

INTERNATIONAL SCIENTIFIC JOURNAL

MECHANIZATION IN AGRICULTURE & CONSERVING OF THE RESOURCES



Issue 5
2017

Year LXIII, ISSN print 0861-9638, ISSN web 2534-8450

SCIENTIFIC TECHNICAL UNION OF MECHANICAL ENGINEERING INDUSTRY-4.0
BULGARIAN ASSOCIATION OF MECHANIZATION IN AGRICULTURE

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SCIENTIFIC-TECHNICAL UNION OF MECHANICAL ENGINEERING "INDUSTRY-4.0"
BUGLARINA ASSOCIATION OF AGRICULTURAL MACHINERY

ISSN (PRINT) 0861-9638, ISSN (WEB) 2534-8450

YEAR LXIII ISSUE 5 / 2017

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CONTENTS

MECHANIZATION IN AGRICULTURE

SUBSTANTIATION OF PARAMETERS OF UNMANNED AERIAL VEHICLES FOR PESTICIDES AND FERTILIZERS APPLICATION IN PRECISION FARMING SYSTEM

D.Sc.(Eng), member of RAS, Izmaylov A.Yu.; D.Sc.(Eng), corr. member of RAS, Lobachevskiy Ya.P.; Ph.D.(Agr.) *Smirnov I.G.; Ph.D. (Eng)Kolesnikova V.A.; Ph.D.(Eng.), Marchenko L.A. 168

INNOVATION SOIL-PROTECTING WORKING ORGANS OF A UNIVERSAL CHISEL PLOW

S.A. Tverdokhlebov, G.G. Parkhomenko, V.A. Dyukarev 171

FIELD EXPERIMENTAL RESEARCH OF THE COMBINED FERTILIZING-SEEDING MACHINE-TRACTOR AGGREGATE

DrSc., prof. Bulgakov V., Eng. Petrychenko I., Eng. Ihnatiev Ye., DrSc., prof. Nozdrovicky L., DrSc., prof. Krocko V., DrSc., prof. Findura P., DrSc., prof., Korenko M., DrSc., prof. Ivanovs S. 174

THEORETICAL INVESTIGATION AND DEVELOPMENT OF A DESIGN OF A NEW HAULM TOPPING MACHINE

Prof. Dr. Volodymyr Bulgakov, Prof. Dr.. Valerii Adamchuk, Dr. Semjons Ivanovs, Yevhen Ihnatiev 180

THE USE OF ARCHIVAL MAPS FOR THE MONITORING OF AGRICULTURAL LAND

Prof. Dr. Krotov D., Prof. Dr. Samsonova V., Ass.Prof. Voronin V. 183

DEVELOPMENT OF HIGH ACCURACY OF THE COPY SOIL SYSTEM

PhD., Assoc. Derkach O., asp. Makarenko D., student Velyka M., Shapoval O. 185

THE STUDY OF MOVEMENT WIDE SPAN TRACTOR (VEHICLES) WITH KINEMATIC (TURN OF WHEELS) METHOD OF ITS CONTROL

DrSc., prof. Bulgakov V., DrSc., Prof. Kyurchev V. PhD., DrSc., Prof. Nadykto V., Assoc. Prof. PhD. Kuvachov V., DrSc., Corresp. Member Prof. Eng. Beloev H., DHC, Prof. Eng. Kangalov P. , PhD, Assos. prof. Eng. Mitev G., PhD 188

METHODICAL BASES FOR SELECTING PARAMETERS OF POST-HARVEST GRAIN PROCESSING POINTS BASED ON STATISTICAL SIMULATION

PhD, s.r.o. Kudrynetsky R., Ph.D., senior research, Dnes V., research, Skibchyk V. 193

CONSERVING OF THE RESOURCES

SOIL WATER MANAGEMENT IN THE SIBERIAN KULUNDA- DRY STEPPE

Prof. Dr. Meissner R., Dr. Rupp H., Dr. Bondarovich A.A., Prof. Dr. Rinklebe J. 197

EFFECT OF SOIL TEMPERATURE AND MOISTURE OVER GERMINATION OF SEED COVERED BY ORGANIC POLYMER

Assist. prof. Vasil Kopchev, PhD, Assist.. Prof. . Krasimir Bratov PhD, Assoc. Prof. Miroslav Mihaylov PhD, Assoc. Prof.. Georgi Mitev DSc. 202

THE MAIN COMPONENTS OF STUDIES AND RESEARCH OF CONSERVING SOILS AND WATER IN TECHNOLOGIES OF AGROENGINEERS TRAINING

Candidate of Technical Sciences, Associate Professor Viktor Pryshliak 207

ROLE OF MINERAL SUBSTRATES IN FORMATION OF HUMIC COMPOUNDS IN SOIL

Prof. Dr. Sc. Pinskiy D., Sc. Mal'tstva A. 211

TO THE STUDY OF PHYTOPLANKTON OF URBAN PONDS IN THE SOUTH-EAST OF THE REPUBLIC OF TATARSTAN IN RUSSIA

senior researcher, doctor biological of Sciences Barieva Faniya Fauatovna, assistant Khamitova Madina Farhadovna, student Babikova Valeria 215

SOIL TILLAGE INFLUENCE ON THE AGGREGATE STABILITY

Krasimir Bratov, Georgi Mitev 217

SUBSTANTIATION OF PARAMETERS OF UNMANNED AERIAL VEHICLES FOR PESTICIDES AND FERTILIZERS APPLICATION IN PRECISION FARMING SYSTEM

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Abstract: The technological process of unmanned aerial vehicles (UAV) application in the system of precise farming includes sequential interrelated operations: monitoring and sounding of crops (using light UAVs equipped with multispectral cameras), obtaining, processing and transmitting information for crop management, differentiated application of pesticides and fertilizers according to a specified treatment program (UAV through a large payload).

KEYWORDS: PRECISION AGRICULTURE; PLANT PROTECTION; FERTILIZATION; UNMANNED AERIAL VEHICLES.

Introduction

Recent trends of development of world agricultural production are based on the use of information technology, global positioning and geographic information systems, automated systems in management and technological process control, robotics and integrated precision farming [1-4]. This requires a technology of remote monitoring of agricultural and forest lands with the use of space, manned, unmanned aircraft [5] and variable rate technology (VRT) fertilizer application, plant and seeds protection modes in off-line or on-line regimes for pre-designed maps-jobs on the basis of field monitoring [6].

The use of unmanned aerial vehicles for monitoring and remote sensing of agricultural crops becomes a routine operation and provides data to build digital maps of fields and the formation of map-tasks for the differentiated application of plant protection products and fertilizers [7].

The development of precision agriculture technology requires a high level of technical support based on a programmable, fully-functioning autonomous or remotely controlled unmanned aircraft systems (UAS), which contain complexes of automatic or remote-controlled unmanned aerial vehicles flying in space is segregated in accordance with the standards of ICAO (International Civil Aviation Organization).

The on-board flight control system consists of the autopilot unit, engine control units, the payload control unit, flight and navigation system with integrated navigation system GLONASS/GPS for flight at low altitudes.

The purpose of the study is the choice and justification of main parameters of unmanned aerial vehicles for the targeted application of liquid chemicals in the system of precision farming.

Materials and methods. Used on UAV standards, methodological recommendations on the use of chemicals in the system of precision farming, the concept of development of operational management of mobile technical devices, applied in agriculture using GPS/GLONASS as well as on the analysis of the generalized classification of unmanned aerial vehicles and unmanned aircraft systems [6, 8-11]. Mass structural analysis of the UAV was carried out on the basis of classical methods [12].

The results and discussion. Functional UAVs for agriculture are subdivided into transport, monitoring, sowing, fertilizer application and plant protection means. The type of construction rotary-wing UAV (gyroplane) and multi-rotor (Quad, hexa or oktokoptyer) types are preferred. UAVs can have automatic or remote control.

The used class of airspace the UAV flight for agricultural purposes must be performed in segregated airspace of established size, designed for the exclusive use of specific users.

From the point of view of take-off and landing the UAV with a small extension for take-off or vertical take-off and vertical landing are preferred.

The most preferred UAVs are those not needing aerodrome for launched and landing, reusable, low-altitude and limited needed height (0-300 m).

The power unit of the UAV may include electric or piston engines with basic refillable fuel tank.

The payload mass is usually 15-30% of the mass of the UAV, and includes the payload (video or photographic equipment, etc.), mass transport of the goods, for example spare parts for agricultural machinery field, a load of fertilizers or pesticides, equipment for their application. Functional load includes a motor (fuel supply) or power supply and servos, aerodynamic controls, complex software and hardware containing the on-board control equipment [13].

The table below shows promising classification of UAV take-off weight and payload.

Table
Classification of UAVs for application of agrochemicals by takeoff weight, payload, range

UAVs	Weight takeoff / useful load, kg	Maximum range of flight, km
Ultra-light near range	(25/7,5)-(150/45)	Less than 30
Light of short range	(50/15)-(250/75)	10-30
Medium short range	(150/45)-(500/150)	80-200
Medium Heavy Short Range	(500/150)-(1500/450)	200-500

In precision agriculture the doses of mineral fertilizers and application rate of pesticides is determined for each elementary area of the field. The number of plots depends on the in-field variability of nutrients, phytosanitary state and the field area. Monitoring of agricultural lands is carried out using a photo or multispectral cameras installed on aircraft or helicopter type drone, i.e. the so-called small take-off weight and low payload multicopter.

The mass balance equations of the aircraft [12] under the all the same conditions shows the connection of take-off weight m_0 to the structural elements: the mass of the structure m_{KOH} , propulsion engine m_{cy} , avionics and control systems $m_{\text{ob.cy}}$, fuel m_{T} , payload m_{nn} :

$$m_0 = m_{\text{KOH}} + m_{\text{cy}} + m_{\text{ob.cy}} + m_{\text{T}} + m_{\text{nn}} \quad (1)$$

The mass balance equation (1) in the first approximation is usually presented in a relative form that allows you to compare aircraft utilization per unit mass:

$$1 = \bar{m}_{\text{кон}} + \bar{m}_{\text{cy}} + \bar{m}_{\text{об.сy}} + \bar{m}_{\text{T}} + \bar{m}_{\text{пн}}, \quad (2)$$

Where $\bar{m}_i = \frac{m_i}{m_0}$ is the ratio of the mass of the i-th element to the takeoff weight.

The mass of the working fluid (fertilizers and pesticides) from cultivated fields can be variable, so the ratio will be variable, provided that:

$$0 \leq m_{\text{рж}} \leq m_{\text{зад}}, \quad (3)$$

where $m_{\text{зад}}$ is the specified mass of working solutions of pesticides and fertilizers for programmable processing of all sections of the field.

When differentiated treatment of crops UAV in the mode of-line allocated to each elementary area of the treated fields with fixed latitudinal-longitudinal coordinates X, Y has length L_i and a width equal to the working width of the spraying B_p . Then the total area of treatment will be:

$$S_{\text{обп.}} = \sum_{i=1}^k L_i B_p, \quad (4)$$

where k is the number of the processed areas.

The total length of the processed areas is equal to:

$$L_{\text{обп.}} = \sum_{i=1}^k L_i. \quad (5)$$

Thus, the flight range of the UAV during Shuttle processing method and the total length of all the treated areas of a field may not match; wherein:

$$0 < L_{\text{обп.}} \leq L_{\text{п.}} \quad (6)$$

The flow of the working fluid for the targeted application on the treated field is set on the basis of calculated doses of pesticides and fertilizers for each defined homogeneous section of fields and the number of extracted elementary parts which are rectangles with a width equal to the working width of the spreading length is equal to the length of a selected path.

Given the fact that the application rate of the working fluid is ensured by its flow through one nozzle g_{ϕ} , number of nozzles N_{ϕ} on the spraying boom of the equipment of the UAV, the width of the deposit B_p and the working velocity $V_{\text{п}}$ and the relative mass of the working fluid can be represented as follows:

$$\bar{m}_{\text{рж}} = B_p \sum_{i=1}^k L_i \left(\frac{N_{\phi} g_{\phi}}{B_p V_{\text{п}}} \right), \quad (7)$$

where k is the number of sites that require treatment for one flight in accordance with the digital map field.

In generalized form the functional relationship of relative mass of the payload with the key components and technological parameters will be:

$$\bar{m}_{\text{пн}} = \theta(\bar{m}, \bar{m}_{\text{н}}, \bar{m}_{\text{ап}}, \bar{m}_{\text{мп}}, S_{\text{п}}, k, B_p, L_{\text{обп.}}, N_{\phi}, q_{\phi}, V_{\text{п}}). \quad (8)$$

Using the expression (8), we obtain the equation of the existence of drones for targeted application fluids pesticides and fertilizers:

$$1 = F(\bar{m}_{\phi}, \bar{m}_{\text{то}}, \bar{m}_{\text{бо}}) + \Omega(\bar{m}_{\text{дб}}, \bar{m}_{\text{уп.дв.тс}}, H_{\text{п}}, V_{\text{п}}) + \Phi(\bar{m}_{\text{из}}, \bar{m}_{\text{эл.об}}, \bar{m}_{\text{ап}}, \bar{m}_{\text{эб}}, \bar{m}_{\text{ахо}}, \bar{m}_{\text{GPS}}) + \Psi(C_{\text{T}}, L_{\text{п}}) + \theta(\bar{m}_{\phi}, \bar{m}_{\text{н}}, \bar{m}_{\text{ап}}, \bar{m}_{\text{мп}}, S_{\text{п}}, k, B_p, L_{\text{обп.}}, N_{\phi}, q_{\phi}, V_{\text{п}}). \quad (9)$$

The difference of the equation of existence (9) from the well-known one is that it is, in addition to the mass and flight performance of the UAV, also displays technological parameters of variable rate application of liquid chemicals to agricultural fields.

The UAV carries a multi-spectral monitoring of agricultural fields and test sites. Next, the device transmits the spectral information with associated geographic coordinates of the elementary parts of the field in the information block of the

database. At the same time. samples of soil and plants on the test sites are taken for the calibration data when processing of the spectral measurements obtained with the UAV laboratory to determine nutrient content at each site and enter the information in the information unit, connected with unit of analysis, processing and transmission of data on the UAV, through which the differential application of pesticides and fertilizers.

Conclusions

1. It was found that reusable UAVs not needed in aerodrome for launching and landing, with a small runway for take-off or vertical take-off and vertical landing, low-altitude, helicopter, rotary wing and multi-rotor types, equipped with an autopilot system and a differentiated distribution of the fluids, fertilizers and pesticides for a given program, developed in accordance with the agrochemical cartogram and map of the phytosanitary state of the field for the targeted application of pesticides and fertilizers are preferred.

2. The equations of mass balance of the UAV for agricultural purposes are derived which can more accurately determine the take-off mass given the masses of the components of the payload intended for differential metering and distribution of fluids fertilizers and pesticides.

3. The technological process of using UAVs in precision farming system includes sequentially executed mutually related operations: monitoring and sensing of crops (with light UAVs equipped with multispectral cameras), reception, processing and transmission of information to manage crops, differentiated application of pesticides and fertilizers for a given program working in a field (via a UAV with a large payload).

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INNOVATION SOIL-PROTECTING WORKING ORGANS OF A UNIVERSAL CHISEL PLOW

ИННОВАЦИОННЫЕ ПОЧВОЗАЩИТНЫЕ РАБОЧИЕ ОРГАНЫ УНИВЕРСАЛЬНОГО ЧИЗЕЛЯ

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Abstract: In this article there were studied the factors of the origin of anthropogenic soil degradation in the result of its processing with soil-processing tools of different types and there were presented the results of carried out researches. There were worked out the recommendations on decrease of their influence on processing soil horizons and there was offered the innovation working organ decreasing the negative influence on soil.

Keywords: chisel plow, working organ, soil processing, reproduction of fertility, anthropogenic degradation.

Аннотация: В данной статье изучены факторы возникновения техногенной деградации почвы в результате ее обработки почвообрабатывающими орудиями разных типов и представлены результаты проведенных исследований. Разработаны рекомендации по снижению их влияния на обрабатываемые почвенные горизонты и предложен инновационный рабочий орган, уменьшающий отрицательное воздействие на почву.

Ключевые слова: чизель, рабочий орган, обработка почвы, воспроизводство плодородия, техногенная деградация.

1. Introduction

The most important task of rational use of soil is provision of reproduction of fertility, one of the conditions of which is a creation of a deep loose layer, the presence of which allows to shorten the amount of following processing of the layer and remultiplex of the layer, to provide the conditions to accumulate the humus.

The remultiplex of the layer depends on humus content and physical clay in soil, it is explained by their colloidal properties [1]. The counter-compaction manifests itself when a sufficient amount of organic matter and moisture. In the zone of insufficient moistening the processes of mineralization of humus prevail over its formation, so the remultiplex increases the density of soil.

2. Preconditions and means of solving of the problem

When working moldboard plows, the density of soil in blocks in 1.24 times higher than in the same layer before processing, and the solidness of soil of the bottom furrow in 1.5...2.0 times more than before processing with a moldboard plow [2].

Remultiplex of soil is able to lead to physical degradation which present the process of negative transformation of the layer's structure with micromorphometric side, the result of which is a decrease of agronomically valuable aggregates amount. Without treatment the layer under prolonged condition in the regime of deposits can no longer thin out to the natural state, but the density of soil is able to decline from 1.40 to 1.50 to 1.20.....of 1.28 g/cm³ [3].

With increase of organic matter in soil the optimum of density of arable layer is shifted in the direction of decrease of its values. According to the regulations of changes of physical properties of chernozems depending on the nature of human impact the ranges of values of optimal density of the arable layer is 1.10...1.25 g/cm³, the critical one – more than 1.35 g/cm³ when the content of humus 3.5...4.5% [4].

According to mechanical (particle size) composition the ordinary chernozems belong to light-clayey soils with the content of physical clay of 63.3 - 66.7%, dust – to 57.4-62.6%, sand – 4,6-6,3% (Table 1).

Silty fraction which is one of the main structure-forming factors is comparatively high in soil – 30,9-37,5%. The high content of dust explains the insufficient stability of soils to mechanical influence during the processing. According to sums of fractions the soils concern to silty-dusty light clays.

A positive feature of black soil is that they do not hinder the deepening of the root system of cultivated cultures, have a good structure, units are characterized by weak cohesion (cohesion), water and air in these soils are not antagonists. From 13 to 15% of its common stock in the meter layer comes to the share of unavailable moisture for the plant.

A negative feature is that a large % of dust fractions (of 57.4 66.7%) are contained in the processing layer.

The content of water-proof units (Table 2) is increased with the growth of depth of sampling of a soil pattern and is determined by the characteristics of the structure of solid phases, a number of organic substances that is formed as the result of irreversible coagulation.

Table 1 – Results of granulometric analysis of soil (in average)

Depth pattern, cm	Fraction content, %					
	water-proof units (0,25-5,0 mm)	agronomically valuable units (0,25-10,0 mm)	silt (< 0,001 mm)	clay (< 0,01 mm)	dust (0,05-0,002 mm)	sand (1-0,05 mm)
chernozems ordinary poor humus high light clayey on forest-type clays						
5-15	70,6	72,0	30,9	63,3	62,6	6,3
15-25	58,0	64,9	36,6	66,7	57,4	6,0
25-35	75,2	75,0	37,5	66,7	57,9	4,6

The water-proof of the bottom half of arable (15-25 cm) and sub-arable (25-35 cm) of soil layers is highly expressed. So at a depth of 15-25 cm, the amount of water-soluble units by 17.4% higher compared to the layer of 5-15 cm, at a depth of 25-35 cm – 24.6%.

It follows from the foregoing that the deepening of arable layer and its mixing with subsoil layer is reasonable on black soil, because the structural layers with more water-proof units are introduced into the culture and microbiological processes are accelerated.

Table 2 – Physical properties of soil (in average)

Depth of pattern, cm	Hygroscopic moisture, %	Soil density, g/cm ³	Density of solid phase, g/cm ³	Porosity, %
5-15	4,7	1,19	2,68	56
15-25	4,4	1,34	2,69	50
25-35	4,6	1,32	2,68	51

Common chernozem has a high absorption capacity. The largest part of absorbed bases comes to calcium cations in the processed layer. It promotes the formation of proper soil structure, is favorable to its water-air regime. The density of the processed layer is 1,19-1,34 g/cm³, specific mass (density of solid phase) 2,68-2,69 g/cm³ shows the provision of soil with organic substance (Table 2), ability to resist to remultiplex of the layer.

The density of soil in the layer 5-15 cm is the least and amounts 1,19 g/cm³, it corresponds to the loose condition, below profile the degree of compaction increases to 1,32-1,34 g/cm³. The lower part of the arable layer and the subsurface layer has almost an equal density. The same applies to the porosity, and the density of the solid phase, on the contrary, are almost identical in all layers (2,68-2,69 g/cm³).

The analysis of structural content of soil before treatment showed that the content of agronomically valuable units (0,25...10 mm) is the most in soil layer 25-35 cm (75%), the least – in the layer 15-25 cm (65%), and in the upper one 5-10 cm amounts (72%) (Table 3).

Table 3 – Data on structural content of soil

Depth of taking of a sample, cm	content of fractions in % from absolutely dry soil								Agronomically valuable air-dry units, 0,25-10 mm
	>10mm	10-5 mm	5-3 mm	3-2 mm	2-1 mm	1-0,5 mm	0,5-0,25 mm		
Chernozems common weak humus powerful light clayey forest-type clays									
Before processing									
5-15	17,7	16,7	11,5	8,4	14,6	10,4	10,4	10,3	72,0
15-25	32,9	28,1	16,8	7,5	6,7	3,4	2,4	2,2	64,9
25-35	21,6	27,9	18,8	9,5	10,0	5,2	3,6	3,4	75,0
Hinge-fixed claws (depth 27 cm)									
5-15	11,5	17,4	16,7	12,1	16,1	9,5	8,8	7,9	80,6
15-25	21,0	24,0	14,5	8,6	11,2	8,2	6,6	5,9	73,1
25-35	31,3	23,0	12,4	7,5	9,4	6,2	5,4	4,8	63,9
Without claws (depth 34 cm)									
5-15	53,1	9,5	5,6	4,9	8,4	6,7	5,9	5,9	41,0
15-25	25,8	20,6	11,4	7,6	11,1	8,4	7,8	7,3	66,9
25-35	11,8	29,6	19,0	11,	11,8	6,9	5,1	4,8	83,4

With the prevalence of agronomically valuable units in the structure of the reservoir the moisture through pores is distributed within the soil and is retained in it. Under these conditions, the decomposition of organic matter by anaerobic bacteria is accompanied by the formation of vegetable acid.

In pores which are present on surface of structural soil, the aerobic processes are present in them, it accompanies by the formation of humic acid. The formation of vegetable and humic acids promotes to the structuring of micro-units of soil under interaction with the calcium ion. This process is irreversible and destroyed by mechanical influence of the soil structure can be restored at the presence of fresh humus.

