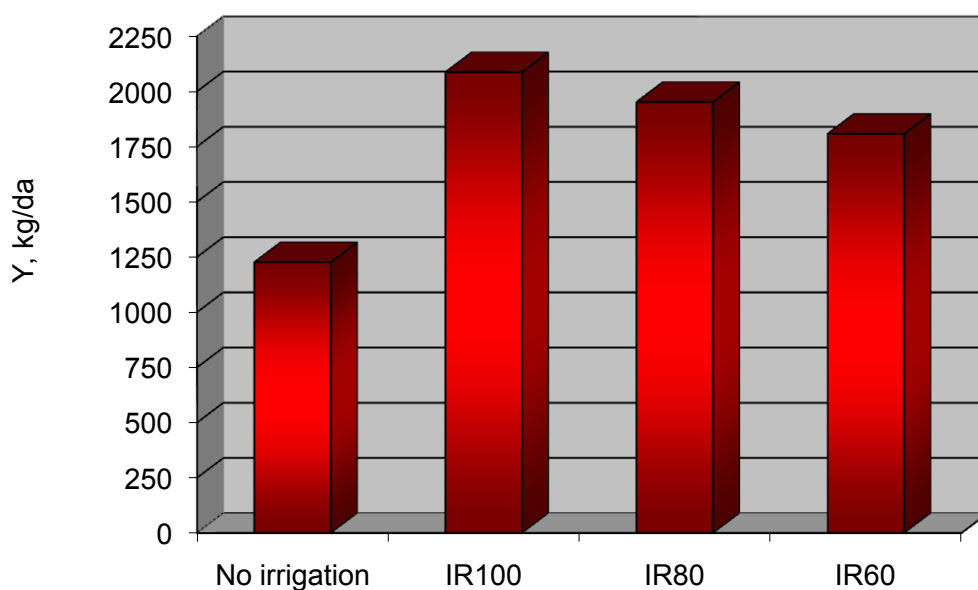


Fig. 3. Dependence of total apple yield (Y, kg/da) on the irrigation rate (IR, % of IR_{100}) in Chelopechene, Sofia, for the period of 2001-2005

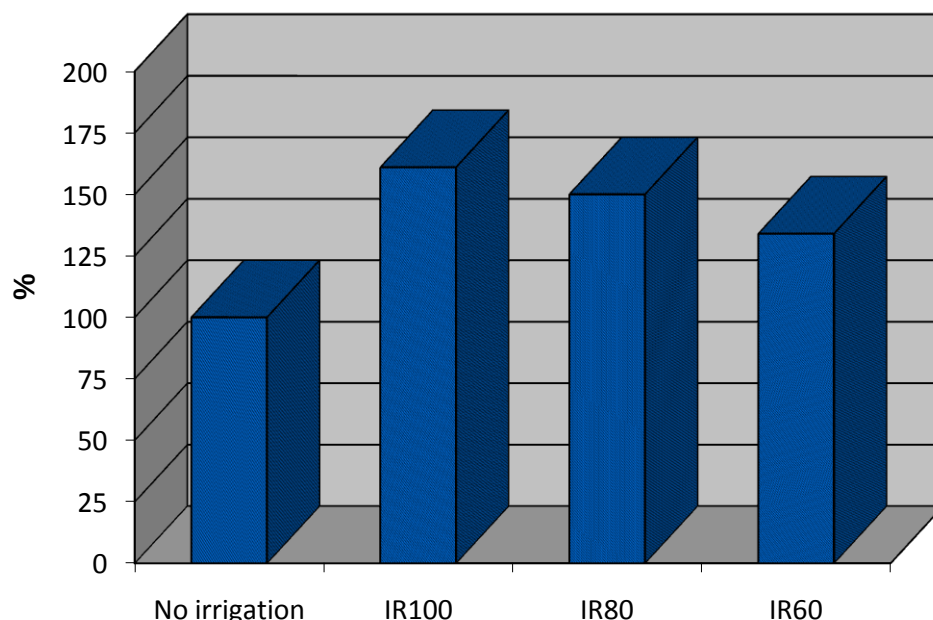


Fig. 4. *relative-to-control (no irrigation) total yield of apples (%) obtained for different regimes of drip irrigation in Chelopechene, Sofia*

The total cost of growing apples under drip irrigation is almost the same for different areas and ranges from 827 to 986 lv / dka. Yields double as a result of which higher net income is generated, even in areas of 1 dka.

The results show that, with drip irrigation of apples, the additional net irrigation income ranges from 392 to 533 lv / dka. For areas up to 5 dka, the additional net income increases with the increase of the

area, above an area of 5 dka it does not depend on the size of the irrigated area. This is due to the large initial investment for command-line equipment for drip irrigation, which is almost the same for areas up to 20 dka. After 20 dka there is also an increase in investment, which is due to the equipment of the system with more powerful pump units with higher value, Table. 5.

Table 5: *Basic production costs for growing apples and total net income for drip irrigation*

№	Culture	1 dka	5 dka	10 dka	20 dka
I.	Apples with drip irrigation				
1.1	Total cost of cultivation of irrigation culture, lv / dka	967	891	827	887
1.2.	yield with Irrigation, kg / dka	2087	2087	2087	2087
1.3.	Production purchase price, lv / kg купна цена на продукцията, lv/kg	0.8	0.8	0.8	0.8
1.4.	Total net income with irrigation, in lv / dka	702	779	843	783
II.	Apples without irrigation				
1.5	Total net income lv/dka	310	310	310	310
	additional net income, lv/dka	392	469	533	473

The main factor in determining the profit or additional net income from irrigation is the purchase price of the production, which is proportional to the income. With a lower purchase price in smaller areas, the irrigation effect is minimal. Another major factor is the cost of irrigation water. When using water supplied by an irrigation canal, the cost of water is high and, although irrigation systems are low in cost, often additional net income is minimal.

The cost of irrigation water is directly dependent on the water source. For surface or groundwater abstraction, the cost is 0.001 lv / m³, and for irrigation from the irrigation canal, the value of 1 m³ of water is 0.23 lv / m³ for gravity water supply and 0.43 lv / m³ for pumping.

Conclusions

Moisture optimization in the active soil layer contributes to a significant increase and stabilization of yields, which for the experimental conditions range from 1266 to 2087 kg / dka, with additional yields ranging from 542 to 821, averaging over the study period.

Reduced irrigation rates during the growing season of apples result in a decrease in yields that is proportional to the percentage reduction in untreated water. At 20% correction of the

irrigation rate the yield decreases by 4% compared to the optimal variant, and at 40% reduction of the irrigation rate - up to 14%

Water productivity at optimum irrigation varies by years from 16.3 to 28.0 kg.ha⁻¹.mm⁻¹, and at 40% reduction of the irrigation rate from 19.3 to 26.0 kg.ha⁻¹.mm⁻¹

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