It is reasonable periodically to carry out the deep soil treatment. There was used the soil with expressed structure, with agronomical-

ly valuable water-containing units improving the physical-mechanical properties in the whole layer and it leads to the increase of processes of microorganisms' life. The working organs must be soil-protecting and the technological process must be energy-saving.

3. Solving of the problem

The present innovation working organs of the chisel plow (Figure 1) contain hinge-fixed claws, the corner of the installation relatively to the pole with the chisel in cross-vertical plane is determined by the action of forces of soil resistance and the destruction of the layer is made by differently directed shifts of movable elements (claws).

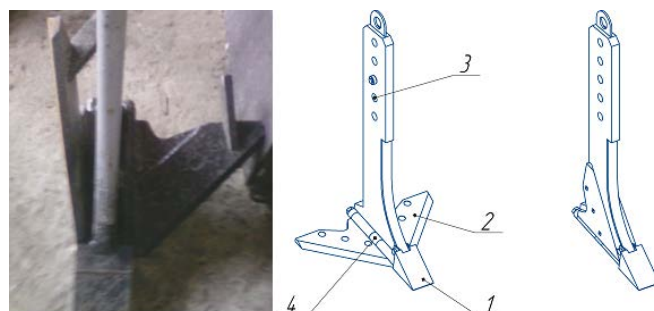


Figure 1 – Scheme of the working organ of the chisel plow: 1 – chisel plow; 2 – flat-cut claw; 3 – hole for changing of depth; 4 – hinged junction for self-adjustment of claws under the angle of soil chip

A comparative analysis of the structural composition of the soil before and after treatment with the chisel plow (Table 3) indicates an increase in the content of agronomically valuable units in layers 5-15 cm and 15-25 cm by 8.2% and 8.6% when using the innovation of the working organ with hinged claws.

The sharp decrease in the content of agronomically valuable units occurs under no claw tillage, on the contrary, in the layer of 5-15 cm there (from 72,0 to 41,0%), in the layer of 15-25 cm – remains the same (and 64.9, and 66.9%), and increases by 8.4% in the layer of 25-35 cm at the depth of the passage of the chisel plow.

So, it is possible to note the increase in the number of agronomically valuable units in layers 5-15 cm and 15-25 cm under the soil treatment by the chisel plow with hinged claws and in the layer of 25-35 cm without claws.

The comparison of a number of agronomically valuable units before and after chiseling to the depth of 34 cm shows that the soil structure deteriorates after processing in the layer of 5-15 cm and improves in the layer of 25-35 cm, being almost constant in the middle layer (15-25 cm).

The destruction of the layer with innovative working organs with hinged claws is carried by the way of the least resistance due to the self-adjustment at the natural angle of the soil chip.

It is confirmed by the reduction of traction resistance (by 12.27%) and specific energy consumption (1.14-fold) in the use of innovative working organs with hinge-fixed claws (table 4) compared with the flat-cutter [5-8], obtained from the experimental studies (Figure 2).

4. Results and discussion

Table 4 – Results of experimental research of energetic indexes of the chisel plow with innovation working organs

Title of index	Value of the type of the working organ	
	Hinge-fixed claws	Flat-cutter
Mode of work: speed, km/h, depth, cm	6,10 27	6,10 27
Traction resistance, kH	32,52±3,2	37,07±3,8
Decrease of traction		

resistance of the chisel plow, %	12,27	–
Specific energy capacity, KWt·h/ga	33,21	37,76
Decrease of specific energy capacity	1,14	–



Figure 2 – Experimental research of the chisel plow

This is confirmed by the theoretically obtained pattern [9-12] of changes of traction resistance of the chisel plow with innovative working units with hinged claws:

$$P_T = f \cdot G + (k + \varepsilon v^2) \cdot ((n-1)M + b)a - ((n-1) \left(\frac{(M-b)^2}{4} \operatorname{ctg} \frac{\omega}{2} + (M-b) \cdot l' \cdot \sin \beta \right)) \quad (1)$$

where P_T – traction resistance, κН; f , k , ε – coefficients; v – velocity, м/с; G – weight, κН; n – amount of working organs; M – distance between working organs; B_K – construction of width of the chisel plow capture; b – width of the chisel plow; a – depth of layer tillage; ω – angle of working organ; h_0 – length of exposed part of the chisel plow (relatively claws) (Figure 3).

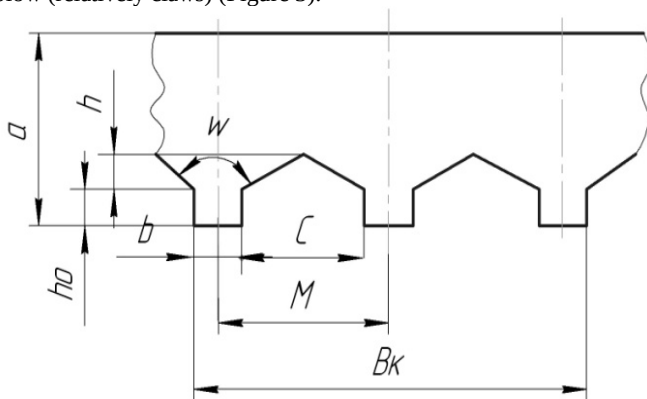


Figure 3 – Scheme of transversal section of the layer under operation of the chisel plow

From the comparison with the same regularity (2) for the flat-cutter, it follows that the reduction of traction resistance of the chisel plow with innovative working units with hinged claws is observed due to the decrease of cultivated area of the cross section of the layer.

$$P_T (\text{плоскорез}) = f \cdot G + (k + \varepsilon v^2) \cdot ((n-1)M + b)a \quad (2)$$

Results of the calculation are presented in the Table 5.

Table 5 – Results of researches of the traction resistance of the chisel plow with different types of working organs

Type of working organ	Traction resistance, κН	
	Teoretical	Experimental
Flat-cutter	37,05	37,07
Hinge-fixed claws	33,26	33,72

Comparative analysis of data of Table 5 allows you to set the relative error not more than 1.5%, indicating the adequacy of the theoretical results to the real process.

Thus, the deep tillage by the moldboard chisel with innovative working organs with hinged claws [13] is agrotechnologically appropriate, energy-saving and soil-protecting technique of soil treatment directed to the ensuring of the reproduction of its fertility.

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FIELD EXPERIMENTAL RESEARCH OF THE COMBINED FERTILIZING-SEEDING MACHINE-TRACTOR AGGREGATE

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Abstract: The scientific problem of this study is the justification of the expediency of combining the technological operations of sowing cereals and applying the main and starting doses of mineral fertilizers when using a combined machine and tractor unit (aggregate). During the research there were used methods of conducting field experiments using standard equipment. During the planned experiments there were used correlation methods and methods of numerical calculations on a PC. The comparative studies of the quality of barley sowing with basic and modernized fertilizer-sowing units showed the following values of qualitative indicators. So, the coefficient of seed depth variation of the base unit was – 8.2%, and the combined (modernized) unit – 4.7%; The uniformity of seed distribution along the length of the line for the basic unit is – 63.8%, for the modernized unit – 84.9%; Field germination of seeds when sowing the basic unit is 80.4%, modernized – 87.4%. Thus, when using the combined fertilizer-seeding unit, the uniformity of seed distribution along the length of the string will be substantially increased. At the same time, the field germination of seeds will increase, and the coefficient of variation in the depth of seed placement in the furrow will decrease. Based on the results of field experimental studies, an increase in the yield of spring wheat and barley was found in the application of a combined fertilizer-seed aggregate with the simultaneous introduction of a basic fertilizer-seeded fertilizer into the soil and sowing of cereals with the application of a starting dose of mineral fertilizer in comparison with the known schemes of such operations. The obtained results confirm the expediency of combining these technological operations with one pass of the combined machine-tractor unit (aggregate).

KEYWORDS: COMBINED AGGREGATE, SEEDER, MINERAL FERTILIZERS, FIELD EXPERIMENTS, QUALITY INDICATORS, FIELD GERMINATION, YIELD

1. Introduction

One of the ways to improve the effectiveness of agricultural machinery in the production of crop production is the use of combined units, in which several operations are performed in a single pass. This makes it possible to reduce labor costs and fuel consumption per unit of grown production, and also reduce the effect on the soil of wheeled (running) systems of mobile machines [1-6].

To increase the efficiency of seeding of the planting crops, the leading firms producing seeding equipment produce high-performance combined seeding units. But simultaneously with the increase of the indicators of technological efficiency when using combined sowing units, a need arises for the use of more powerful power units (tractors), and they are characterized by a high cost.

Therefore, the search for ways to comprehensively improve the effectiveness of seeding technology there is an urgent task in the field of mechanization of agricultural production.

On the basis of previous research and design work, a new design and technological scheme for a combined aggregate for intrasoil fertilizer and simultaneous sowing of grain crops using a wheeled tractor, traction class 1.4 (Figure 1) was proposed. The main advantage of this fertilizer-sowing machine-tractor unit is the possibility of placing the main dose of mineral fertilizers in the soil below the simultaneously sown seeds in the form of a ribbon, i.e. in the zone where the roots of grain crops are located, which in turn increases the efficiency of using the basic dose of mineral fertilizers.

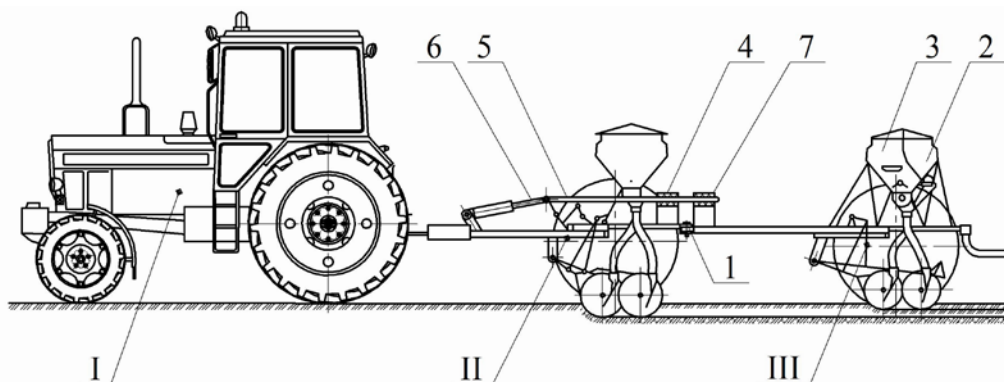


Fig. 1. Unit for underground soil mineral fertilizer and simultaneous sowing of grain crops (side view):

I – tractor; II – machine for applying the main dose of mineral fertilizers; III – machine for sowing grain and introducing a starting dose of the mineral fertilizers: 1 – the hinge; 2 – bunker for starting fertilizers; 3 – seed hopper; 4 – a directing element; 5 – blocking element; 6 – the rod; 7 – fixing element

2. Preconditions and means for resolving the problem

2.1. Analysis of recent research and publications

When creating the sowing units, the two main directions can be found: the creation of aggregates based on one operating machine, and the creation of specialized combined units. The practice of using aggregates that are made up of individual machines allows, if

necessary, to carry out different technological operations, and the use of combined sowing units that perform several technological operations in one pass makes it possible to reduce the number of passes of the unit and compaction of the soil, increase the yield of agricultural crops, and keep the soil moisture content [1-6].

On the basis of the analysis of the agrotechnological peculiarities of sowing of agricultural crops, it was suggested, when sowing grain crops, to combine the implementation of the crop with the introduction of the starting and the main dose of mineral

fertilizers with the application of a two-machine combined seeding unit using a two grain seeders and a tractor of traction class 1.4.

2.2. Purpose of the study

The purpose of the study is the experimental substantiation of the expediency of combining technological operations of sowing grain crops and application the starting and main dose of mineral fertilizers when using a combined seeding unit.

2.3. Methods of research

For the experimental study of the expediency of combining the process of sowing grain crops and introducing a starting and basic dose of mineral fertilizers, field experience was also established in the production conditions in the research fields of the Yelenovskoye

Research Farm of the Fastovsky District of the Kiev Region during the sowing of spring wheat and barley according to known methods [7-9].

The field research conditions were determined according to the existing methods and make up: previous cultivation pre-sowing cultivation, soil type chernozem, relief of the field level, microrelief - leveled, soil moisture content: in the layer 0 – 5 cm it was 17.4 – 18.7%, in the 5 – 10 cm layer it was 20.1 – 22.3%, the soil hardness: in the 0 – 5 cm layer it was 0.20 – 0.35 MPa, in the layer 5–10 cm it was 1.38 – 1.57 MPa, weed infestation it was 13 g·m⁻².

The investigations were carried out on an experimental equipment – on a combined seeding unit, which was formed from two grain drills (Figure 2).



Fig. 2. General view on the field experimental machine – tractor aggregate

The first seeder of the sowing unit provides for the in-soil application of the required starting dose of mineral fertilizers to the required depth with a row spacing of 25 cm, and the second seeder – provides sowing of grain crops to the appropriate depth with a row spacing of 12.5 cm with simultaneous application of the main dose of mineral fertilizers. To assemble seeders among themselves and with the tractor, a special coupling was designed and manufactured, the use of which will ensure the necessary maneuverability of the combined unit (aggregate) during operation and transportation [10].

To conduct field experimental studies, we have developed a general methodology for experimental studies.

Experimental field research, which is defined in the program, involves the use of both standard and partial techniques:

- methodology for determining the conditions for conducting the research;
- methodology for determining the main agrotechnical indicators;
- the methodology of conducting laboratory and field studies to determine the influence of parameters and operating conditions of the unit (aggregate) on the quality of sowing;
- the methodology for conducting field studies to justify the feasibility of combining technological operations in a single pass of a combined seeding unit.

The general methodology of the field experimental research included the selection of the necessary instruments, equipment, devices and techniques that will be used for fixing and measuring of different parameters.

For the experimental seeding on given field, the areas were identified that were sown for one day according to the following schemes: 1) pre-sowing the soil tillage without the application of granular mineral fertilizers (control); 2) with a continuous surface application of the starting dose of fertilizers, pre-sowing soil tillage and sowing of seeds with the simultaneous introduction of a basic dose of fertilizers into the soil; 3) standard pre-sowing soil tillage and seed sowing with the simultaneous introduction of fertilizer into the soil with a starting dose [11].

The sowing process was carried out by a combined aggregate to a seeding depth of 5 cm, a fertilizer depth of 8 cm with a seeding machine speed of 10 km·h⁻¹ (2.78 m·s⁻¹), which were justified by the

results of previous laboratory-field experimental studies. The evaluation of the efficiency of sowing was carried out according to the yield (q·ha⁻¹), which was determined by the standard method during the full maturity of the crops by manually collecting them from the area, which is limited to a 1 m x 1 m frame and further weighing.



Fig. 3. Experimental aggregate during providing the research

In addition, experimental studies were carried out comparing seed productivity with basic and modernized seeding units. The seeding depth variation coefficient (%), the uniformity of seed distribution in a row (%) and seed germination (%) were used as an indicators of crop efficiency. For this purpose, sowners were raised during the sowing and, by measuring at five points of the field, the depth of sowing of seeds and the number of seeds on one running meter of the row were monitored five times in succession, and after the shoots were opened a row at five points of the field and the number of sprouted and not germinated seeds were determined.

3. Results and discussion

Experimental studies were carried out using the standard matrix 2 ** 3 [9, 12, 13]. Number of experiments: 9. The repetition of the experiments was determined according to the established

procedure [9] to ensure the required accuracy of the studies and is at least 3.

For each series of experiments, the arithmetic mean of the measured value was determined as a product of these values effected by their frequencies

$$\bar{X} = \frac{1}{n} \sum_{i=1}^n x_i \cdot f(x_i). \quad (1)$$

Estimation of the dispersion of the actual values of the measured values with respect to their mean value is characterized by the root-mean-square deviation and dispersion [12, 13].

Dispersion of a discrete random variable is defined as the sum of products of squares of deviations of the actual value from the mathematical expectation by the corresponding probability:

$$D_x = \sum_{i=1}^n (x_i - M_x)^2 \cdot p(x_i). \quad (2)$$

Then for a continuous random variable the expression (2) will have the form:

$$D_x = \int_{-\infty}^{+\infty} (x - M_x)^2 \cdot \varphi(x) dx. \quad (3)$$

Then for empirical determination of random variables:

$$\sigma_x^2 = S_x^2 = \frac{1}{n} \sum_{i=1}^n (x_i - \bar{X})^2 \cdot f_i, \text{ for } n > 30, \quad (4)$$

$$\sigma_x^2 = S_x^2 = \frac{1}{n-1} \sum_{i=1}^n (x_i - \bar{X})^2 \cdot f_i, \text{ for } n < 30. \quad (5)$$

The variance according to (2) – (5) has the dimension of the square of the dimension of the random variable.

The root-mean-square deviation is defined as the square root of the variance (4) and (5), which is taken with a positive sign:

$$\sigma_x = +\sqrt{D_x}. \quad (6)$$

The variability of the measured values is characterized by the coefficient of variation, which is determined by the ratio of the root-mean-square deviation (6) to the mathematical expectation (arithmetic mean) according to (1) of the corresponding random variable:

$$V = \frac{\sigma_x}{M_x} (\times 100\%). \quad (7)$$

Having obtained the data obtained as a result of experimental studies, it is necessary to verify their reproducibility and adequacy of the regression models obtained [12, 13].

To evaluate the reproducibility, the Cochran test was used

$$G = \frac{S_{u \max}^2}{\sum_{u=1}^n S_u^2} \leq G_{tab.}(0,05; n; f_u), \quad (8)$$

where $G_{tab.}(0,05; n; f_u)$ – table value of the Cochran test at 5% significance level, with the number of experiments n and the number of degrees of freedom; $f_u = m - 1$ – with the number of replicates m ; $S_u^2, S_{u \max}^2$ – variance at the u -th level and its maximum value.

Dispersion (3.7) can be determined by the following way:

$$S_u^2 = \frac{1}{m-1} \sum_{i=1}^m (y_{uik} - \bar{y}_u)^2, \quad (9)$$

where y_{uik} – the value of the original parameter on the corresponding replication.

Then, in general, the error of the experiment is calculated using the following expression:

$$S_y^2 = \frac{1}{n} \sum_{u=1}^n S_u^2. \quad (10)$$

After determining the statistical indicators for each series of experiments, the results were processed to obtain a regression model in the form of a polynomial of the 2 and degree, which characterizes the influence of the factors and their interaction on the quality characteristics of the combined seeding unit. The general regression equation has the following form:

$$Y = b_0 + b_p X_p + \dots + b_{pr} X_p X_r + \dots \quad (11)$$

The coefficients in equation (11) are determined according to the following expressions:

$$\begin{aligned} b_0 &= \frac{1}{n} \sum_{i=1}^n \bar{y}_u, \\ b_p &= \frac{1}{n} \sum_{i=1}^n X_p \bar{y}, \\ b_{pr} &= \frac{1}{n} \sum_{i=1}^n X_p X_r \bar{y}. \end{aligned} \quad (12)$$

This regression equation (11) is an empirical model of the process and describes the influence of individual factors and their interactions on the qualitative performance indicators.

The adequacy of the regression equation (11) is checked by the Fisher criterion:

$$F = \frac{S_{ad}^2}{S_y^2} < F_{tab.}(0,05; f_{ad}; f_y), \quad (13)$$

where $S_{ad}^2 = \frac{1}{f_{ad}} \sum_{u=1}^n (y - \bar{y}_u)^2$ – variance (dispersion) of adequacy;

$f_{ad} = n - k - 1$ – number of degrees of freedom of the variance of adequacy for the number of factors equal to k ; $f_y = n(m-1)$ – number of degrees of freedom of variance of reproducibility.

Having checked the adequacy, it is necessary to evaluate the importance of regression coefficients (12), using the Student's test.

The regression coefficient is significant if:

$$|b_i| \geq t_{tab.}(0,05; f_y) \frac{S_y}{\sqrt{n}}, \quad (14)$$

where $t_{tab.}(0,05; f_y)$ – table value of the Student's test at 5% level of significance.

Since the effect of individual factors and their interactions, taking into account random perturbations and unaccounted for factors, has not been fully investigated, we will retain all the terms in equation (11) when processing the research data.

In addition, in order to determine the relationship between the values (between the initial parameter and the factor, and also the factors among themselves), a correlation analysis was carried out by determining the correlation coefficient between the parameters x and y :

$$r_{xy} = \frac{K_{xy}}{S_x S_y}, \quad (15)$$

where S_x, S_y – standard deviation of the corresponding parameters; K_{xy} – correlation moment.

If the correlation coefficient according to (15) is equal to zero, then the parameters are uncorrelated, provided that the correlation coefficient is greater than 0.7 the correlation is strong, 0.3-0.7 – average correlation, less than 0.3 – correlation is weak.

In this case, the root-mean-square error of the correlation coefficient is determined in this way:

$$S_r = \sqrt{\frac{1 - r_{xy}^2}{n - 2}}. \quad (16)$$

The relationship between the values is significant in case that the value of the Student's test criterion is greater than its table value, i.e.:

$$t_r = \frac{r_{xy}}{S_r} \geq t_{tab.}. \quad (17)$$

With simultaneous action of several values on the optimization parameter, it is advisable to apply a multiple correlation coefficient. The tightness of the relationship between parameter x with parameters y, z can be determined from the following expression:

$$R_{x,yz} = \sqrt{\frac{r_{xy}^2 + r_{xz}^2 - 2r_{xy}r_{xz}r_{yz}}{1 - r_{yz}^2}}, \quad (18)$$

and the parameter of the positive with the boundaries of the possible change from 0 to 1. The zero value of the multiple

correlation coefficient means that there is no linear relationship between the parameters, but the possible nonlinear one. If this coefficient is equal to 1, then there is a linear relationship, and all the experimental data lie in one plane, which can be considered as a response surface.

The square of the correlation coefficient is a determination that shows the proportion of changes in the flow and expresses the dependence of one parameter on the other parameter.

When processing the results of experimental studies, the application packages EXCEL, STATISTICA v 10.0 and MathCAD were used.

During the first stage of laboratory-field experimental studies, the influence of parameters and operating conditions of the combined fertilizer-seed aggregate on the indices of the quality of barley sowing was carried out with the simultaneous introduction of the starting and the main dose of mineral fertilizers into the soil.

In this case, the main factors are the depth of sowing of seeds and placing of the fertilizers, as well as the forward speed of the machine-tractor unit (aggregate). The depth of sowing of seeds was taken as 2 cm, 4 cm and 6 cm, the depth of placing of fertilizers into the soil was 7 cm, 8 cm and 9 cm, and the forward speed of the machine-tractor unit was $1.0 \text{ m}\cdot\text{s}^{-1}$, $1.5 \text{ m}\cdot\text{s}^{-1}$ and $2.0 \text{ m}\cdot\text{s}^{-1}$ (i.e. $3.6 \text{ km}\cdot\text{h}^{-1}$, $5.4 \text{ km}\cdot\text{h}^{-1}$ and $7.2 \text{ km}\cdot\text{h}^{-1}$, respectively).

As a qualitative indicators of the work was adopted the coefficients of variation (in %) the location of seeds and mineral fertilizers along the row (furrows), the deviation of seeds and fertilizers relative to the row axis and the depth of laying of seeds and fertilizers in the furrow. In order to control the placement of mineral fertilizers, soybean seeds were sown in the furrow.

Field studies with barley sowing were carried out on sites with previous ploughing and pre-plant cultivation.

Based on the results of statistical processing of the results of field experimental studies, the following performance indicators of the combined fertilizer-seeding unit were obtained:

- uniformity of the distribution of mineral fertilizers (soybean seeds) along the row:

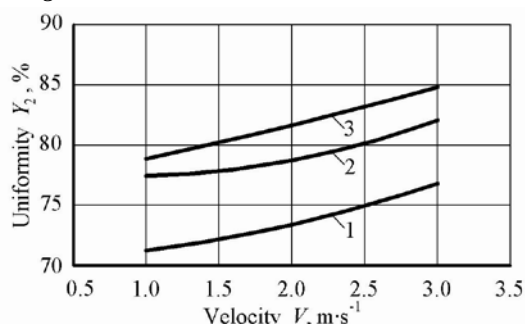


Fig. 3. The effect of the speed of the fertilizer-seeding unit on the uniformity of the distribution of fertilizers (soybean seeds) along the line at a different depths of laying fertilizers in the soil: 1 – $H = 7 \text{ cm}$; 2 – $H = 8 \text{ cm}$; 3 – $H = 9 \text{ cm}$

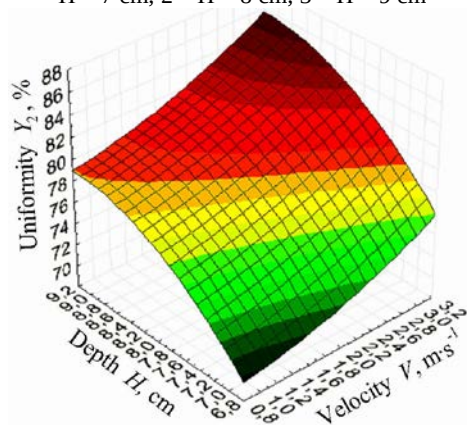


Figure 4. The effect of a forward speed of movement of the fertilizer-seed aggregate and the depth of fertilization in the soil on the response surface of the dependence of the uniformity of the distribution of fertilizers (soybean seeds) along the row

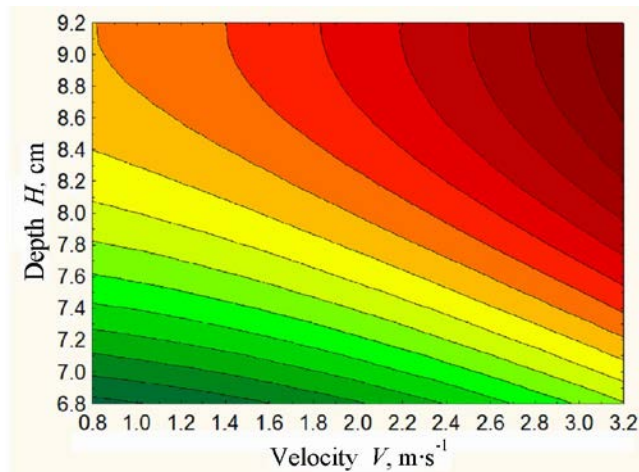


Fig. 5. Two-dimensional section of the dependence of the uniformity of the distribution of fertilizers (soybean seeds) along the row on the speed of movement of the fertilizer-seeding unit and the depth of fertilization in the soil

As a result of the studies (Figures 3, 4, 5) it was established that with an increase in the forward speed of movement of the fertilizer-seeding unit and the depth of placing of mineral fertilizers into the soil, the uniformity of their distribution at the bottom of the furrow will increase.

The regression equation that will describe this dependence will have the following form:

$$Y_2 = -60.6811 - 0.4867 V + 30.41 H + 0.6167 V^2 + 0.09 V H - 1.6633 H^2. \quad (19)$$

- coefficient of variation of the depth of sowing of barley seeds:

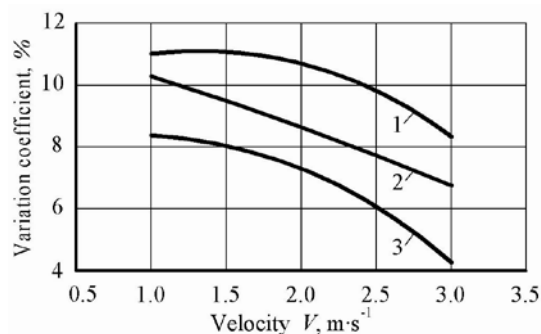


Fig. 6. Effect of the forward speed of the fertilizer-seeding unit on the variation coefficient of the depth of sowing of barley seeds at a different depths of seed sowing: 1 – $H = 2 \text{ cm}$; 2 – $H = 4 \text{ cm}$; 3 – $H = 6 \text{ cm}$

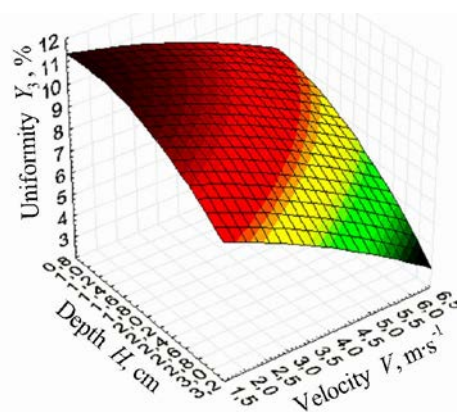


Fig. 7. Effect of forward speed of the fertilizer-seeding unit and the depth of sowing of seeds on the response surface of the dependence of the coefficient of variation of the seeding depth of barley seeds

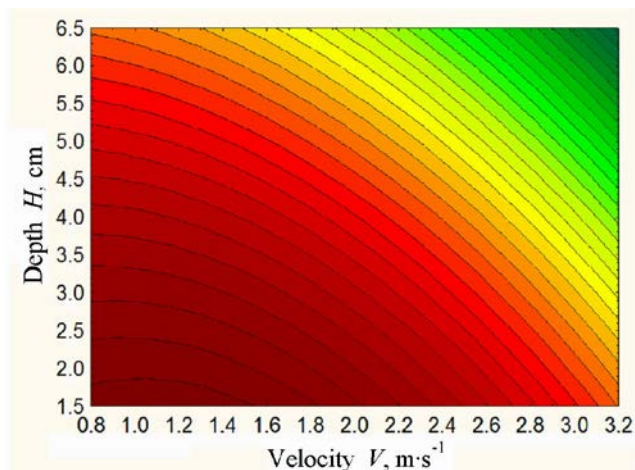


Fig. 8. Effect of the forward speed of the fertilizer-seeding unit and the depth of sowing of seeds on the two-dimensional cross-section of the coefficient of variation of the depth of sowing of barley seeds

The analysis of the results obtained (Figures 6, 7, 8) made it possible to determine the decrease in the deviation of the depth of seed sowing from the set value and the depth of sowing of seeds with increasing speed of movement.

The functional dependence for this case will have the following form:

$$Y3 = 10.79 + 1.7883 V - 0.05 H - 0.705 V^2 - 0.18 V H - 0.055 H^2. \quad (20)$$

When carrying out comparative field experimental studies of the quality of barley sowing with basic and modernized sowing units (aggregates), the following values of qualitative indices were obtained according to the adopted methodology:

- coefficient of seed depth variation for the basic unit was 8.2%, and for modernized unit was 4.7%;
- uniformity of seed distribution along the row length for the basic unit was 63.8%, for the modernized unit was 84.9%;
- field germination of seeds when sowing by the basic unit was 80.4%, for modernized unit was 87.4%.

So, based on the analysis of the results of the research results, it is established that when the combined seeding machine is used, the uniformity of seed distribution along the length of the row will be substantially increased. Simultaneously, the field germination of the seeds will increase, and the coefficient of variation in the depth of seed placement in the furrow will decrease. The obtained data of experimental studies confirm the improvement of the quality of sowing when combining technological operations with a combined sowing unit. At the same time, it was established that in the process of the combined unit operation in the field conditions, there could be flaws in the mutual arrangement of the rows of passes of the two seeders of the unit due to the imperfect construction of the coupling.

Experiments were conducted to justify the expediency of combining the above technological operations in one pass of the unit (aggregate). For this purpose, the research areas on which spring wheat and spring barley were sown within experiments which was divided into three main schemes:

- 1) sowing of grain crops after cultivation without applying fertilizers (control = scheme I);
- 2) continuous introduction of a starting dose of mineral fertilizers in a dispersed way + pre-sowing cultivation + combined sowing with simultaneous application of the basic rate of fertilizers (scheme II);
- 3) pre-sowing cultivation + combined sowing by the experimental seeding unit with simultaneous application of the starting and basic fertilizer rate (scheme III).

Also, studies were carried out to evaluate the yield increase when applying a modernized seeding unit in comparison with conventional pre-sowing soil without applying granular mineral fertilizers and with a continuous superficial application of the starting fertilizer dose, with further pre-sowing soil cultivation and sowing of seeds, while simultaneously introducing the main dose of

fertilizers into the soil. As a result of the studies (Figure 9) it was received an information that when using a combined seeding machine for simultaneous sowing with the introduction of the starting and basic fertilizer doses, the yield of spring wheat is 5.64 t·ha⁻¹ and spring barley 5.73 t·ha⁻¹.

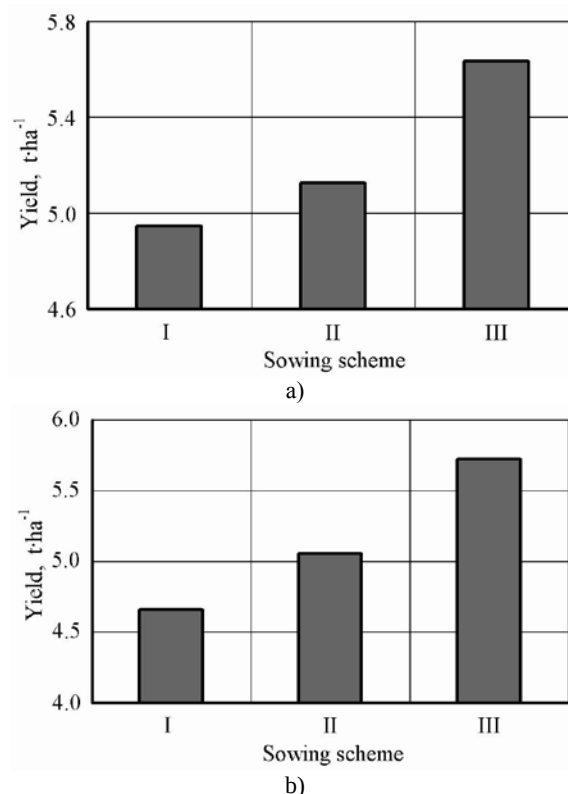


Fig. 9. The diagrams presenting the yield of grain of spring wheat (a) and spring barley (b) when sowing according to schemes: I, II and III

In this case, compared with the application of a full-area fertilizing of the fertilizer starting rate in a spreading method, pre-sowing cultivation and combined sowing with the simultaneous introduction of the basic fertilizer rate, the yield of spring wheat was increased by 0.51 t·ha⁻¹ and spring barley by 0.67 t·ha⁻¹. The increase in yields when using the modernized aggregate in comparison with sowing without fertilization is 0.69 t·ha⁻¹ for spring wheat and 1.06 t·ha⁻¹ for spring, respectively.

Taking into account the price of 1 metric center of grain crops (as of January 2017), the economic effect of increasing the yield of grain crops for spring wheat is 2652.00 UAH·ha⁻¹, and for spring barley is 3048.50 UAH·ha⁻¹.

Table 1 Technological and operational parameters of the combined seeding unit

Parameter	Value
Turning radius, m	6.5 – 8.9
Duration of the turning, s	18.4 – 24.7
Average forward speed on the headland, m·s ⁻¹	1.78
Deviation of the trajectory of the second machine relative to the trajectory of the first machine, cm:	
when turning	23.7
during the working pass	3.6
Specific fuel consumption, lt·ha ⁻¹	3.77
Shift time utilization coefficient	0.85

When conducting field studies using the standard method, the shunting and operating parameters of the combined seeding unit (Table 1) were also determined, which confirm the compliance of these indicators with the requirements for effective sowing.

According to the analysis of the obtained results of field studies of the work quality indicators, as well as the evaluation of the increase in the yield of cereals due to the application of the combined seeding unit, the expediency of combining the technological operations of sowing grain crops with the introduction of the starting and the main fertilizer dose in one pass of the proposed combined seeding unit has been proved.

4. Conclusions

As a result of field experimental studies, an increase in the yield of spring wheat and spring barley was confirmed with the use of a combined seeding machine for simultaneous sowing of cereal crops with application of a starting and basic dose of fertilizers into the soil in comparison with known sowing schemes. The obtained results of field research confirm the expediency of combining the technological operations of sowing seeds of cereal crops from the intra-soil application of the starting and basic norms of fertilizers in one pass of the combined seeding unit.

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THEORETICAL INVESTIGATION AND DEVELOPMENT OF A DESIGN OF A NEW HAULM TOPPING MACHINE

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Abstract. Theoretical investigations have been conducted of the technological process of a sugar beet haulm topping machine with a rotary cutter mechanism, as a result of which there is developed a refined mathematical model of interaction of the cutting blade with a bundle of leaves, the blade being pivotally fixed on the horizontal drive shaft of the arcuate cutting blade. Basic analytical dependencies have been obtained, application of which in designing and constructing of a haulm topping machine will ensure guaranteed quality removal of the bundles of leaves without extracting the sugar beet roots from the soil. The numerical calculations of the obtained analytical expressions performed on the PC, using a prearranged program, made it possible to determine the design parameters of the rotary haulm topping apparatus.

KEYWORDS: SUGAR BEET, HAULM TOPPING, ROTOR, MATHEMATICAL MODEL.

1. Introduction

Irrespective of the remarkable progress made in the creation, production and operation of high-performance beet harvesting equipment, there remain up to this day a number of unsolved essential problems which are of global importance, as well as a series of still unanswered questions directly connected with sugar beet harvesting in Ukraine and other countries in Eastern Europe. This, of course, is a problem how to improve the quality of the beet raw material, particularly in case it is obtained under complicated harvesting conditions (increased hardness of the soil or its excessive humidity, irregular and not straight sowings, excessive weediness, and so on), which are widespread in the production of this industrial crop [1-4]. That is why a search for new theoretical developments and design solutions are now going on in the world with intensity not less than at the start of the development of the first specimens of beet harvesters [5-6]. Besides improving the quality of the raw material, the scientists and designers of Europe and the world make considerable efforts looking for the conditions of an essential decrease in the specific energy intensity of the root crop extraction process, an increase in the efficiency and reliability of machines, as well as a significantly lower pollution of the heap by soil impurities because, due to ecological requirements, it is not allowed to carry away from the fields the fertile soil together with the root crops.

The above concerns, first of all, haulm topping machines the high-tech and high-quality work of which ensures also the high quality of topping the haulm now used efficiently as a raw material for the biogas extraction. An important condition is also that the root crops must not be damaged and there are minimum losses of their upper parts – the sugar beet heads as a sugar-bearing mass.

2. Materials and methods

The aim of the research is development of a new design of a haulm topping machine the technical and operational performance indicators of which should be at the level of the best world analogues, applying the results of the conducted theoretical investigations of the technological process of its operation.

The methods used for the execution of the investigation were: methods of designing and constructing agricultural machines, methods of building computational mathematical models based on higher mathematics, theoretical mechanics, as well as compilation of programs and numerical calculations on the PC.

On the basis of the developed new theories of beet harvesting machines [7] basic provisions for the calculation and design of rotary haulm topping machines have been elaborated. Thus, a computational mathematical model was constructed for continuous, complete removal of a bundle of leaves by a rotary cutter mechanism, i.e. a mechanism with a horizontally placed drive shaft having pivotally fixed arcuate cutting blades, rotating with a definite frequency and moving with a preset speed of the forward movement. An equivalent scheme of this technological process,

used in the theoretical research, is presented in Fig. 1.

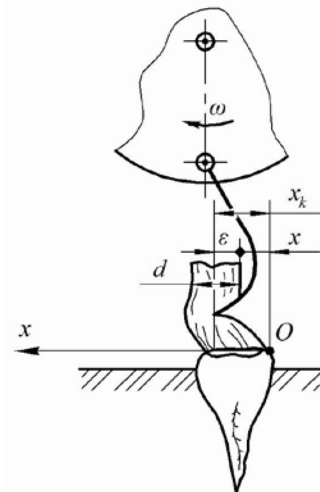


Fig. 1. An equivalent scheme of interaction of the arcuate blade of the rotary cutter mechanism with a bundle of leaves

3. Results and discussion

On the basis of the conducted theoretical investigation a condition of complete removal of the entire bundle of leaves with a diameter d was specified at the first contact of the edge of the arcuate blade with this bundle of leaves. Taking into consideration the penetration value ε of the blade into the bundle of leaves (Fig. 1), which is equal to $\varepsilon = x_k - x$, and considering the condition that for complete removal of the bundle of leaves with a diameter d at the first contact of the edge of the arcuate blade with the bundle it is necessary that $\varepsilon = d$, the finally obtained condition for complete removal of the bundle of leaves is:

$$d = \varepsilon = V_{cr} t - \frac{P_m}{\mu} \left(1 - \cos \sqrt{\frac{\mu}{M_{br}}} t \right) - \frac{P_m}{\mu} \left(1 - \cos \sqrt{\frac{c}{m_{bt}}} t \right). \quad (1)$$

where ε – the penetration value of the tip of the arcuate blade into the bundle of leaves; P_m – the average cutting force; M_{br} – the applied mass of the blade (the mass of the knife applied to the point of impact of the blade upon the bundle of leaves); m_{bt} – the mass of the bundle of leaves applied to the point of impact; V_{cr} – the critical speed of the forward movement of the blade at which non-supported cutting of free-standing bundles of leaves is possible; $V_{cr} t$ – movement of the edge of the blade at the moment of time t when no contact with the bundle of leaves takes place and the blade is in a radial position; c – the elasticity coefficient of the leaves; μ – the

proportionality coefficient (the intensity of the load which acts upon the blade when it deviates per unit of length).

The obtained expression (1) provided a possibility to set such design and kinematic parameters of the rotary haulm topping mechanism at which cutting of the bundle of leaves takes place in the process of a single contact of the edge of the arcuate blade with the bundle.

Theoretically determined was also the rotational speed n of the shaft of the rotary cutter mechanism on the basis of the critical linear velocity V_{cr} that is necessary for cutting free-standing bundles of sugar beet leaves. The analytical expression for the determination of the number of revolution n of the shaft of the rotary cutter mechanism, on condition of guaranteed and quality cutting of the haulm, has the following form:

$$n > \frac{30 V_{cr}}{\pi R}, \quad (2)$$

where R – the radius of the rotor (in this case from the rotation axis of the rotor to the edge of the arcuate blade), which is selected on condition that the vertical dimension of the cutting area should not exceed its size, i.e. $R > H - h$; H – the height of the leaves above the soil surface; h – the height of the installed continuous, uncopied cut of the sugar beet leaves.

By numerical calculations performed on the PC the value of radius R of the rotor of the rotary cutter mechanism was determined, which is within the limits 300...350 mm. Also on the basis of numerical simulation the width of the arcuate blade was found out considering the maximum diameter d_{max} of the bundle of leaves, which is equal to $B = d_{max} + (30 \div 50)$, mm. In order to achieve qualitative non-supported uncopied cutting of the sugar beet haulm, the rotational speed n of the rotor of the cutter mechanism should be not less than 600 min^{-1} .

The numerical calculations of the obtained theoretical dependences provided a possibility to design a rotary cutter mechanism of the sugar beet haulm with new design parameters for which patents of Ukraine have been granted [8]. A superlight highly reliable rotary haulm topping machine was developed the design and technological scheme of which is presented in Fig. 2 [9]. At the same time, the haulm topping machine of such a design is frontally mounted on the wheeled tractor of traction class 1.4 – 3.0.

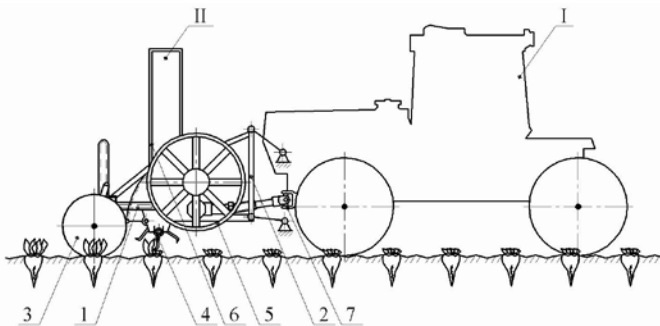


Fig. 2. A design and technological scheme of the haulm topping machine frontally mounted on a wheeled tractor:

I – the tractor; II – the haulm topping machine; 1 – the frame; 2 – suspension; 3 – pneumatic tracer wheels; 4 – the rotary haulm cutter; 5 – the screw conveyor and the paddle thrower; 6 – the discharge chute

The haulm topping machine may be used practically under all weather conditions. The use of an aggregating tractor of traction class 3 is allowed in the case of a rear mounted root harvesting machine.

In order to theoretically assess the efficiency of a haulm topping machine which front-mounted on the wheeled tractor, using the well-known dependencies to determine the productivity of the machine-tractor unit, the following expression was obtained:

$$W = 0,1B \left\{ \frac{3600 \cdot \xi \cdot N_e \eta_t \eta_v \left[1 + \frac{1}{b} \ln \frac{(mg \cdot \psi + kB) \cdot (mg \cdot \lambda)^{-1} - \varphi}{\alpha} \right]}{(kB + mg\psi) \eta_v + 10N_p B \cdot H \eta_t \left[1 + \frac{1}{b} \ln \frac{(mg \cdot \psi + kB) \cdot (mg \cdot \lambda)^{-1} - \varphi}{\alpha} \right]} \right\}, \quad (3)$$

where: N_e – nominal efficient engine capacity, kW; ξ – engine loading factor; N_p – specific energy consumption of energy for the execution of the technological process of harvesting sugar beet tops, $\text{kW} \cdot \text{s} \cdot \text{kg}^{-1}$; $\hat{f}$ – yield of sugar beet tops, $\text{cent} \cdot \text{ha}^{-1}$; η_t – coefficient of efficiency of the transmission of a wheeled aggregating tractor; η_v – coefficient of efficiency of the frontal power take-off shaft of the tractor; α – angle of elevation, rad; m – mass of the wheeled aggregating tractor, kg; g – acceleration of gravity, $\text{m} \cdot (\text{s}^2)^{-1}$; k – specific resistance of the frontally mounted top removal machine, $\text{N} \cdot \text{m}^{-1}$; ψ – resistance coefficient to the movement of the wheeled aggregating tractor; φ – coefficient of the use of the drawbar weight; a, b – constant coefficients, which depend on the type of the wheeled aggregating tractor and the agrobbackground on which the removal of the sugar beet leaves takes place; λ – coefficient of the drawbar weight of the tractor; $\hat{A}$ – working width of the top removal machine frontally mounted on the wheeled tractor, m.

The obtained expression (3) is a mathematical model of aggregation of the top removal machine frontally mounted on the wheeled tractor. Using this expression (3), we will determine the efficiency of the given machine and tractor aggregate, which consists of a developed haulm topping machine and tractor of traction class 3 (Fig. 3).

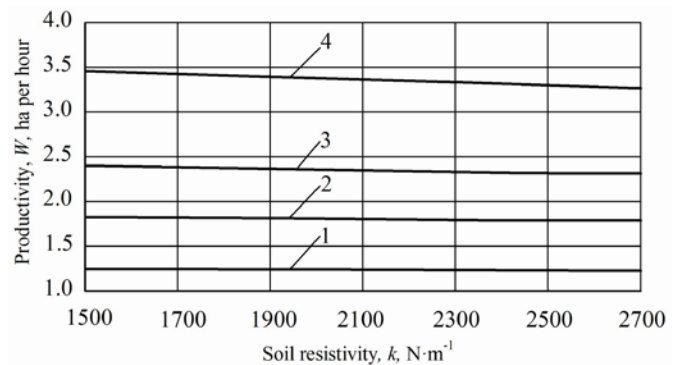


Fig. 3. – Dependence of the efficiency W of the top removal machine frontally mounted on the wheeled tractor, traction class 3, on the specific resistance k at various working widths B :

1 – $B = 0.9 \text{ m}$; 2 – $B = 1.35 \text{ m}$; 3 – $B = 1.8 \text{ m}$; 4 – $B = 2.7 \text{ m}$

As a result of numerical simulation on the PC it was established that the wheeled tractor of the traction class 3 will ensure efficiency more than $3.0 \text{ ha} \cdot \text{h}^{-1}$ when a six-row frontally mounted top removal machine is aggregated at any values of the specific resistance, and, due to the power reserve, there remains a possibility to use a rear-mounted cleaner of the sugar beet heads or a similar sugar beet harvesting machine.

The results of the manufacturing tests of the new haulm topping machine showed that a significant reduction in the amount of the haulm on the sugar beet heads is achieved – up to 1.5... 3.0 %; a reduction in the losses of the haulm – by 5...7 %; a decrease in the energy parameters of the cutting process of the sugar beet haulm, on the average, 1.5 – 1.8 times in contrast to the haulm topping machines which are now produced in the world in large quantities [10].

4. Conclusions

A theory of the technological process for a non-supported uncopied cutting the bundle of leaves, which allows to determine the

analytical condition of complete removal of the bundle of leaves of a preset diameter depending on the design and power parameters of the rotary cutter mechanism has been developed.

The numerical calculations of the obtained analytical expressions performed on the PC made it possible to determine concrete values of the indicated kinematic and design parameters.

The results of the conducted manufacturing tests show that the developed design of the haulm topping machine has good technical and operational characteristics with aggregating tractor of traction class 3.

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THE USE OF ARCHIVAL MAPS FOR THE MONITORING OF AGRICULTURAL LAND

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Abstract The results of the regional soil survey conducted in 1983 (scale 1:50000) were compared with the data obtained during the agrochemical survey in 2016. It was found that classification soil map are poorly connected with the modern agrochemical status of cultivated soils. However, archival maps can serve as a valuable source of information about the former state of the territory.

KEY WORDS: ARCHIVAL MAPS, AGRICULTURAL LAND, MONITORING, GEOSTATISTICS

Introduction

There are a large number of soil surveys data that were collected in the Soviet Union in the late 20th-century. They were generalized in the form of large-scale soil maps of farms, districts and a whole region. The accompanying descriptions contain a large amount of information about morphological properties, particle size distribution, soil organic matter content (SOC) and basic agrochemical properties of soil profiles on the basis of which was allocated to the soil contours. The soil profiles locations were pointed on soil maps with the scale 1:10000. But, as a rule, generalized soil-agrochemical maps of regions of scale 1: 50000 are more accessible. These data can serve as a point of reference in assessing changes in land cover that have occurred over the last 25-30 years. However, there are several uncertainties due to both technical and purely subjective reasons. Not always the satisfactory quality of the topographic basis, the inability to verify the geographic location of the soil profiles, the inevitable disruption of paper maps over time due to aging, the various methods of determining soil properties make it difficult to directly compare values at points, but modern geostatistical methods of spatial interpolation can somewhat offset these uncertainties. Another source of uncertainty can be the spatial variability of soil properties. It is known that its numerical measure, namely the variance, depends on the sampling method [1], so the comparison of time-varying data can be difficult due to different methods of sampling at certain points in time. Inaccuracies arising from the attribution of individual sites to a particular soil category make an additional contribution to the overall uncertainty of the results.

Objects and methods

The study was performed on the Bryansk region landscapes, which are the part of the Opolje- Polesye landscape zone of the Russian Plain (Fig.1).

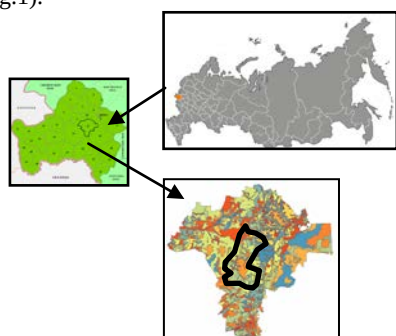


Fig.1. Soil map 1983 and study area 2016

The study area was equal about to 10000ha. The basic classification was the classification of soils of USSR, 1977. Within the area studied in 1983, 46 soil classification units were identified. The soil cover is dominated by Albeluvisol Umbric and Phaeozems Albic, which are almost completely under cultivation. Phaeozems Gleyic were associate to depressions. Fluvisols Umbric were marked as part of the territory.

We compare the soil properties (pH, soil organic matter content (SOC), mobile P2O5 and exchangeable K2O) of the top 0-20 cm

horizon obtained in 2016 survey on the part of Vygonichsky district of the Bryansk region (Russia) with the data from archive soil map of 1983 (scale 1:50,000). There were 39 individual samples in 1983 and 564 composed samples in 2016 (Fig.2). Modern boundaries of fields are shown in Fig. 2 (a).

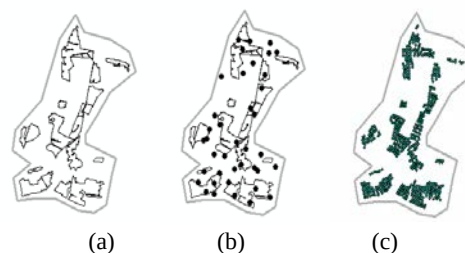


Fig.2. Soil sampling in 1983 (b, n=39) and 2016 (c, n=564)

Ordinary kriging technique [2] was used to construct soil property maps for the data collected in 2016. As a model of the structure function (semivariogram), a spherical model was used, with preliminary logarithmisation of the data for the content of phosphorus and potassium. Then values in points of 1983 sampling were interpolated and compared with the initial data.

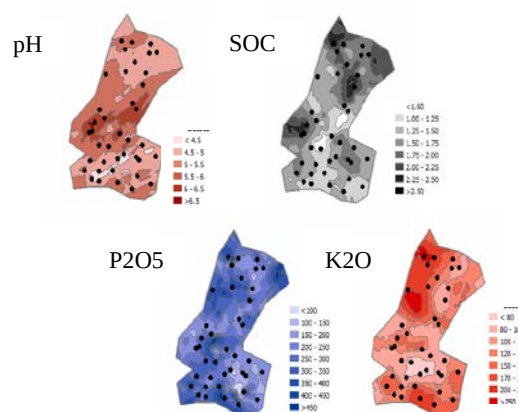


Fig.3. Maps of soil properties (2016 with points 1983)

An analysis of the spatial distribution of the values of agrochemical properties was performed using the "hot spots" technique, when the entire available data set is divided into 5 classes corresponding to the selected grades of normalized deviations. [3].

Results and discussion

From soil properties maps one can see that there are high variation inside area under study (Fig.3). Comparison of the statistical characteristics shows that in 33 years the acid-alkaline properties and SOC of the arable horizon within the surveyed territory did not change. However, it can be noted that for pH, both the minimum and maximum values increase, while for SOC the upper bound of the variation range does not change, and the minimum boundary

shifts strongly toward higher values (Table 1). The content of mobile phosphorus and potassium increased statistically significantly. In 1983 more than 50% of the surveyed area was in the category of low availability of mobile phosphorus, although in a small number of the surveyed points, the amount of mobile was above average. By 2016, the minimum detectable value is also in the category of low availability, but the maximum value so exceeds the commonly held values that may already indicate excess fertilizer application. The content of exchangeable potassium also increases, but not so much. (Table 1).

Table 1: Statistics of soil properties

	pH	SOC, %	P2O5, mg/kg	K2O, mg/kg
1983, n=39				
Mean	5.33	1.56	74	133
St.dev.	0.61	0.5	65	58
Min	4	0.3	12	20
1-quartile	4.9	1.3	27	100
Median	5.2	1.5	50	123
3-quartile	5.7	1.8	94	170
Max	6.7	2.7	250	316
2016, n=564				
Mean	5.59	1.67	239	189
St.dev.	0.57	0.43	101	90
Min	4.43	0.75	49	52
1-quartile	5.15	1.37	166	132
Median	5.51	1.61	231	170
3-quartile	5.99	1.89	293	219
Max	7.26	2.76	1005	813

The proportion of the random component in the spatial variability of the properties was evaluated according to the nugget/sill ratio, where nugget and sill are the parameters of semivariograms. It can be seen that the SOC and P2O5 values have greater spatial ordering, since the random component makes up only about a quarter of the total variability. Random components for other properties were about 60% (Table 2). The ranks of the semivariograms vary considerably, which can also be an indication of different spatial structures of individual properties.

Table 2 : Parameters of spatial model and correlation between independent (1983)) and predicted (2016) values (marked value is statistically significant at the 0.05 level)

Propertie	Nugget/sill ratio, %	Rang, m	Correlation coefficient between time points
pH	68	3600	0.014
SOC	25	2867	0.600**
P2O5	26	1200	0.268*
K2O	54	4200	0.007

**Statistically significant at $\alpha=0.05$ and * - at $\alpha=0.10$

The structure of the spatial variability of properties varied with time in time. There is no correlation between individual time points for the pH and the content of mobile potassium (the correlation coefficients are close to zero), but for the content of organic matter and mobile phosphorus, the relationship between the values at different instants of time is statistically significant (Table 2). This

is a reflection of the different temporal stability of the spatial structures of individual properties. The spatial distribution of SOC is most stable in time. On the one hand, it may be due to the slow variability of this property over time, and on the other hand, to insufficient application of organic matter during the period under review.

The increase in the average content of mobile phosphorus and potassium is due to the massive application of fertilizers in the territories exposed to radioactive contamination as a result of the Chernobyl accident. The different temporal stability of the spatial structures of these indicators correlates well with the different mobility of the elements in the soil. As a rule, phosphorus fertilizers move poorly in the soil profile, and if high doses were once introduced, the spatial structures will be retained for a long time. Potassium can not only move along the profile, but also be fixed by soil minerals, so that the expression of spatial structures in this case will be weaker.

The relationship between the content of organic matter and soil classification units is manifested only at the level of soil types (correlation coefficient 0.65). Other agrochemical properties are practically independent of soil conditions. In this way, classification of soils of the USSR in 1977, which was the basic genetic classification in Russia at the end of the 20th century, almost did not take into account the degree of possible anthropogenic transformation of soils. The visual images of the soil underlying it are loosely related to the substantive characteristics. Some connections are detected only at the level of the subtype of soils.

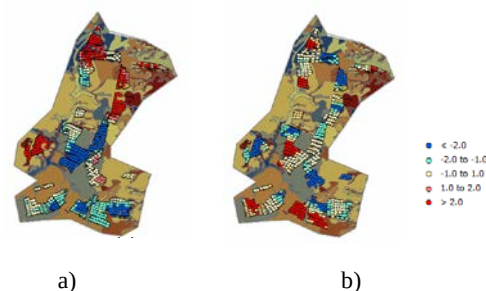


Fig.4. Hot points (clusters of normal scores) for SOC(a) and P2O5 (b)

Analysis of the "hot spots" shows that the values of agrochemical properties within individual fields form compact clusters of one (more rarely two) categories (Fig. 4). This confirms that the spatial structure of agrochemical properties in the first is determined by the type of management. Therefore, the digital data of archival soil maps are more informative for monitoring the condition of cultivated soils.

Conclusion

Thus, over the past 33 years the agrochemical status of the surveyed territory has changed significantly. A moderate relationship between the previous state is expressed only for SOC. Spatial structures of agrochemical properties primarily depend on the history of the site and to a small extent on the classification of the soil.

Acknowledgements

The study was supported by RFBR grant №16-44-320069.

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DEVELOPMENT OF HIGH ACCURACY OF THE COPY SOIL SYSTEM

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Data actuality. Ukraine is the largest agricultural country in Europe and all over the world. Foreground job of nation is guarantee of grocery safety – has accomplished in our country today. For this reason nowadays it goes increasing export of grains. For stable entrance to international market it's planning to grow crops every year from 70 till 100 mil. ton. Due to reach this result that desirables applying innovational equipment and technologies in agricultural manufacturing.

At the same time, Ukraine is situated in risk area of crop farming with lack of moisture quantity. It's known, that in the steppe region of Ukraine at the certain temperature conditions on the field after cultivation, prepared for seeding, daily lacks of ground moisture consist from 20 till 60 ton per ha [1]. That's why now technologies are extending to the growing agricultural crops widespread, focused on freeze of moisture in the ground. Accordingly agricultural requirements to operation «seeding» start ridiculous. So, for example, seeding should be accomplished during one or two days on a field; deviation from selected depth of seeding placement at the Mini-till technology - 17%, at No-till technology - 25%; pre-planting fertilizing is obligatory and so on. To the construction of the sowing machines' tools, working in energy-saving conditions, making demands to moisture-holding functions and providing additional cutting of crop residues.

Analysis of mechanical facilities, employed at the growing early grain crops and technologies has shown, that one of prohibitive and little-investigated factor in increasing of productivity and grains' quality is existence of mixed-age cultures in the field (Picture 1). The reason of getting such crop stands is neither non-appropriative agricultural technologies, nor modern sowing complexes of machines' perfection. Unevenness seedlings - is consequence of imperfect work of sowing machines' copying mechanisms. As can be seen from the above, creating of high accuracy of copy soil system is actual and it's a new direction in modernizing the sowing machines.

Problem statement. High evenness of the depth of seeding placement is one of uninvestigated and unused source of feasibility constructions of the sowing machines. The copy of soil systems were created to control this index, identified as pantograph or parallelogram systems (Picture 2). They are required in constant monitoring of their technical conditions and service. As follows, the sowing machines have 10 % of downtime at the planned maintenance.

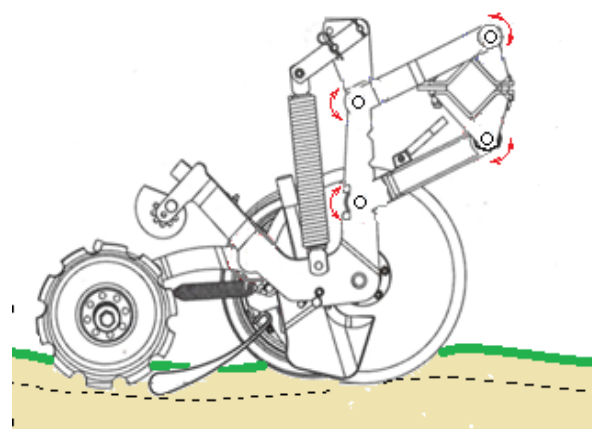
Analyze of constructions showed, that at the present technological developments no one domestic (such as, PJSC «Elvorti Group», LLC «Benec-Arpo») and foreign suppliers of high technological agricultural machines (John Deere, Gaspardo, Kinze ect.) isn't applicable the building principle of the copy soil system, which don't need in maintenance. (Table 1).

As can be seen from performed data in the Table 1 we can assume, that proposed maintenance systems to modern sowing machines are labor-intensive. The main reason of applying in the joint connections of parallelograms the rubbing-mates type of “shaft-bushing”. The constructions are able to withstand huge loads, but in case of intensive greasing with plastic materials. Default of the requirement leads to fast wear of details, locking and fail-

ure of the movable connections of parallelogram systems (Picture 2), making it impossible to conduct in order to growing-on requirements. .



Picture 1. Example of unevenness sun flower's seedlings at the violation of the depth of seeding placement.



Picture 2. Principle work of the copy soil system.

Due to this the main aim of the project is development of high accuracy of the copy soil systems (СІІККІІІІ). Mistake of the depth of the seeding placement aren't be exceed $\pm 0,5$ cm.

Solving the issue. Above said one of the most effective solution of the issue is creating tribosystem, that corresponds to the maintenance or much more service time, center around the application of composite materials for structural purpose [2, 3]. Problem of developing and involving new engineering plastics in agricultural machinery has been researched by many scientists, in several, like of Abramov L.M., Burya A.I., Kreydlin L.M., Klimchuk J.F., Tsurpal I.A., Murgas M. [4-8] and ect. Ageing process of plastics [9] and their methods of heat treatment were investigated [10].

Table 1
Quantity of movable connections in the sowing machines' constructions that required maintenance at the using and its periodicity

Production plant	Mark of machine	Working width, m	Quantity of servicing point with the frequency (service hours)		
			8-12 hours	15-25 hours	40-50 hours
Great Plains	3S-4010 HD (HDF)	12	94 (115)	9	7
	3S-4000 HD	12	22	6	14
	Yield-Pro YP2425A-2470	16,8	82	48	68
	Centurion CDA600	6	-	-	68
Horsch	Pronto 7/8/9 DC (8 DC PPF)	7,5/8/9(8)	24	-	29 (27)
	Maestro 12/24SW	8,4/16,8	-	-	79/127
Agro-Souz	Agro-Souz Turbosem II 19-60	11,4			183
John Deere	Deere Bauer 44/58/60	16,8/22,4/25,2	72/96/108	72/96/108	48/64/72
	JD 1710/1740	8,4	36	36	24
Amity Technology	Till Drill 4010	12,2	68	-	18
	Till Drill 6015	18,3	100	-	36
Vaderstad	Rapid RDA 600J(800J)	6(8)	-	-	85 (101)
	Spirit ST 600C(800C)	6(8)	-	-	66 (500ha)

For resolving the tasks, connected with development and tests of new composites' facilities (CM) in sowing machines' movable connections, required to conduct full spectrum of the works, such as: theoretical calculations, benchmark (laboratory) trials, composite materials' property corrections (if applicable) and production tests.

Based on the conducted calculations [11, 12] definitive reactions and loadings, that appeared in the friction assembly of the copy soil mechanism of the sowing complex «Agro-Soyuz Turbosem II 19-60».

Equipment and methods of investigation. Machine CMI-2 was being used for tribological tests of materials by scheme of friction «disk-shoe». Temperature in contact area is counted by electronic thermocouple «Termometer 301 Type K».

The testing of samples on the fractional tabor abrasion were conducted in accordance with ГОСТ 23.208-79 on the special prepared laboratory equipment based on the friction machine CMI-2.

Investigation of water absorption was accomplished in accordance with ГОСТ 4650-80.

Heat treatment of completed details based on the carbon fibers, due to reducing the water absorption, accomplished by own methodology [14].

Some results of laboratory investigations. In Problematic research laboratory of maintenance Dnipropetrovsk State Agrarian and Economic University (DSAEU) ga-

thered valuable experience related to creating and widespread investigation of new composite materials from non-metallic source [13].

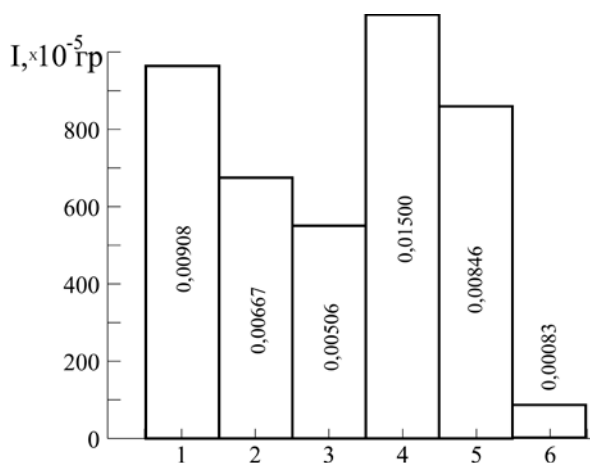
For laboratory tests took materials, extended on the EU market:

- sample № 1 – Nylon 66;
- sample № 2 – ПИА-6-210KC;
- sample № 3 – PA6/6.6 R196-GF30 (rain forced 30% glass fiber, Black 91410), factory «Almaak»;
- samples № 4 and 5 accordingly – Kocetal GF705 and Kocetal K300, factory «Kolon Plastics»;
- sample № 6 – CCMM-30M, the Republic of Belarus production and modified in DSAEU.

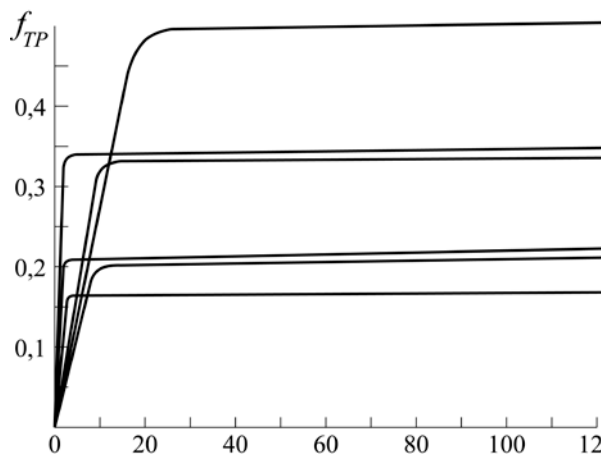
Having determined, that at the friction mode without greasing at the minimal tear of polymeric unit provides in case of using the sample № 6 (Picture 3). It explains by presence the carbon fiber materials, graphite and modifications, showed as low values of this index, as temperature rejection from friction area.

Coefficient of friction f_{TP} among tested samples characterized by stability. Thus, samples № 1, 4, 3 can be related to frictional materials, because of they have $f_{TP} \geq 0,3$. Such materials are not satisfied work conditions of tribosystem in the sowing machines.

In addition, material CCMM-30M (sample № 6) is water- absorbing (to 2 %) it was developed method of heat treatment of finished parts [14], can reduce moisture on composite materials to 40% compared with the standard.



Picture 3. Value of the weight wear of the samples at the temperature without greasing on steel 45; pressure $P=0,5$ MPa, velocity $V=0,785$ m/s.



Picture 4. Impact of service time t to coefficient of friction f_{TP} in tribosystem «metal-polymer».

Results of field tests. Field tests were made in the township Mayskoe, Dnipropetrovsk region on the territory of CJSC «Agro-Soyuz». By sowing complex «Agro-Soyuz Turbosem II 19-60» modernized with experimental ploughshares for period from April 2014 till October 2016 has fulfilled in amount of 17 521 ha. Among this period regulation works with experimental details were conducted only one. Greasing and other works for maintenance of units weren't accomplished.

Modernization technology of movable connections was developed and involved to the sowing complex «Agro-Soyuz Turbosem II 19-60» provided reducing labourship at the maintenances to 25 %, increasing of work speed to 10 %, although accurate shooting of seeds took raised harvest for winter wheat from 0,3 to 0,6 ton/ha [15] and Table 2.

Positive results of the tests of sowing complex «Agro-Soyuz Turbosem II 19-60» made in Ukraine let to modernize СПККПП in sowing machines and complexes John Deere 1895, John Deere 7000, and some other models Gaspardo, Kinze ect.

Table 2

Counted indexes of the lacks of harvest based on the evenness of the depth of winter wheat seeding placements

Counted biological harvest *, t/ha	Parentage of mixed-age groups, %	Fact harvest, t/ha	Lacks of biological harvest, t/ha
5,4	5	5,27	0,13
5,4	10	5,15	0,25
5,4	15	5,02	0,38
5,4	20	4,89	0,51

*at the sowing norm of seeding 5 ml. grain/ha, considered in mass of grains in ear.

Conclusion. Modified (improved and adopted to operating environment) polymeric composite materials furnish high-wearing feature and low coefficient of friction 0,16...0,26.

Provided stable work of movable connections of the machines and mechanisms, which work in the friction conditions without greasing and at a few quantity of abrasive work with implementation the polymeric composites, modified in DSAEU, which at the loading $P = 0,5$ MPa and velocity $V = 0,785$ m/c provide minimal coefficient of friction ($f_{TP} = 0,16$) and temperature in the friction area ($T = 44^\circ$ C).

Implementation the modified polymeric composites to СПККПП constructions increased the work rate to 10%, provided the depth of seeding placement with accuracy $\pm 0,5$ cm from determined depth, reduced the cost of labor for the maintenance to 25%. As follows, quantity of even-aged plants increased in average from 73...85 % to 88...92%. It provides stable increasing of the harvest, for example, for winter wheat to 0,3...0,6 t/ha at the different agricultural backgrounds and crop rotations.

Developed measures, methodologies and technologies might be adapted to any type of agricultural machines with the copy of soil system type "pantograph" or "parallelogram".

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THE STUDY OF MOVEMENT WIDE SPAN TRACTOR (VEHICLES) WITH KINEMATIC (TURN OF WHEELS) METHOD OF ITS CONTROL

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Abstract: Prospective energy technology devises for controlled traffic farming is the wide span tractor (vehicles). Their driving can be built behind the kinematic or force principle of the turn. At the kinematic turn, the schemes are applied by turning the steered wheels (front, rear or both front and rear) relative to the car's frame. The widest distribution in wide span tractor (vehicles) was obtained by turning schemes with all steerable wheels. The theoretical foundations of the dynamics of the parallel-span parallel motion tractor (vehicles) in the horizontal plane are presented in the article under the kinematic method of its control (by turning the wheels). Theoretical research is based on the basic principles of theoretical mechanics, tractor theory, statistical dynamics and the theory of automatic control of linear dynamical systems when they reproduce statistically random control and disturbing input effects. The amplitude and phase frequency characteristics are based on the analysis of the evaluation of the degree of influence of the circuit and parameters of the investigated wide span tractor (vehicles) on its controllability and stability of motion. The physical object of the theoretical studies was the prototype of the wide span tractor (vehicles) of the new design. Mathematical models of the wide span tractor (vehicles) movement are represented in the differential and operator form of recording. On the basis of mathematical models, the calculated amplitude and phase-frequency characteristics of the dynamic control system development are plotted, represented by the average rotation angle of the front wheels of the wide span tractor (vehicles). The constructed mathematical models, amplitude and phase-frequency characteristics allow estimating the effect of the control parameter of the wide span tractor (vehicles), as well as its design and other parameters on the controllability and stability of motion.

KEY WORDS: CONTROLLED TRAFFIC FARMING, WIDE SPAN TRACTOR (VEHICLES), THEORETICAL STUDIES, KINEMATIC METHOD OF CONTROL

1. Introduction

Analysis of the prospects for the introduction of controlled traffic farming [1-4] found that the wide span tractor (vehicles) is the main autonomous mobile energy technology complex characterized by high potential technological properties [5-9].

Research and study of the stability and controllability of the wide span tractor (vehicles) movement is the subject of special attention, since the trajectory parameters of their movement are limited by the parameters of the constant technological track. In this regard, from the position of satisfactory controllability and the stability of their movement, unresolved questions arise concerning the study of conditions that are superimposed on constructive and other parameters of the wide span tractor (vehicles). Therefore, carrying out, first of all, theoretical studies of the wide span tractor (vehicles) movement, choosing the most rational of their layout scheme, and also constructive and regime parameters, provides it with an optimal transformation of the control and disturbing influences acting on it.

Wide span tractor (vehicles) for controlled traffic farming, like any vehicle, is a rather complex control object that can be adapted to manual or automatic control and built after the kinematic or force principle of the turn. The kinematic turn is known to be realized by turning the steered wheels (front, rear or both front and rear) relative to the car's frame. The most widely used schemes are the rotation of a wide span tractor (vehicles) with steerable wheels [5-8].

It is known that the operation of a wheeled vehicle occurs under the conditions of a large number of disturbing factors (forces and their moments) that change its position in space and deflect movement from a given trajectory. The quality of development of a particular dynamic system of input variables depends on its characteristics. Relatively wide span tractor (vehicles) such are its scheme, as well as constructive and other parameters. Therefore, the correct choice of the latter, from the position of the necessary controllability and stability of its movement, ensures to it the optimal transformation of the controlling and perturbing influences acting on it.

2. Preconditions and means for resolving the problem

2.1. Analysis of recent research and publications

All known studies on this issue are aimed at studying the dynamics of the movement of agricultural units built on the basis of traditional tractors and do not concern the solution of this problem. The accumulated scientific and practical experience of using traditional machine-tractor units in controlled traffic farming allowed to substantiate certain requirements to the parameters of the constant technological track and power facilities [10]. However, these requirements do not take into account the atypical layout of the wide span tractor (vehicles), the specifics of their aggregation and the operating conditions, and therefore must be specified. At the same time, the currently known methodology for selecting design schemes, parameters and operating modes of machine-tractor aggregates can not be used to study the dynamics of the wide span tractor (vehicles). In this connection, from the position of effective use of the wide span tractor (vehicles), there are unsolved questions concerning the study of conditions that are superimposed on their constructive and other parameters.

2.2. Purpose of the study

The purpose of researches is the development of a dynamic model of a plane parallel motion in the horizontal plane of a wide span tractor (vehicles) under the kinematic way of its control (by turning the wheels), by means of which it is necessary to investigate the influence of the parameters of the control and disturbing influences on the controllability and stability of its motion.

3. Results and discussion

The theoretical studies are based on the foundations of theoretical mechanics, the theory of mobile energy facilities, statistical dynamics and the theory of automatic control of linear dynamical systems when they reproduce statistically random control and disturbing input effects. In particular, the amplitude and

It should be noted that even in a linear interpretation, the mathematical model of the wide span tractor (vehicles) movement is a system of rather complex differential equations. Therefore, in order to simplify their compilation, the following assumptions are accepted: roll and trim wide span tractor (vehicles) are absent; Wide span tractor (vehicles) is regarded as a physical solid body that has a longitudinal plane of symmetry passing through the center of its masses; The oscillation of the traction resistance of agricultural implements does not significantly affect the speed of translational motion, so that it is assumed to be constant; The lateral interaction of wide span tractor (vehicles) tires with a deformable surface is considered within the framework of the hypothesis of “lateral withdrawal”; The gyroscopic and stabilizing moments of the tires and the moments of resistance to their twisting, relative to the vertical axis, are not taken into account due to their smallness.

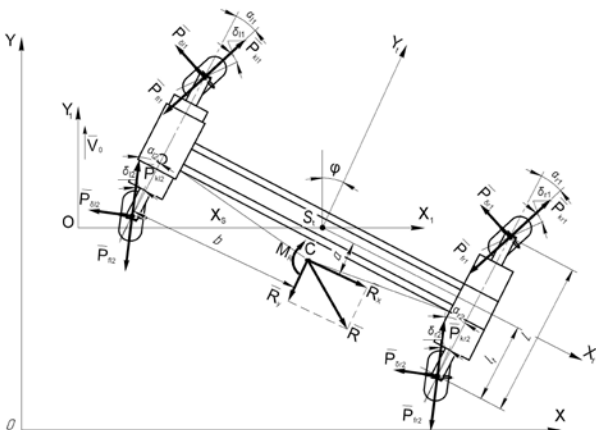
$$\begin{aligned}
Q_X &= (P_{kl1} - P_{\beta1} + P_{kr1} - P_{fr1})\alpha - \\
&\quad - (P_{kl2} - P_{\beta2} + P_{kr2} - P_{fr2})\beta + R_x - P_{\delta1} - P_{\delta2} - P_{\delta1} - P_{\delta2}; \\
Q_\varphi &= (L - l_t)(P_{kl1} - P_{\beta1} + P_{kr1} - P_{fr1})\alpha + \\
&\quad + l_t(P_{kl2} - P_{\beta2} + P_{kr2} - P_{fr2})\beta + \\
&\quad + b(P_{kl1} - P_{\beta1} + P_{kl2} - P_{fr2}) - (K - b)(P_{kr1} - P_{fr1} + P_{kr2} - P_{fr2}) - \\
&\quad - (L - l_t)(P_{s1} + P_{s1}) + l_t(P_{s2} + P_{s2}) + M_v - R_a,
\end{aligned} \tag{6}$$


Fig. 1. The scheme of the forces acting on the wide span

where: L , l_i and K , and a are design parameters, the nature of which is clear from Fig. 1; α and β – the average rotation angles of the front and rear wheels of the wide span tractor (vehicles), respectively.

After determining the angle of the tire's wide span tractor (vehicles) and lateral forces, after substituting (6) into (5) and carrying out a series of transformations, we obtain a mathematical model of the wide span tractor (vehicles) movement in the horizontal plane under the kinematic method of controlling it in a differential form Records:

$$\left. \begin{aligned} A_{11} \cdot \ddot{x}_s + A_{12} \cdot \ddot{x}_s + A_{13} \cdot \ddot{\varphi} + A_{14} \cdot \dot{\varphi} &= f_{11} \cdot \alpha + f_{12} \cdot \beta + R_x, \\ A_{21} \cdot \ddot{x}_s + A_{22} \cdot \ddot{x}_s + A_{23} \cdot \ddot{\varphi} + A_{24} \cdot \dot{\varphi} &= f_{21} \cdot \alpha + f_{22} \cdot \beta - \\ - R_x a + M_R - (K - b)(P_{kr1} - P_{fr1} + P_{kr2} - P_{fr2}) + \\ + b(P_{kl1} - P_{fl1} + P_{kl2} - P_{fl2}), \end{aligned} \right\} \quad (7)$$

where: $A_{11} = M_t$;

$$A_{12} = (k_{l1} + k_{l2} + k_{r1} + k_{r2})/V_0;$$

$$A_{13} = ((k_{l1} + k_{r1}) \cdot (L - l_i) - (k_{l2} + k_{r2}) \cdot l_i)/V_0;$$

$$A_{14} = -(k_{l1} + k_{l2} + k_{r1} + k_{r2});$$

$$f_{11} = (P_{kl1} - P_{fl1} + P_{kr1} - P_{fr1}) + k_{l1} + k_{r1};$$

$$f_{12} = k_{l2} + k_{r2} - (P_{kl2} - P_{fl2} + P_{kr2} - P_{fr2});$$

$$A_{21} = J_i;$$

$$A_{22} = ((k_{l1} - k_{r1}) \cdot (L - l_i)^2 + (k_{l2} - k_{r2}) \cdot l_i^2)/V_0;$$

$$A_{23} = -(k_{l1} + k_{r1}) \cdot (L - l_i) + (k_{l2} + k_{r2}) \cdot l_i;$$

$$A_{24} = (k_{l1} + k_{r1}) \cdot (L - l_i) - (k_{l2} + k_{r2}) \cdot l_i/V_0;$$

$$f_{21} = (L - l_i) \cdot ((P_{kl1} - P_{fl1}) + (P_{kr1} - P_{fr1}) + k_{l1} + k_{r1});$$

$$f_{22} = l_i \cdot ((P_{kl2} - P_{fl2}) - (P_{kr2} - P_{fr2}) - k_{l2} - k_{r2}).$$

In the operator form of writing, the system of differential equations (7) has the following form:

$$\left. \begin{aligned} K_{11} \cdot X_s(s) + K_{12} \cdot \varphi(s) &= F_{11} \cdot \alpha + F_{12} \cdot \beta + F_{13} \cdot R_x + \\ + F_{14} \cdot M_R + F_{15}, \\ K_{21} \cdot X_s(s) + K_{22} \cdot \varphi(s) &= F_{21} \cdot \alpha + F_{22} \cdot \beta + F_{23} \cdot R_x + \\ + F_{24} \cdot M_R + F_{25}, \end{aligned} \right\} \quad (8)$$

где: $K_{11} = A_{11} \cdot s^2 + A_{12} \cdot s$; $K_{21} = A_{24} \cdot s$;
 $K_{12} = A_{13} \cdot s + A_{14}$; $K_{22} = A_{21} \cdot s^2 + A_{22} \cdot s + A_{23}$;
 $F_{11} = f_{11}$; $F_{21} = f_{21}$;
 $F_{12} = f_{12}$; $F_{22} = f_{22}$;
 $F_{13} = 1$; $F_{23} = -(l_m + a)$;
 $F_{14} = 0$; $F_{24} = 1$;
 $F_{15} = 0$;
 $F_{25} = -(K - b) \cdot (P_{kr1} - P_{fr1} + P_{kr2} - P_{fr2}) +$
 $+ b \cdot (P_{kl1} - P_{fl1} + P_{kl2} - P_{fl2});$
 $s = d/dt$ – differentiation operator.

The constructed mathematical models (7) and (8) allow estimating the stability and controllability of the motion of practically any wide span tractor (vehicles) with its kinematic control method.

In the mathematical model (8) of the dynamical system under consideration in the operator form of recording, control operators are the angles of rotation of the front α and rear β wheels. And the characteristics of the disturbing effect are: the component R_x of the principal vector R of the resistance of the agricultural implement and the main moment of the M_R . For the construction of amplitude and phase-frequency characteristics of the expression transfer functions of the dynamics of plane-parallel motion in the horizontal plane of the wide span tractor (vehicles) with the kinematic method of its control have the form:

1) on the control effect of the angle of rotation of the front wheels α :

– linear displacement X_S :

$$W_1 = \frac{D_1 + (0,5L - l_m) \cdot D_3}{D_\Delta}; \quad (9)$$

– relative to the course angle φ :

$$W_3 = \frac{D_3}{D_\Delta}; \quad (10)$$

2) by the disturbing effect of force R_x :

– linear displacement X_S :

$$W_2 = \frac{D_2 + (0,5L - l_m) \cdot D_4}{D_\Delta}; \quad (11)$$

– relative to the course angle φ :

$$W_4 = \frac{D_4}{D_\Delta}; \quad (12)$$

where: $D_\Delta, D_1 \dots D_4$ – the determinants, the expressions of which are defined as follows:

$$D_\Delta = K_{11} \cdot K_{22} - K_{12} \cdot K_{21};$$

$$D_1 = A_{21} f_{11} s^2 + (A_{22} f_{11} - A_{13} f_{21}) s + (A_{23} f_{11} - A_{14} f_{21});$$

$$D_2 = A_{21} F_{13} s^2 + (A_{22} F_{13} - A_{13} F_{23}) s + (A_{23} F_{13} - A_{14} F_{23});$$

$$D_3 = A_{11} f_{21} s^2 + (A_{12} f_{21} - A_{24} f_{11}) s;$$

$$D_4 = A_{11} F_{23} s^2 + (A_{12} F_{23} - A_{24} F_{13}) s.$$

After substituting these determinants in (9-12), each i -th transfer function takes the form:

$$W_i = \frac{b_2 \cdot s^2 + b_1 \cdot s + b_0}{a_4 \cdot s^4 + a_3 \cdot s^3 + a_2 \cdot s^2 + a_1 \cdot s + a_0}, \quad (15)$$

where: $a_4 = A_{11} \cdot A_{21}$,

$$a_3 = A_{11} \cdot A_{22} + A_{12} \cdot A_{21},$$

$$a_2 = A_{11} \cdot A_{23} + A_{12} \cdot A_{22} - A_{13} \cdot A_{24},$$

$$a_1 = A_{12} \cdot A_{23} - A_{14} \cdot A_{24},$$

$$a_0 = 0,$$

$b_0 \dots b_2$ – coefficients, the nature of which is due to the functional relationship between the design and technological parameters of the wide span tractor (vehicles) and the characteristics of the disturbing and control actions:

– for W_1 :

$$b_2 = (0,5L - l_i) \cdot A_{11} f_{21} + A_{24} f_{11};$$

$$b_1 = A_{12} f_{11} - A_{13} f_{21} + (0,5L - l_i) \cdot (A_{12} f_{21} - A_{24} f_{11});$$

$$b_0 = A_{23} f_{11} - A_{14} f_{21};$$

– for W_2 :

$$b_2 = (0,5L - l_i) \cdot A_{11} F_{23} + A_{24} F_{13};$$

$$b_1 = A_{22} F_{13} - A_{13} F_{23} + (0,5L - l_i) \cdot (A_{12} F_{23} - A_{24} F_{13});$$

$$b_0 = A_{23} F_{13} - A_{14} F_{23};$$

– for W_3 :

$$b_2 = A_{11} f_{21}; \quad b_1 = A_{12} f_{21} - A_{24} f_{11}; \quad b_0 = 0;$$

– for W_4 :

$$b_2 = A_{11} F_{23}; \quad b_1 = A_{12} F_{23} - A_{24} F_{13}; \quad b_0 = 0.$$

The physical object of the theoretical studies was the prototype wide span tractor (vehicles) for the track farming system developed by us [11]. The results of calculating the amplitude- and phase-frequency characteristics from (15) are shown in Fig. 2-5.

Analysis of the calculated amplitude-phase and phase-frequency characteristics under the kinematic control method of wide span tractor (vehicles) showed that its controllability is essentially dependent on the speed of motion. At low velocities ($V_0 = 1.0 \text{ m} \cdot \text{s}^{-1}$), we have a significant under-regulation in the dynamical system (curve 1, figure 2). At the same time, the desired oscillation frequency of the angle of rotation α of the front wheels is at the level of 0.5 s^{-1} , where the value of the gain of the input control is approaching 1.

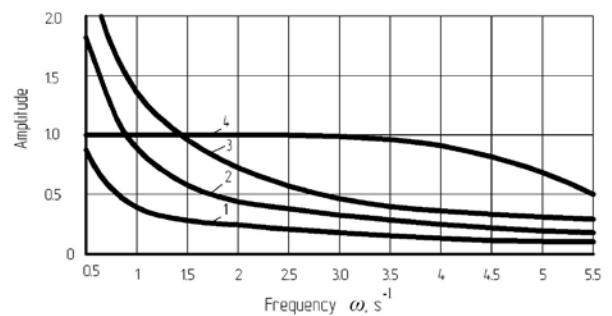


Fig. 2. Amplitude-frequency characteristics of the wide span tractor (vehicles) fluctuations in the course of controlling it (the angle of rotation α of the front wheels) with the kinematic method of its control and various speeds of motion:

- 1 – 1.0 m·s⁻¹;
- 2 – 2.0 m·s⁻¹;
- 3 – 3.0 m·s⁻¹;
- 4 – ideal characteristics.

Together with this, the increase in the speed of the wide span tractor (vehicles) to 2.0 and 3.0 m·s⁻¹ at low frequencies ($\omega < 1.3$ s⁻¹) contributes to the overshoot of the dynamic system (curve 2 and 3, figure 2). And at frequencies $\omega > 1.3$ s⁻¹, on the contrary, we have a slight under-regulation with respect to the ideal characteristic (curve 4, figure 2).

As for the phase shift of the development by the dynamic control system, as the working speeds of the wide span tractor (vehicles) increase to 3.0 m·s⁻¹ (curve 3, figure 3), the phase-frequency response is closest to ideal.

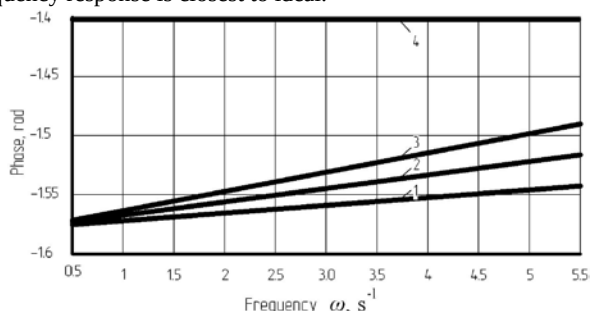


Fig. 3. Phase-frequency characteristics of fluctuations in the course angle φ wide span tractor (vehicles) when exercising control action (the angle of rotation α of the front wheels) with the kinematic method of its control and various speeds of motion:

- 1 – 1.0 m·s⁻¹;
- 2 – 2.0 m·s⁻¹;
- 3 – 3.0 m·s⁻¹;
- 4 – ideal characteristics.

An analysis of the amplitude and phase-frequency characteristics of working out the wide span tractor (vehicles) for controlling the angle of rotation α of the front wheels with respect to the transverse deviation of X_S (Figures 4 and 5) showed that as the speed of motion increases, the amplitude X_S also increases. This process is most pronounced at the oscillation frequencies of α close to zero.

At the same time, the maximum amplitude of the transverse deflection of the wide span tractor (vehicles) at low frequencies ($\omega = 0.5$ s⁻¹) and low speed mode ($V = 1.0$ m·s⁻¹) is 2 m per 1 radian (Figure 4). And with the increase in the speed regime to $V = 3.0$ m·s⁻¹, the amplitude of the transverse deflection of the wide span tractor (vehicles) is increased by 8 times, which, in practice, can lead to overshooting of the dynamic system and the complexity of its control. The information obtained allows us to predict the actual width of the constant track for the motion of the wide span tractor (vehicles), which is very important for the arrangement of the engineering zone of the field of controlled traffic farming.

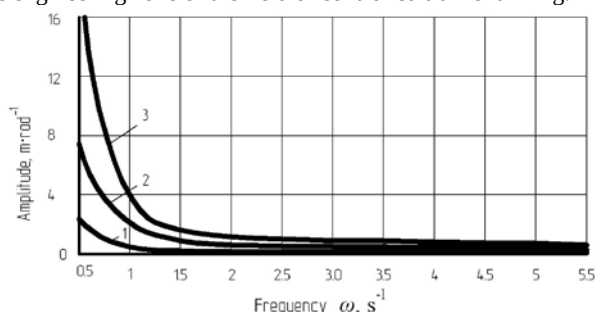


Fig. 4. Amplitude-frequency characteristics of the X_S -wide span tractor (vehicles) vibration oscillations when working out the control influence (the angle of rotation α of the front wheels) with the kinematic method of its control and various speeds of motion:

- 1 – 1.0 m·s⁻¹;
- 2 – 2.0 m·s⁻¹;
- 3 – 3.0 m·s⁻¹.

As for the phase shift of the development by the dynamic control system, when the working speeds of the wide span tractor (vehicles) are increased to 3.0 m·s⁻¹ (curve 3, figure 5), the phase-frequency response is also closest to the ideal.

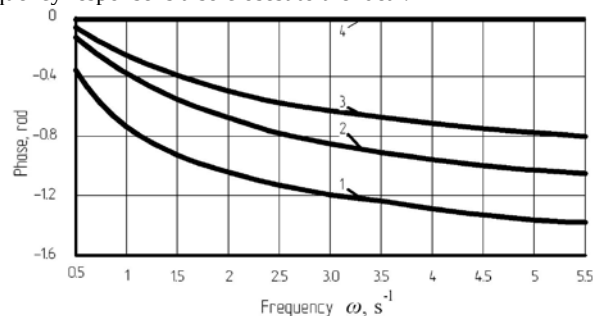


Fig. 5. Phase-frequency characteristics of the X_S -wide span tractor (vehicles) oscillations in the process of controlling it (angle of rotation α of the front wheels) under the kinematic method of its control and different speeds:

- 1 – 1.0 m·s⁻¹;
- 2 – 2.0 m·s⁻¹;
- 3 – 3.0 m·s⁻¹;
- 4 – ideal characteristics.

The amplitude and phase-frequency characteristics of working off the wide span tractor (vehicles) of the steering action of the angle of rotation β of the rear wheels are analogous.

From the above analysis, it can be stated that when a wide span tractor (vehicles) is operating at a high speed mode (close to 3.0 m·s⁻¹), only an effective control system will allow it to have satisfactory traffic controllability.

4. Conclusion

Mathematical models have been developed and new regularities of the parallel span tractor (vehicles) for controlled traffic farming under kinematic control have been obtained. Theoretically, new schemes, design parameters and operating modes can be substantiated with acceptable controllability and stability of movement in the horizontal plane.

From the position of minimizing the area of the field to the engineering zone for the movement of the wide span tractor (vehicles) at a high speed mode (close to 3.0 m·s⁻¹), only an effective control system will allow it to have satisfactory controllability and stability of motion.

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METHODICAL BASES FOR SELECTING PARAMETERS OF POST-HARVEST GRAIN PROCESSING POINTS BASED ON STATISTICAL SIMULATION

МЕТОДИЧЕСКИЕ ОСНОВЫ ВЫБОРА ПАРАМЕТРОВ ПУНКТОВ ПОСЛЕУБОРОЧНОЙ ОБРАБОТКИ ЗЕРНА НА ОСНОВЕ СТАТИСТИЧЕСКОГО ИМИТАЦИОННОГО МОДЕЛИРОВАНИЯ

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Abstract: Developed method rationale parameters equipping items postharvest processing of grain under the coordination of programs with the characteristics of industrial harvesting of early grain crops and grain systems parameters given the variability of agrometeorological conditions of the region.

KEYWORDS: POSTHARVEST PROCESSING OF GRAIN ITEM, PROCESS, SYSTEM, PARAMETERS, STATISTICAL SIMULATION.

1. Introduction

During the production of field crops, namely in the final stages of production, there is a number of negative phenomena - the loss of crops by farms due to untimely harvesting is more than 9,6% [9], the loss of harvested crop due to the untimely post-harvest harvest of 10-30% [10], As well as high costs associated with the inefficient use of appropriate technical equipment, energy and labor resources.

Improve the efficiency of mechanized harvesting and post-harvest processing processes due to the systematic coordination of the characteristics of production plans for harvesting early grain crops, the parameters of the grain harvesting complexes (TPP) and the parameters of the technical equipment of the corresponding points (P POZ), taking into account the stochastic influence of agrometeorological conditions. This will allow you to perform the specified technological processes with a minimum total specific cost of funds.

2. Preconditions and means for resolving the problem

Today developed many scientific and methodological approaches to justify the logistics processes of gathering early grain crops [11-17, 24] and postharvest processing of grain [18-20]. However, no approach systematic study parameters equipping P POZ positions, which would take into account the variability of the flow characteristics of grain on point throughout the day, due agrometeorological conditions of the region, the characteristics of harvesting and transport facilities and features of their operation and reverse effect on the functioning of these systems process postharvest Grain processing. Therefore, there is the problem of developing methods justification parameters P POZ technical equipment, which will take into account the cumulative effect of a plurality of the aforementioned factors.

3. Results and discussion

The basis of the development of a methodology for justifying the parameters of technical equipment for post-harvest grain processing are based on previously established methods for justifying the parameters of the technical equipment of technological systems for the collection of early grain crops (TS ZRZK)[11, 16] and post harvest cultivation of grain (TS POZ) [21]. These methods are based on statistical simulation of the corresponding technological processes and take into account the stochastic influence of the factors of their efficiency on the course of the corresponding processes.

The simulation of the TS ZRZK takes place in a discrete-event approach. Accordingly, a plurality of variants of reaching early grain crops are formed, as well as for each crop the time of occurrence τ_{HB} losses is determined (Fig. 1, 2, a). On the basis of the distributions of the start and end time of the cloudy intervals, a plurality of variants of alternation of these intervals are formed (Fig.

1, 2, b). For each good model day, the actual fund of working time, as well as the nature of the air humidity deficit change during this day, is determined for each variant of the weathered and subtropical intervals [16].

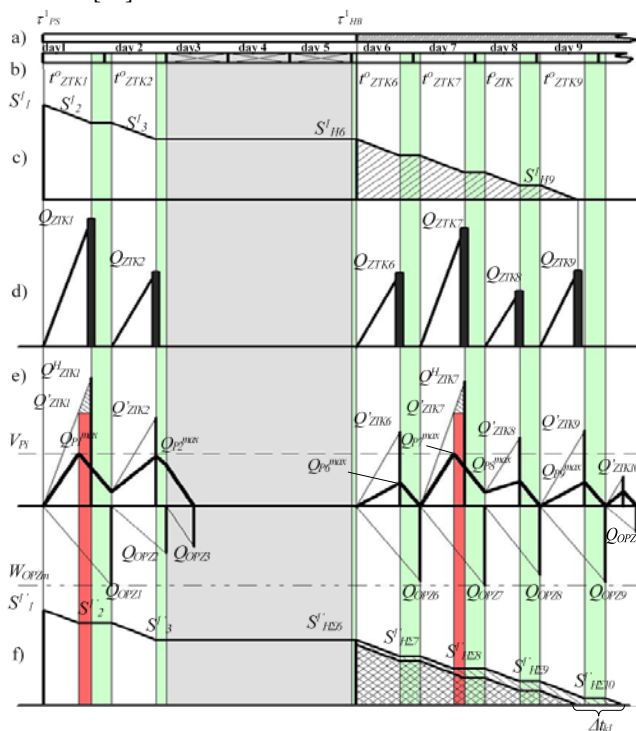


Fig.1. Graphical interpretation determine the impact of post-harvest grain handling process to combine on a single field:

□ - duration of rainy periods of time; □ - duration of the dew period; ■ - duration of downtime ZTK due to delay in servicing the grain flow to the P POZ; a) option ripening grain crop in the field; b) a fine option and rainy periods; c) graphical representation of the decrease in the volume of the unassembled area of the field as a result of grain harvesting; d) graphical representation of the daily formation of grain flow per item without taking into account the influence of the functioning of the technological system of post-harvest grain processing on the grain harvesting process; e) graphical representation of the service of grain flow at a point with given parameters and its influence on the grain harvesting process; f) graphical representation of the decrease in the volume of the unassembled area of the field as a result of grain harvesting, taking into account the impact on it of the TP POZ.

In the process of simulation of the day-to-day operation of the TS ZRZK due to the reduction of the unassembled area of the field under the grain crop (Fig. 1, c), the daily flow of grain is formed up to P POZ (Fig. 1, d). It is characterized by quantitative (daily volume Q_{ZTK}), temporal (duration of receipt of the flow of the organizationally adjusted working time ZTK t_{ZTKj}^o) and qualitative

characteristics: the nomenclature (culture, variety) η_j , humidity $w(\tau)$ and debris $\varphi(\tau)$ of grain at a certain time τ . The stochastic influence of agrometeorological conditions on the work of the ZTK in a separate day, as well as on the change in the characteristics of grain stem blasts, causes a probabilistic change in the characteristics of the daily grain flow to item [22]. Therefore, the volume and duration of the flow of grain every day are different (Fig. 1, d).

If we simulate the operation of the TC ZRZK for each day of harvesting the plurality of the seasonal program fields, we obtain a variation in the values of the unloaded areas Z_n of each culture and the number of realizations in which these volumes occurred. The resulting variation series is used to construct an empirical function of the distribution of unplanned areas collected Z_n in corresponding realizations [11, 16].

The quantitative estimation of the probability of untimely gathered areas ($P[Z_n > 0]$) during the harvesting of early grain crops is defined as the proportion of the number of implementations (seasons) of the model when there was a delay in the collection ($n[Z_n > 0]$) to the total number of realizations of statistical simulation. The model [16]:

$$(n_p) - P[Z_n > 0] = n[Z_n > 0] / n_p.$$

In order to evaluate the efficiency (timeliness) of grain harvest operations without taking into account the influence on their operation, the generalized volume of unplanned areas collected (its mathematical expectation) should be determined, which characterizes the average amount of untimely gathered areas in all implementations of TP ZRZK:

$$Z_n = M[Z_n] \times P[Z_n > 0]. \quad (1)$$

System analysis of integrated technological systems for the collection of early grain crops and post-harvest treatment shows the mutual influence of these systems on one another in the process of their functioning. In particular, there is a reverse effect of the technological processes of post-harvest grain processing on the course of grain harvesting [23]. In the first place, it is conditioned by the parameters of the subsystem pre-cleaning of the TS POZ (P OPZ) by the performance m -th machine pre-cleaning of grain W_{OPZm} and the capacity of the i -th reserve volume V_{pi} . The productivity of the machine W_{OPZm} determines the intensity of the service of the incoming grain Q'_{ZTKj} flow in the j -th day and the possible daily volume of the purified grain Q_{OPZj} (Fig. 1, e). The capacity of the reserve volume V_{pi} should be such as to ensure the full utilization of the daily working time of the machine of pre-cleaning the grain. That is, on a separate day, it should provide a technological reserve of crude grain at the time of the absence of the flow of grain per item as a result of the impossibility of performing the TP ZRZK due to the appearance of bad weather periods (deposition of dew) (Fig. 1, e).

It should be noted that the duration of the idle time of the combine harvester is influenced by: 1) the intensity of servicing the grain flow by the machine of preliminary cleaning of the given productivity, taking into account its change from the qualitative characteristics of the grain in the reserve volume, which determines the length of stay of the TZ in the queue for unloading; 2) the duration of filling the hopper of the combine harvester, taking into account the field performance characteristics, on which his work is modeled; 3) the duration of the transfer of TZ from the point to the combine, which depends on the distance of this move.

Due to the occurrence of ZTK downtime caused by the untimely service of the grain flow at the point, the length of the collection of a separate γ -th field ($\Delta t_{k\gamma}$) and, correspondingly, the amount of untimely collected areas will increase. Therefore, the harvesting of the crop in the considered field will end not on the 9th day ($S'_{H\gamma 9}$) (Fig. 1, c), but on the 10th day ($S'_{H\gamma 10}$) (Fig. 1, f). It should be noted that the obtained values of late-assembled areas ($S'_{H\gamma 6} \dots S'_{H\gamma 10}$) collectively characterize the efficiency of the technological processes of harvesting grain on a separate field and its post-harvest processing.

In order to assess the impact of the TS POZ on the operation TS ZRZK on a separate field, it is necessary to find the difference in the volumes of late-assembled areas received as a result of the cumulative functioning of these systems ($\sum S'_{H\gamma j}$) and the

operation of the TS ZRZK ($\sum S'_{H\gamma j}$) alone, as well as the increase in the length of the collection of this field due to the impact of the TS POZ (Δt_{kt}). The determined indicators allow estimating the losses of the cultivated yield on a given field, caused by the influence of the TS POZ on the operation TS ZRZK.

To assess the statistical regularities of functioning TS POZ on the functioning TS ZRZK should determine the likelihood and statistical evaluation of changes in the amount of time harvesting area and increase durations harvesting of early grain crops in certain fields, due to this influence during set seasons (iterations of a simulation model). This will allow to determine the statistical estimations of the generalized volume of untimely collected areas. Conversion of these areas based on length growth duration of the grain will work to assess crop losses grown $B_{nOPZ.mi}$ as a result of the impact TS POZ set parameters m -th grain cleaning machines and i -th reserve volume P OPZ operation on TS ZRZK.

The next stage of justification of the rational parameters of the technical equipment of the item is to determine the direct operating costs $J_{OPZ.mi}$ for the functioning of the pre-cleaning subsystem with the given parameters W_{OPZm}, V_{pi} . For this purpose, according to known methods, the expenses for the salary of the servicing personnel of the machine for preliminary cleaning of the grain and the reserve volume, the cost of depreciation of the specified grain cleaning machine and the reserve volume, as well as the expenses for electricity, maintenance, current and capital repair of the specified technical equipment of P OPZ.

Knowing the total crop losses in the monetary equivalent $B_{nOPZ.mi}$ and direct operating costs $J_{OPZ.mi}$, the total costs $C_{OPZ.mi}$ operation P OPZ with the given parameters are determined (Fig. 2).

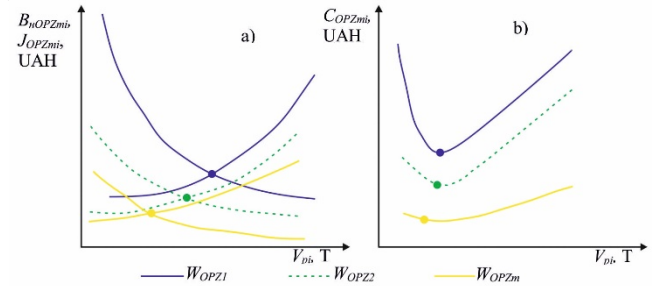


Fig. 2. Graphical representation of the comparison of cumulative harvest losses in cash equivalent, direct operating costs (a), and the determination of aggregate costs (b) for the operation of P POZ with different parameters (grain cleaning capacity W_{OPZm} and reserve capacity V_{pi}) and the choice of rational values of these parameters

The total costs $C_{OPZ.mi}$ due to the use of a given m -th grain cleaning machine and i -th reserve capacity will be:

$$C_{OPZ.mi} = B_{nOPZ.mi} + J_{Opz.mi}. \quad (2)$$

According to the results of statistical simulation of the technological systems of harvesting early grain crops and post-harvest grain processing for the given characteristics of the production program and the parameters of the ZTK, for each of the plurality of variants of the technical equipment of the P OPZ the total costs are determined $C_{OPZ.mi}$ (Fig. 2).

The analysis of the received dependencies of the change in the total cost $C_{OPZ.mi}$ operation of the P OPZ with different parameters of the parameters allows us to justify the optimum capacity of the reserve volume for each pre-purification machine and determine the rational parameters P OPZ in which the value of these costs will be minimal:

$$Z_{OPZ} \rightarrow Z_{OPZ}^p, \text{ якщо } C_{OPZ.mi} \rightarrow \min. \quad (3)$$

However, the rational parameters Z_{OPZ}^p will not always be rational for the whole TS POZ. Therefore, the next step in justifying the rational parameters of the technical equipment of the item is the coordination of the specified variants of the parameters of the subsystems of preliminary purification and drying of grain (P SZ).

In order to calculate the parameters P SZ (productivity of the grain dryer W_{ZSm} and the necessary capacity of the reserve volume for its functioning V_p^{sw}) it is necessary to establish statistical estimates of the daily grain volume per dry matter Q_{ZTKT}^{sw} , the humidity of this grain w_j and the length of its arrival t_{ij}^{sw} in this day, taking into account the impact on the grain harvesting process m -th grain cleaning machine. These estimates are determined on the basis of statistical simulation modeling of the technological processes of harvesting and post-harvest processing for the given production characteristics of the fields of the economy and agro-meteorological conditions in the region, technical support of these processes.

Knowing the estimation of the mathematical expectation of the daily grain volume to the point requiring drying $\bar{M}[Q_{ZTKj}^{sw}]$ and estimating the mathematical expectation of the length of its processing in a separate day $\bar{M}[t_{noj}^{\phi}]$ can be determined by the necessary hourly productivity of the grain dryer:

$$W_{ZSm}^g = \frac{\bar{M}[Q_{ZTKj}^{sw}]}{\bar{M}[t_{noj}^{\phi}]} \quad (4)$$

Depending on the duration arrival t_{ij}^{sw} of moist grain during the day, its daily volume and grain dryer performance, provided that the grain has to be pre-cleaned ($W_{OPZm}^g \geq W_{ZSm}^g$), the necessary capacity of the reserve volume is substantiated to ensure the work of the dryer during the day:

$$V_p^{sw} = \bar{M}[Q_{ZTKj}^{sw}] - W_{OPZm}^g \times \bar{M}[t_{ij}^{sw}]. \quad (5)$$

It should be noted that the capacity V_p^{sw} is part of the capacity V_{pi} , because the wet grain is temporarily stored there before it is cleaned up, and then it goes directly to the grain dryer.

To substantiate the capacity of the reserve volume of the item as a whole, it is necessary to compare certain capacities of the variants of the technical equipment P OPZ and the justified variants of the capacity between them will be sought by the capacity of the reserve volume P OPZ, and the set of parameters of each variant of the technical equipment of the subsystems will be parameters of the variant of the technical equipment of the item (Table).

Table. Justification options technical equipment item postharvest processing of grain

№	Subsystem pre-cleaning of grain		Subsystem grain drying		Necessary reserve volume P OPZ, t	Variant of technical equipment P OPZ
	Productivity of the machine for pre-cleaning the grain	Required reserve capacity, t	Productivity of the dryer	Required reserve capacity, t		
1	W_{OPZ1}	V_{p1}	W_{ZS1}	V_{p1}^{sw}	$V_{p1} < V_{p1}^{sw}$	$W_{OPZ1}; V_{p1}^{sw}; W_{ZS1}$
2	W_{OPZ2}	V_{p2}	W_{ZS2}	V_{p2}^{sw}	$V_{p2} < V_{p2}^{sw}$	$W_{OPZ2}; V_{p2}^{sw}; W_{ZS2}$
...						
m	W_{OPZm}	V_{pm}	W_{ZSm}	V_{pm}^{sw}	$V_{p3} < V_{p3}^{sw}$	$W_{OPZm}; V_{pm}^{sw}; W_{ZSm}$

4. Conclusion

Rationale parameters equipping items postharvest processing of grain should be carried out in four stages: first rationale set the best options of technical equipment subsystem pre-cleaning of grain for a given production plan and options harvesting-transport complex management; second - justification subsystem grain drying parameters for each subsystem variant of equipping its previous purification; third - support capacity backup volume for each variant of technical equipment subsystems preliminary cleaning and drying of grain justifying the capacity reserve volume, ensuring the functioning of both subsystems; four - definition of rational option equipping paragraph postharvest processing of grain for the whole criterion of minimum total unit cost of funds for post-harvest processing of grain.

The method of justification rationale parameters equipping items postharvest processing of grain is based on the statistical simulation modeling processes of collection and post-harvest grain handling system and allows you to take into account the variability of grain flow characteristics over a day caused by the characteristics and parameters grainplants fields agrometeorological conditions combine period parameters harvesting and transport systems and organizational mode of use, and also the reverse effect processes post-harvest grain handling performance.

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SOIL WATER MANAGEMENT IN THE SIBERIAN KULUNDA- DRY STEPPE

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Abstract: From 1954 to 1963, approximately 42 million ha of the Southern Russian steppe, of which 6.2 million ha are located in Western Siberia, were converted into large-scale intensive agricultural area. The affected areas are highly vulnerable to wind erosion and the presently ongoing climate change effect. The establishment of sustainable land management practices is essential to secure agricultural production and the further economic development of the region. The assessment and management of the soil water is of great importance for crop yield potentials and protection against wind erosion. The paper presents a meteorological and soil hydrological measuring network. The results showed that the No-Tillage technology gradually formed soil conditions close to the natural dry steppe background. Furthermore, the installed techniques can be used to measure the parameter “actual evapotranspiration” which is a key factor to evaluate climate change impacts.

Keywords: ACTUAL EVAPOTRANSPIRATION, KULUNDA– RESEARCH PROJECT, LYSIMETER, MEASURING TECHNIQUE, PRECIPITATION, SOIL TILLAGE, SOIL WATER

1. Introduction

The Altai region is one of the most important grain-producing regions in Russia. Its total area of cultivated land is 5.4 million hectares, of which 3.5 million hectares are designated for grain and leguminous crops, including maize. From 1954 to 1963 approximately 42 Mio ha of the Southern Russian steppe, of which 6.2 Mio ha are located in Western Siberia, were converted into a large-scale intensive agriculture area. This area was highly vulnerable to wind erosion that results in decreased top soils thickness and humus content and therefore in decreased concentrations of carbon. The adversely influenced soil water and nutrient regime as well as the declining fertility have resulted in a decrease in crop yields. In 1963-1965, more than 1 million hectares of eroded land was set aside in Altai. In 1960-1970, a set of measures aimed at soil conservation was implemented, including the establishment of plantations and shelter belts, conservative tillage, soil-protecting crop rotation, crop lane placement, mulch with straw, etc. However, the problem of “black storms” (wind erosion) resolved in the 1960s and 1970s is currently reappearing. “Black storms” were recorded in the Altai region in the mid-1990s and in the 2000s [1].

The region is part of the Southwest Siberian Kulunda steppe lowland and located between the Central Asian steppe and the North Asian forest-steppe. In the North, the Kulunda steppe borders on the Baraba forest steppe with a vegetation mosaic composed of steppe communities and birch “kolki” (birch islets). The Western part of the Kulunda steppe borders on Eastern part of the Irtysh valley in Kazakhstan. The Kulunda depression is located at altitudes of 100-140 m asl. The lowland is covered by a 50 to 60 m thick layer of pleistocene alluvial and 0.5 - 10 m of eolian sediments. The soil cover of the Kulunda dry steppe consists of chestnut soils, meadow-chestnut soils, meadow soils, solonetz and solonchaks with different degrees of hydro-morphism. The chestnut soils significantly vary in texture as a result of the ancient limnic and eolian genesis of the territory. Sandy loams (15 - 19% clay, 11 - 20% silt, 65 - 70 % sand) are predominant; their contents of humus (2 - 4 %) and carbon (5 - 8 %) are comparatively high [2].

In the continental climate of Kulunda steppe long, cold and little-snowy winters and short, but hot and dry summers occur. Due to its open position, the steppe is often affected by cold air masses from the Kara Sea, and warm and dry ones from Kazakh and Middle Asian steppes and deserts. Thus, the temperature is highly variable: May and September often have night frost, in late snow-free autumn periods the temperature can drop to -20 °C or lower,

spring sometimes has very dry periods, and dry winds are common throughout the year. The mean annual temperature is about 0 °C, the mean temperature of January (the coldest month) is -19 °C, the absolute minimum is -47 °C, the mean temperature of July (the warmest month) is +19 °C, the absolute maximum is +40 °C. The frostless period lasts 112-120 days per year from May 15-25 till September 10-15. The annual precipitation is about 250-450 mm; the precipitation in April to October is about 200 mm. The duration of a stable snow cover reaches 140-150 days (from November 10-15 to April 5-10). The mean depth of the snow cover is 15 cm (absolute maximum 35-38 cm). Such a thin snow cover does not protect the soil from frost, so in winter soil freezes down to 2 m deep (and even more). The amount of global radiation is 2-3 times higher than it is required for the evaporation of such an amount of precipitation [3].

From 2011 until 2016 the German-Russian interdisciplinary research project KULUNDA was carried out [4]. The main goal of the project was to mitigate degradation and desertification processes in the Southern Siberian agriculturally used steppe sites, to stimulate and, in the long run, to enhance carbon sequestration in soils of the Kulunda steppe. The project also aims to increase crop yields and to implement sustainable land management practices for agricultural areas and thereby to contribute to rural and regional development. The gained knowledge and the results of the KULUNDA project will largely contribute to the research on climate change, sustainable land management practices and rural and regional development.

The assessment and management of water and solute balance of soils are of great importance for crop yield potentials and sustainable development of the territory. A key factor in soil water management is the natural availability of precipitation during the vegetation period. Also in former Soviet Union research activities were started to minimize the water deficit in the region. Already in the seventies of the last century Kulunda plain was included in the national Russian economic plan of reclamation to increase the area of irrigated land. But the economic conditions have changed and present land management activities in the region showed that irrigation don't play an essential role in agriculture. Alternative methods to improve the soil water efficiency have been developed and tested. In [5] it was demonstrated that the main agricultural methods to retain soil moisture are minimum or No-Till-technologies including stubble and chopped crop residues.

An essential topic of the interdisciplinary KULUNDA-project was the impact of land management practices on the soil water and

solute balance of the Kulunda steppe in Altai Krai. For this reason a pedo-hydrological measuring network was installed and measurements were carried out during the investigation period. The objectives of this paper are i) to describe the design and establishment of the monitoring system and ii) to explain some essential results regarding soil water management in the Kulunda steppe.

2. Materials and Methods

The monitoring network consists of a weather station, two soil-hydrological measuring stations and a weighable gravitation lysimeter station (Table 1). The weather station was installed in September 2012. It was equipped with a pyranometer (at height of 2.0 m) to measure the solar radiation, a multisensor "Vaisala" (Vaisala Weather Transmitter –VWT, at a height of 2.3 m), measuring wind speed and direction, air temperature and humidity, barometric pressure and rainfall. Additionally, the liquid and solid precipitation was measured by a pluviometer, which is mounted in "Hellmann" rain gauge (Hellmann tipping bucket rain gauge – HRG) on the standard height of 1 meter. The two soil hydrological measuring stations (SHMS 1 and 2 - manufacturer "Eco-Tech", Germany) were also established in September 2012. They were equipped with sensors to measure soil water content, soil temperature, osmotic pressure, and electric conductivity fitted at depths of 30 cm, 60 cm, and 120 cm in automatic mode. During June-August 2013 a containerized (Polyethylene PE-HD) lysimeter station with two weighable soil monoliths (manufacturer "UGT-Muencheberg", Germany and Helmholtz Centre for Environmental Research – UFZ, Germany) was installed at the test farm "Partner" of the KULUNDA- project in Poluyamki (dry steppe region). This site was chosen because the South-Western Kulunda steppe region is mostly affected by soil degradation processes compared with the other parts of the administrative unit Altai Krai [6].

It is well known that a weighable gravitation lysimeter is a sufficient tool to measure the relevant parameters of the soil water balance equation with high precision [7]. Such data are missing for the dry steppe conditions of Siberia but they are essential for the evaluation of the former development of this region. Especially the climate change is a main driver regarding the direction of future land use. The lysimeter measuring results will help to investigate and establish sustainable land management strategies for this region. The aim is to deepen the understanding of relevant processes concerning the interaction of land degradation and climate change, to quantify fluxes of water, nutrients, carbon, and other relevant matters. The results serve as the basis to simulate the effects of land management on soil and matter balance by using adequate models (for example the hydrological model HYDRUS). In cooperation with German and Russian project partners the soil monoliths (surface area of 1 m², 2 m depth) were monolithically extracted from both an arable land (lysimeter 1 – LYS 1) and a fallow site which was ploughed once in the 1950s, but since then covered with natural, nearly pristine steppe vegetation (lysimeter 2- LYS 2) for the lysimeter-based investigations. Following the FAO guidelines the soils are identified as Calcic Chernozems (Table 2). The LYS 1 consists of a 25 cm thick humic horizon including a plough layer at its bottom. It is followed by a crossing A-C-horizon with its bottom at 50 cm depth. Beneath there is a subsoil C-horizon from parent material including calcareous deposits. The grain size distribution in the upper part of the profile (0-50 cm) indicates sandy loamy silt, beneath silt loam and below 70 cm loamy sand occurs. The site was under intensive agricultural usage for 60 years.

Table 1 Design of the pedo-hydrological monitoring network in the Kulunda steppe

Name and coordinates	Lysimeter	Soil-hydrological measuring station		Weather station
	N 52°03.959' E 79° 42.786'	DATT ¹⁾ (SHMS 1) N52 04.180 E79 54.014	No-Till (SHMS 2) N52 04.128 E79 54.006	N 52° 03.959' E 79° 42.786'
Parameters	Soil monolith mass for registration of various atmospheric precipitation, amount and concentration of seepage, soil temperature,	Water content and soil temperature, soil water pressure, (tension) suction, electrical conductivity		Amount of liquid precipitation (multi-sensor), equivalent of frozen precipitation (pluviometer in Hellmann rain gauge), wind power and direction, air temperature, humidity, and pressure, solar radiation
Sensor types	1. FDR- and temperature sensor, soil moisture content and temperature 2. Watermark sensor-matrix potential 3. Ceramic suction cups-sampling soil solution (nutrients, pollutants)	1. TDR-sensor: soil moisture content and temperature 2. pF-Meter: Stress meter: soil water pressure, (tension) and electrical conductivity		1. Multisensor «Vaisala»: air temperature and humidity, atmospheric pressure, wind speed and direction. 2. Radiometer: solar radiation. 3. Pluviometer in Hellmann rain gauge-measurement of frozen precipitation.
Height and depth of sensor location (cm)	-30; -50; -120	-30, -60, -120		+100 (Rain gauge) +200 (Radiometer) +230 (Multi-sensor)

Note: ¹⁾ - Deep autumn tillage technology on 22-24 cm depth

The LYS 2 consists of a 30 cm thick humic Ah-horizon, followed by a 15 cm thick crossing A-C-horizon and by the subsoil from parent material which is interjected by calcareous deposits. The upper 30 cm consists of sandy loamy silt, below silty loam occurs, which is underlain by loamy sand beneath 70 cm.

Table 2 Soil properties of the lysimeter extraction sites in the Kulunda steppe, Siberia.

Name/No.	Extraction site Lysimeter 1 (LYS 1)			
Date	28.06.2013			
Position	N52 04.012 - E79 54.526			
Altitude	138 m			
Slope/Exposition	>1			
Usage	Field/ Wheat			
Notice	Amazone test field; Poluyamki / Conventional tillage			
Soil Type	Calcic Chernozem			
Horizon	Ah	AC	Ckc	C
Lower boundary (cm)	25	50	70	120+
Grain size fraction	SLSi (Uls)	SLSi (Uls)	SiL (Lu)	LS (Sl4)

Name/No.	Extraction site Lysimeter 2 (LYS 2)			
Date	28.06.2013			
Position	N52 03.778 - E79 55.868			
Altitude	142 m			
Slope/Exposition	>1			
Usage	Natural steppe vegetation			
Notice	No tillage for decades			
Soil Type	Calcic Chernozem			
Horizon	Ah	AC	Ckc	C
Lower boundary (cm)	30	45	70	110+
Grain size fraction	SLSi (Uls)	SiL (Lu)	LS (Sl4)	LS (Sl4)

After the extraction of the soil columns a 20 cm thick filter layer (geotextile over fine-coarse sand over gravel) was placed at the bottom of the lysimeter vessels to minimize disturbances to the natural flux. The depths of the soil columns are greater than the natural flux plane, which lies referred to the environmental and management conditions at the extraction sites between 0.9 and 1.3 m below the surface. Hence, it can be assumed that seepage flow in the lysimeters is not affected before it reaches the filter layer. The composition of the filter layer was chosen to allow free drainage of seepage water.

The vessels were transported to the Poluyamki site and positioned into the lysimeter station on load cells by using a three-legged steel frame (Fig. 1). The lysimeter station measures mass changes with sufficiently high precision (± 20 g) to enable the calculation of water fractions input (dew, rime and the water equivalent of snow) and the rates of actual evapotranspiration (ET_a). The total mass of each lysimeter vessel is approximately 4 t (the mass changed in dependence on the water content of the vessel). Both lysimeter vessels are equipped at different depths (0.30 m, 0.50 m and 1.20 m) with frequency-domain reflectometry (FDR) stick probes to measure the soil moisture content and soil temperature, watermark-sensors to measure the matrix potential and suction cups to extract soil solution (cf. Fig. 1). The lysimeter is specifically adapted to the cold winter conditions in Siberia by adding an extendible cutting ring to burst bridges between the snow on lysimeter surface and adjacent snow in the surrounding.

The measured values are consolidated and stored in a data logger with a recording interval chosen by the user. It permits a very high temporal resolution (< 1 minute). The amount of seepage water is measured with a tipping bucket (values are stored by the data logger) and collected in a storage container from which water samples can be taken for chemical analysis. The installed computer

software makes it possible to present all measured parameters in different ways (e.g. average, minimum, maximum or all values).

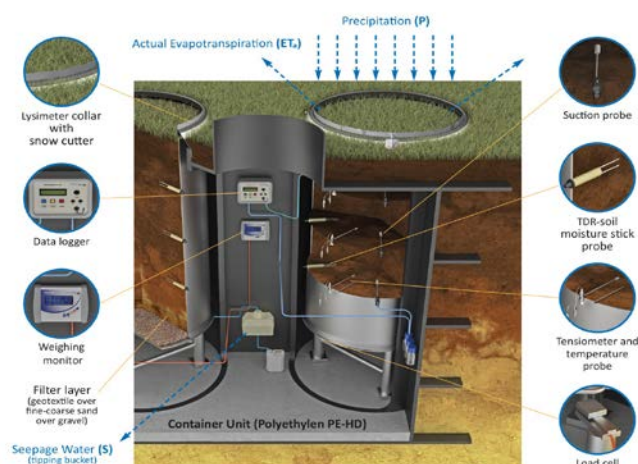


Fig. 1 Sketch of the weighable two-fold containerized lysimeter station established at Poluyamki site, Russia, Siberia.

3. Results and Discussion

3.1 Precipitation

As already mentioned, the annual amount of precipitation is about 250-450 mm with a tendency of declining because of global climate change effects. The available meteorological data base is rare and the above explained monitoring network should improve our knowledge regarding the soil water budget. Especially the parameter precipitation is fundamental to reach this aim. The precipitation was measured by three different methods, the HRG, the VWT and the weighable lysimeters LYS 1 and 2. The different devices used for precipitation recording have specific systematic measurement errors (wind field deformation above the gauge orifice, wetting loss at the internal wall of the container, evaporation, splashing, size of the gauge etc.) and thus deliver individual value arrays, even if they are installed in vicinity. These errors have to be detected and can be reduced for example by correction factors [8]. Due to the relative large size of a lysimeter vessel (usually 1 m² surface area) random errors are widely reduced. If the lysimeter vessel contains a complete soil-plant system, interception of the vegetation is part of the precipitation term. Based on the lysimeter weighing system measuring errors may occur regarding vibrations caused by wind, maintenance and field work respectively or due to animals entering the lysimeter vessel. In [8] it is demonstrated that a sophisticated weighable lysimeter can be used as a reference to compare different rain gauge devices.

Precipitation measurements by HRG, VWT, LYS 1 and LYS 2 are presented in Figure 2. LYS 1 showed in the observation period a precipitation of 121.5 mm whereas 143.4 mm were measured at LYS 2. The precipitation measured in the observation period by HRG and VWT was 100.1 mm and 136.3 mm, respectively. Precipitation measurement by lysimeters can be regarded as reliable with insignificant systematic errors. The different amounts of precipitation of LYS 1 and LYS 2 can be attributed to the different vegetation cover. The steppe vegetation of LYS 2 is characterized by higher leaf area coverage than that of LYS 1. Therefore, the precipitation measurements of both, LYS 1 and LYS 2 showed different results. The precipitation amount measured by HRG was continuously lower in comparison to VWT, LYS 1 and LYS 2. These deviations exist further on even after application of the correction factor of approximately 10 % according to [8] on HRG results to compensate effects of different measurement heights.

The results of precipitation measurements by VWT are very similar to that of LYS 2 regarding the registered precipitation events and amounts. It was already mentioned, that precipitation measurements by VWT were carried out in height of 2.3 m. The measuring height is predetermined by the manufacturer of the meteorological station. Correction factors for VWT precipitation measurement systems are not available.

In general, all devices recorded precipitation and showed analogies concerning the distribution of rain events, but the amounts are different. Referred to LYS 1, the precipitation amount measured by HRG reached only 90.6 %, whereas the amount of LYS 1 was exceeded by VWT and LYS 2 (112 % and 118 %, respectively).

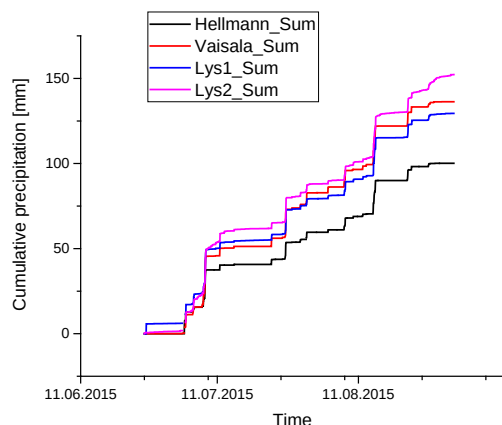


Fig. 2 Cumulative precipitation rates of HRG, VWT, LYS 1, and LYS 2 during the investigation period.

3.2 Soil moisture

The SHMS 1 and 2 were installed directly in the field inside the trials. The following soil tillage technologies were tested:

- «DATT» technology with deep loosener on 22-24 cm depth (SHMS 1). Crop rotation: wheat (2013) – fallow (2014) – wheat (2015) – wheat (2016);
- «No-Till» technology, without autumn tillage (SHMS 2). Crop rotation: wheat (2013) – rape (2014) – wheat (2015) – peas (2016).

Additional measurements of soil moisture content were performed by LYS 1 and LYS 2 at depths 30-50-120 cm for different crop rotations LYS 1: wheat (2013) – peas (2014) – wheat (2015) – fallow (2016). LYS 2: natural feather grass (Stúpa pennáta) dominated dry steppe (2013-2016).

Analysis of the soil moisture regime of SHMS 1 and 2 for 2013 - 2016 (not displayed) showed that advantages of No-Till revealed only in the third year, since 2015 (Tab. 3). The results from SHMS 2 demonstrated the advantages of No-Till at a depth of 30 cm and 60 cm in June-July 2015, when the site was seeded with spring wheat. Also in 2016, we observed the same effects, when it was seeded with peas, which had higher soil moisture consumption than spring wheat. In general, the measurements under No-Till system demonstrate the similarity dynamic of soil moisture in different depths for the vegetation season 2015-2016.

Table 3 Monthly average soil moisture in depths 30, 60, 120 cm during the vegetation season in 2015 and 2016, SHMS 1 and 2 «Poluyamki».

Period	Soil moisture in depth 30 cm (Vol. %)		Soil moisture in depth 60 cm (Vol. %)		Soil moisture in depth 120 cm (Vol. %)	
	DATT	No-Till	DATT	No-Till	DATT	No-Till
2015						
May	-	16.1	-	22.7	-	23.1
June ¹⁾	11.8	18.0	15.4	21.6	15.4	19.0
July ²⁾	10.2	15.0	13.8	15.5	13.8	12.9
August	11.3	12.6	13.0	14.5	13.0	12.5
September	14.9	12.4	12.5	14.1	12.5	12.7
Average	12.0	14.8	13.7	17.7	13.7	16.0
2016						
May ³⁾	21.4	17.5	21.6	22.6	20.7	23.2
June	-	17.9	-	22.6	-	20.8
July ⁴⁾	12.7	17.5	14.5	17.4	16.2	14.3
August	11.6	16.4	13.6	15.0	16.5	12.4
September ⁵⁾	11.2	15.5	13.3	14.8	16.9	11.8
Average	15.6	17.0	16.8	18.5	18.2	16.5

Note: ¹⁾ data for June 25 - June 30 2015

²⁾ no data from July 11 – July 15 2015

³⁾ data by DAAT only for May 05 2016

⁴⁾ data by DAAT for July 23 - July 31 2016

⁵⁾ data for September 01 - September 25 2016.

3.3 Actual Evapotranspiration

Lysimeters are typically used to quantify rainfall, drainage and ETa [9]. According to the water balance equation, the changing masses (weights) represent the water storage within the soil monoliths. These changes can be displayed as positive or negative values. A mass gain of the soil monolith means precipitation; mass reduction must be interpreted as seepage or as a release of gaseous water from plants and soil in the form of evaporation or transpiration respectively. Hence the rising and falling masses of the soil monoliths are the basis for calculations of precipitation and ETa, which can be displayed as quantities in mm.

To demonstrate the operational reliability of the lysimeter station, Fig. 3 shows the mass of the installed lysimeter recorded over a three-day period in August 2013 based on a one-hour measurement. There was no drainage from the lysimeters in that period. While the mass of LYS 1 (arable land, spring wheat) on 2013/08/25 08:00 was 3914.1 kg, the LYS 2 mass (natural steppe vegetation) was 3707.4 kg.

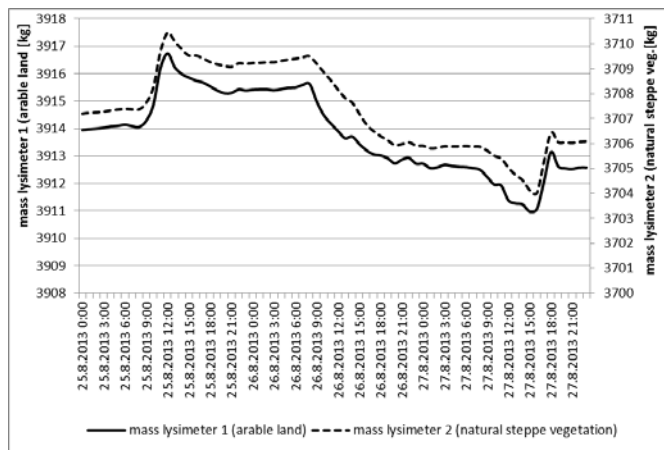


Fig.3 Example of the diurnal mass changes of two gravitation lysimeters planted with spring wheat and a pristine plant cover.

Both soil monoliths registered a precipitation event on 2013/08/25 08:00-12:00 resulting in mass increases about 2.7 kg (= 2.7 mm) (LYS 1) and 3.1 kg (= 3.1 mm) (LYS 2) respectively. The differences between the two monoliths are mainly based on the different vegetation covers and associated interception. Between 12:00 and 21:00 both monoliths registered a mass reduction about 1.4 kg (= 1.4 mm), which has to be interpreted as ETa. At the following day the monolith mass decreased with the rising sun; during 08:00 to 12:00 an ETa of 2.9 mm (LYS 1) and 3.6 mm respectively was measured. Also on 2013/08/27 between 08:00 and 15:00 ETa values of 1.5 mm (lysimeter 1) and 1.7 mm (LYS 2) were determined. The precipitation event after 16:00 (LYS 1: 2.2 mm, LYS 2: 2.4 mm) stopped the ongoing ETa. From 18:00 until the end of the measuring period ETa occurred and caused a small mass loss of 0.5 kg (= 0.5 mm, LYS 1) and 0.4 kg (= 0.4 mm, LYS 2) respectively. Considering the entire study period (2013/08/25 00:00 – 2013/08/27 23:00) it was seen that on LYS 1 the mass was reduced about -1.4 kg during a precipitation amount of 4.9 mm, this leads to an ETa of 6.3 mm. In comparison for LYS 2 a mass change of -1.6 kg and a precipitation amount of 5.5 mm were recorded; based on this data the calculated ETa was 7.1 mm.

Due to technical reasons, there was the problem of continuity of measurements and there are some gaps in the data, especially during winter time. The measuring system must be adapted better to the meteorological conditions of the region.

4. Conclusions

Based on the collected data, it could be shown that the precipitation measurement by HRG, VWT, LYS 1, and LYS 2 delivers plausible datasets regarding the precipitation dynamics. As expected, precipitation measurement by lysimeter resulted in a precise and reliable detection of rainfall. HRG installed at 1 m height underestimated significantly the amount of precipitation. Measuring results from VWT as integrated part of a meteorological station can be used for advanced assessments.

There are certain advantages of No-Till management compared to DATT technology due to more available soil moisture at depths of 30-60-120 cm. Moreover, the rise of moisture from the deeper soil horizons probably occurs at topsoil aridization. We suggest that No-Till technology gradually forms soil conditions close to the natural background (steppe) with respect to possible errors caused by technical measurements.

Based on sophisticated lysimeter measurements it was possible to estimate for the first time reliable data concerning the amount of ETa for the environmental conditions of the Kulunda dry steppe.

Further research is necessary to get certain information regarding precipitation measuring during the whole year in Siberia and to improve the lysimeter measuring during winter time in this region. To tackle these problems the new research project

“Innovations for sustainable use of agricultural resources and climate adaptation in the arid steppes of Kazakhstan and Southwestern Siberia” (ReKKS) started in August 2017. The research is sponsored from the German Federal Ministry of Education and Research (BMBF).

5. Acknowledgements

The paper is based on research studies which have been funded by the German Federal Ministry of Education and Research (BMBF) in frame of the projects KULUNDA (FKZ 01LL0905D) and ReKKS (FKZ 01LZ1704C). The intellectual content of the paper is the responsibility of the authors.

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EFFECT OF SOIL TEMPERATURE AND MOISTURE OVER GERMINATION OF SEED COVERED BY ORGANIC POLYMER

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Abstract: Organic polymers used for seed coating have been reviewed aiming to protect the seeds placed into the soil under unfavorable for them conditions. Organic materials could be important hydrophobic agent in both high moisture and low temperature which could protect seeds from early germination. At the same time polymer film couldn't be a obstacle for seed germination in favorable environment. Study of the polymers is important issue for the agricultural science and practice. In present work effect of soil temperature and moisture over germination of seed covered by organic polymer have been studied. It has been found that seeds coated with thin layer of organic polymer stand in dormancy under 8 °C independently of soil moisture. The polymer doesn't effect on seeds germination ability as well.

Key words: Seed coating, organic polymer, germination rate, soil temperature effect, soil moisture effect

1. Introduction

Sowing of corn seeds is usually done in the spring months in the presence of a changing climate and often unfavorable conditions. Optimal weather condition which are suitable for preserving the viability of seeds at the same time (temperatures over 8° C and soil moisture of 13-16%) are available for too short periods of time. Sowing seeds at high temperature and higher soil moisture and then rapidly declining could lead to seeds frosting due to premature germination.

To initiate the germ growth process, the seeds must be hydrated. They are located in the soil and therefore the degree of hydration will depend on the water soil potential. Hydration works because of the difference in water content in seed and soil. [10]

Each crop has different requirements about soil moisture, for example, this value for corn is 30%, wheat 40% and soybean 50%. The amount of water the plant receives is very small, but it is enough to initiate the process [4].

The temperature is an another important factor for seed germination, biochemical reactions course and germ cells growth. Optimal temperature for corn seeds germination is 15-30°C. Low temperature delay germ growth also it could be deadly for germ If the temperature is too low for long period of time [5].

A method of corn seed germination delay has been study in present work. It's been necessary for reliable seeds germination in appropriate weather and soil conditions i.e. germ grow could be possible only when temperature is optimal for long period of time and have a minimum risk for germ frosting.

This effect can be achieved by additional protection of organic polymer seeds to which the following requirements have to be faced [11] such as: water-soluble; biodegradable; to allow good aeration and hydration of the seed; cheap and affordable for farmers; to cover easy and complete seed surface; non toxic.

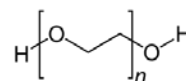
The plant cell has a natural cellulose exoskeleton, therefore modified cellulose polymers could be potential seeds coating agent, e.g. Methylcellulose, ethylcellulose ect [7].

Chitin is another natural biopolymer that could be used as seed coat. It covers insect cells and have cell protection function similar to cellulose at plant cells [6].

Some synthetic polymers are possible options for seed coating: polietilenglikoli, polyvinyl alcohol, polyacrylamide, etc. They have different properties and rate of water solubility. That could affect of their seed coverage ability [8].

2. Preconditions and means for resolving the problem

In this study has been used polyethylene glycol (PEG) as a coating agent with the general chemical formula:



Precisely PEG has been chosen because it meets most of the requirements: comparatively inexpensive, biodegradable and non-toxic, water-soluble and easy to apply to seeds [8,9].

Similar to all water-soluble polymers, PEG has a hydrophobic "tail" represent by a long polymer chain of ethylene glycols and a hydrophilic "head" which is a polar hydroxyl group at both ends of the polymer chain. A schematic structure is shown in Figure 1

When polar molecule of water reach polymer coated seed surface, a swelling process is observed. As a result, would be slowed down the process of transfer of water molecules onto the seed. Increasing the temperature accelerates the process of water diffusion through the polymer sheath.

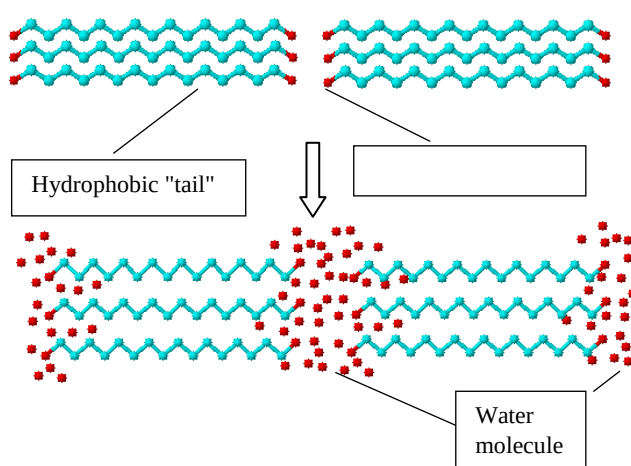


Fig.1 PEG molecule chemical structure and mechanism of water molecule diffusion through the polymer chains

For the purposes of the experiment, aqueous solutions of high molecular weight polyethylene glycol with a concentration of 0.1 and 0.05% were used. Some of the physicochemical properties are presented in Table 1.

Table 1 Physicochemical properties of PEG

Properties	Units	0,1% PEG	0,05% PEG
Viscosity (Brookfield)	cP	80	50
pH		9	9
Density	g/cm ³	1.003	1.002

Test seeds were placed in the beaker and pour the previously prepared PEG aqueous solution. The seeds were mechanically stirred for 5 minutes, then the solution was decanted and the seeds were placed in petri dishes on a filter paper for drying. The drying process is continued for 24 hours under intensive ventilation under laboratory conditions.

In accordance with the tasks set, an active experiment is being conducted. By its nature, it is a multifactorial regression analysis performed in laboratory conditions.

For conducting the regression experiment, control factors include: soil temperature x_1 , absolute soil moisture x_2 and polymer concentration x_3 . It is known that the nature of appearances occurring during seed germination has many and difficult to determine factors, but the three chosen are important for solving the task. Accepted levels of controllable factors are consistent with the recommended values given to them in the literature [1].

The task in conducting these tests is to check the possibility of controlling the germination process of maize seeds. In this sense optimization parameter is germination of the seeds defined in % – Y .

The cybernetic approach is used in the study. This approach allows you to study and manage an object just by its reactions Y_j , $j=1,2,...,p$, due to the external influences exerted on it, called factors - manageable ($x_1, x_2, ..., x_m$) and unmanageable. If the controllable factors are quantifiable (measurable) general appearance of the relationship between the parameter Y_j the manageable factors are represented by the so-called "Response function" [2]:

$$E[Y_j / x_1, ..., x_m] = \varphi(x_1, x_2, ..., x_m) \quad (1)$$

where $E[Y_j / x_1, x_2, ..., x_m]$ is the conditional average of the parameter Y_j .

The type of function $\varphi(x_1, x_2, ..., x_m)$ depends on the nature of the parameter change Y_j in the selected area of change of factors $x_1, x_2, ..., x_m$ and is called the equation of regression. In conducting multifactor experiments that have the character of optimization tasks to obtain the type of equation (1), a second-order polynomial model is used which has the following factor:

$$\tilde{y} = \sum_{i=0}^m \beta_i x_i + \sum_{i,k=1}^m \beta_{ik} x_i x_k + \sum_{i=1}^m \beta_{ii} x_i^2 \quad (2)$$

where $\beta_0, \beta_1, ..., \beta_m$ are the parameters of the model.

It should be borne in mind that the polynomial model simply approximates the function with some accuracy $\varphi(x_1, x_2, ..., x_m)$ in a small area of variability of the

manageable factors. Therefore, one of the main tasks of each experimental study is the search for some approximation of the response function based on the received experimental data. In order for this approximation to be good, the experiments must be carried out on a special scheme - a plan of the experiment.

Very good properties are plans type B_m . In order to simplify the recording of the experiment conditions and to facilitate the processing of the experimental data, the coded factor values are used in planning the experiment in the plans. If the factor x_j , $j = 1, 2, ..., m$ ranges at three levels - lower, middle and upper, the coded values of these levels will be -1, 0 and +1, respectively.

To find a polynomial of the type (2) relating to the series of experiments, a second-order plan Ha_3 (Hartley plan) [2] is used, which is written in Table 2. The use of compositional plans in the study allows to evaluate the individual and mixed influence of the individual manageable factors as well as to look for a possible optimum of the observed parameter.

The processing of all the results of the experiments carried out, as well as the determination of the necessary numerical characteristics of the studied parameters, was carried out with the help of the specialized software product "Statistics" 10.

Essential for the reliability of the resulting test results is the exclusion of non-established modes. In specific experiments, such a mode is the process of adapting the soil in the sample boxes to a certain level of the controllable factors x_1 and x_2 . The duration of the individual experiments of the multifactor experiment at predefined levels of controllable factors is 4 days. Within this range, seed germination is reported at 12 hours. Each sample contains 50 pcs. Seeds of hybrid maize P9911.

All samples are placed in a special thermal insulated chamber (fig. 2), which provides the desired levels of temperature ($0 \div 40^\circ\text{C} \pm 0.1^\circ\text{C}$), relative air humidity ($0 \div 100\%$) and level of lighting ($0 \div 2300 \text{ lm}$) for a chosen period. Their control and management is achieved through an electronic control system. The operator can define levels of controlled factors and activate regime heating/cooling, damping pump and lighting system through the touch display of the chamber (fig. 3). During the experiments, humidity and temperature of the air in the chamber and soil in the samples are monitored using a set of sensors.



Fig. 2. Thermal insulated chamber

The average and upper levels of the factor x_2 correspond to 50% of the field capacity (FC) and of the FC

for the type of soil in the vessels. According to its mechanical composition the type of soil used is leached black earth [3].

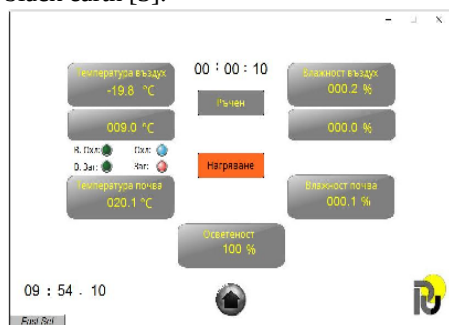


Fig. 3. Operator's interface for programming

The electronic control system of the chamber is in automatic regime during all experiments. This way the programmed by operator levels of air temperature and humidity and hourly level of lighting are guaranteed.

The results for the Y parameter at the respective factor levels and the output matrix of the experiment are shown in Table 2. The graphical these results are represented by the surface of the response and the lines of the same level shown in Fig.4

Table 2. Factor levels, experiment matrix, and plan Ha3 research results

Levels					Factors						
					Temperature of the soil $x_1 - ^\circ\text{C}$		Absolute soil moisture $x_2 - \%$			Polymer concentration $x_3 - \%$	
Low (-1)					8		0			0	
Middle (0)					11		18			<0,1	
High (+1)					14		37			0,1	
Experiment matrix and results											
№	x_0	x_1	x_2	x_3	x_1x_2	x_1x_3	x_2x_3	x_1^2	x_2^2	x_3^2	Parameter Y, %
1	1	+1	+1	+1	1	1	1	1	1	1	98
2	1	-1	+1	+1	-1	-1	1	1	1	1	0
3	1	+1	-1	+1	-1	1	-1	1	1	1	0
4	1	-1	-1	+1	1	-1	-1	1	1	1	0
5	1	+1	+1	-1	1	-1	-1	1	1	1	100
6	1	-1	+1	-1	-1	1	-1	1	1	1	0
7	1	+1	-1	-1	-1	-1	1	1	1	1	0
8	1	-1	-1	-1	1	1	1	1	1	1	0
9	1	+1	0	0	0	0	0	1	0	0	99
10	1	-1	0	0	0	0	0	1	0	0	0
11	1	0	+1	0	0	0	0	0	1	0	98
12	1	0	-1	0	0	0	0	0	1	0	0
13	1	0	0	+1	0	0	0	0	0	1	100
14	1	0	0	-1	0	0	0	0	0	1	100
15	1	0	0	0	0	0	0	0	0	0	98

3. Results and discussion

According to experimental data from Table 3 it was found that the average seed germination was 99%, which is close to 97% germination of the seeds from the control according to standard methodology. The germination rate of the seeds from the samples and the control corresponds to the germination indicated by the producer - over 96%.

The results of the Multi-factor regression analysis carried out with the "Statiska 10" multi-factor regression analysis are shown in Table 3. It shows that the germination factors are important for the factors x_1 and x_2 . They

Affect both their linear parts and their mixed interaction with their quadratic part. This is confirmed by the obtained p-value, which for these two factors and their parts is less (the red lines) of the significance level $\alpha = 0,05$. As unimportant, the analysis indicates the factor x_3 , in which, in all its parts, the probability p is greater than α . Consequently, the presence or absence of seed coating does not affect their germination. In this sense, the polymer used at different concentrations does not adversely affect the genetic potential of the seeds.

Table 3. Results of multifactorial regression analysis performed with "Statistica-10"

Regression Summary for Dependent Variable: Y (Spreadsheet1)						
R= ,97215595 R²= ,94508719 Adjusted R²= ,84624414 F(9,5)=9,5615 p<,01145 Std.Error of estimate: 20,048						
N=15	b*	Std.Err. of b*	b	Std.Err. of b	t(5)	p-value
Intercept			90,0889	10,77548	8,36055	0,000401
X ₁	0,490950	0,104798	29,7000	6,33973	4,68474	0,005411
X ₂	0,489297	0,104798	29,6000	6,33973	4,66897	0,005488
X ₃	-0,003306	0,104798	-0,2000	6,33973	-0,03155	0,976054
X ₁ X ₂	0,365933	0,104798	24,7500	7,08804	3,49180	0,017437
X ₁ X ₃	-0,003696	0,104798	-0,2500	7,08804	-0,03527	0,973229
X ₂ X ₃	-0,003696	0,104798	-0,2500	7,08804	-0,03527	0,973229
X ₁ ²	-0,368496	0,119317	-38,6111	12,50212	-3,08836	0,027210
X ₂ ²	-0,373268	0,119317	-39,1111	12,50212	-3,12836	0,026006
X ₃ ²	0,113465	0,119317	11,8889	12,50212	0,95095	0,385299

With the results obtained from the program, the following adequate regression model for the parameter Y is obtained:

$$Y = 90,09 + 29,7 \cdot x_1 + 29,6 \cdot x_2 + 24,75 \cdot x_1 \cdot x_2 - 38,61 \cdot x_1^2 - 39,11 \cdot x_2^2 \quad (3)$$

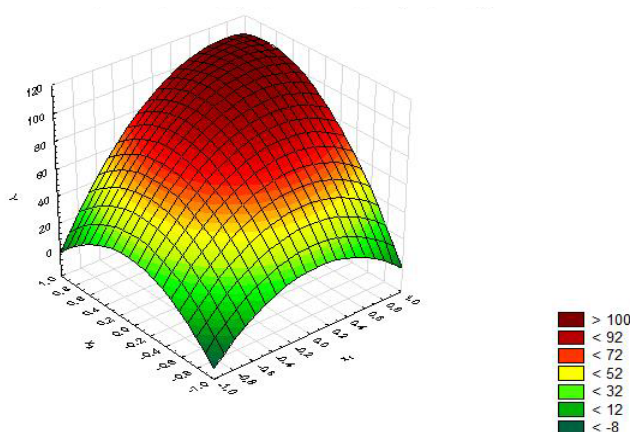
The adequacy of the model is proved by the calculated probability p that satisfies the condition:

$$p < \alpha \quad (4)$$

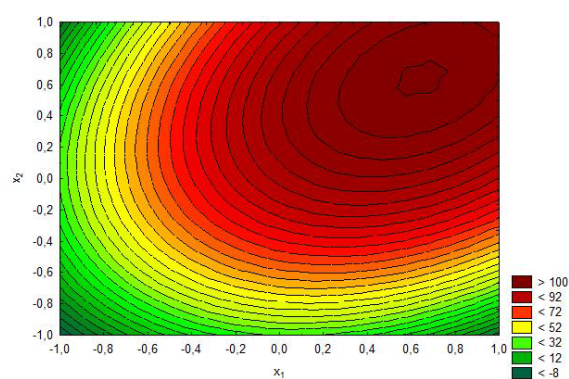
or

$$p_2 = 0.011 < \alpha = 0.05 \quad (5)$$

The analysis of equations (3) shows that the influence of soil temperature (x_1) and soil moisture (x_2) is equivalent to Y. This is confirmed by the values for the coefficient of determination (R^2) For the model after the sequential exclusion of these factors from the expression (3). In both cases, it has a value of 0.46. In its fullest form, an expression (3) shows that 95% ($R^2 = 0.945$) of the change of Y is due to the control factors x_1 and x_2 , and is described with the represented second-degree model.



a)



b)

Fig.4. Graphic presentation of experiment results: a) - the surface of the response; b) - lines of the same level

Referring to Fig. 4 (a) and (b) graphs show that the regression equation for the Y parameter takes high enough for the practice values at factor levels: $x_1 > 0$ и $x_2 > 0$.

4. Conclusion

According to obtained experiment results could be made following conclusions

1. PEG as seed coat have no negative influence over seed germination, and couldn't be a limitation factor on seed growth
2. All PEG-coated seeds do not germinate at temperatures below 8 ° C, regardless of the soil moisture, which allows the seeds to remain at dormancy until monthly temperatures become stabile above this temperature, and hence to reduce the chance of frost.
3. Detailed studies are needed to establish the exact PEG coated seed germination temperature.

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THE MAIN COMPONENTS OF STUDIES AND RESEARCH OF CONSERVING SOILS AND WATER IN TECHNOLOGIES OF AGROENGINEERS TRAINING

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Summary. The basis of study of soils and water resources by future specialists in agroengineering in higher educational institutions is presented. Innovative pedagogical technology is developed according to the method of gradually increasing educational load, which follows from previously learned and mastered material. The acquisition of professional competencies for agroengineering will ensure the development of project activities on the basis of preservation and even multiplication of natural resources. In the training process of agroengineering development, it is important to develop the mathematical apparatus for the necessary calculations, which will ensure optimization of the parameters of technological processes and structures.

Keywords: agroengineering, technological process, soil, agricultural machines, slopes, water erosion.

1. Introduction

In higher agricultural educational institutions of Ukraine, agroengineers obtain higher education of the first (bachelor) and the second (– master's) educational-professional levels. Applicants of higher education of the first educational-professional level get a degree – a bachelor, qualification – an expert in the field of agroengineering. At the same time, the normative term of training is three years ten months, and the volume of educational-professional program – 180-240 credits ECTS. The second level of higher education is awarded to a degree – a master's degree, qualification – a master's degree in agroengineering. ECTS credits required for a higher education degree – master; on the basis of the first (bachelor) level, the educational-professional program is 90 credit ECTS, and educational-scientific program – 120 credits. At the same time, at least 35% of the volume of the educational program should be aimed at obtaining general special (professional) competencies in the specialty defined by the Standard of Higher Education. Along with the acquisition of special professional competencies, it is important that agroengineering specialists be aware of the problematic issues of soil protection energy, resource and moisture technologies of growing crops both in Ukraine and in the world as a whole.

2. Prerequisites and means for solving the problem

Due to the considerable scientific contribution of scientists, agroengineering pedagogical science and educational practice have great achievements and results. Significant contribution to the fundamental scientific results from the study of problem issues on the theory of content and technology of psychological and pedagogical training of specialists in agroengineering in their scientific works was highlighted by I. Bender, V. Manko, O. Kulchytska, I. Lerner, V. Rybalka, M. Dumchenko, N. Kuzmin, P. Luzan, V. Duganets and others.

New standards of education include significant changes in the structure, content, goals and objectives of training agroengineering specialists. With this in mind, the research of the role of project preparation in shaping the professional competences of future specialists in agroengineering, the results of which are presented in [1]. In [2], the peculiarities of using the method of projects in pedagogical theory and practice of forming professional competences of future agroengineers in higher educational institutions are highlighted. The method of projects in teaching technology involves solving the actual production agrotechnical problem or task, and with this method obtain a concrete result in the form of innovative scientific and technical documentation or other product that can be presented, publicly defended, passed on to the customer.

A number of scientific works of well-known scientists such as M. Shikul, P. Zaika, N. Dolya, O. Gnatenko, L. Petrenko, M. Kapshtika, M. Manojlovich, R. Meissner and others are devoted to the urgent problems of protection of soils and water resources. The especially important production problem is the optimization of nutrient and water regimes of the soil on the slopes. A number of scientific works are devoted to the features of soil preparation for sowing crops on sloping lands, optimization and management of

technological processes in these conditions. These include [3, 4, 5]. Classical, practically oriented, as well as the most up-to-date developments and developments of scientists in the form of didactic materials are covered in textbooks, manuals, methodological textbooks, and they are used in the training process of agroengineering.

The textbook [6], which consists of the theoretical part, the methodological development of laboratory and calculation works and test tasks, presents the results of research on the man-caused pollution of soils, their detoxification and recultivation, describes the design, methodology of calculation and designing of machinery and equipment for the preparation of land for development, culturological works and irrigation of fields, regulation of water regime of soil, laying of open channels, their maintenance and cleaning, formation of anti-filter irrigated screens, the determination of the stability of the bulk part of anti-erosion structures on the slopes, the study of the influence of soil categories on the productivity and traction resistance of bulldozers, etc.

3. Results and discussion

In pedagogical technologies of agroengineering training, considerable attention is paid to the study and study of soil condition with the detailed description of their mechanical and technological properties. This is happening at each course during the entire period of training in accordance with the cross-cutting structural and logical scheme of preparation of agroengineering specialists, which is reflected in separate points of the programs of academic disciplines such as "Introduction to the specialty" and training practice in agricultural machines - 1st course of training, "Mechanic-technological properties of agricultural materials", "Plant growing" – 2nd year, "Agricultural machines" – 3rd year, "Operation of Machines and Equipment" – 4rd year. The normative part of the master's educational-professional program of both research and production in the specialty "Mechanization of Agriculture" ("Processes, Machines and Equipment for Agricultural Production," "Agroengineering") includes disciplines that study "Machines and Equipment in Agricultural Land Reclamation".

In the first year of studying students are forming a key content and conceptual apparatus, which is based on the understanding that in the field of plant growing, land resources form the basis of agro-industrial activities, and the soil environment is the main means of production. In the technological processes of cultivating agricultural crops, the land is exposed to various influences on it by the working bodies, as well as the supporting and moving elements of machine-tractor aggregates. The main condition is that this effect does not destroy the structure of the soil, retain its natural fertilizing properties, and even better to enhance them. But the intensive use of land resources leads to land degradation. Thus, only for the period from 1986 to 2010 the content of humus decreased by 0,2% and amounted to 3,1% on average in Ukraine [4]. During this period, losses of humus in the arable layer amounted to 5,5 t/ha. Together with a crop of crops from one hectare of land each year 77 ... 135 kg of nutrients are exported. Unfortunately, such a negative trend - the decline of soil fertility, continues to this day. Students need to know about it, and becoming experts in the field of

agro-industrial production in the future not only to prevent these negative phenomena, but also to care for the growth of the fertility of the land.

At the 2nd year of training in accordance with the program "Plant Growing" students learn how to sample and conduct agrochemical analysis of the soil: the content of humus, as well as nitrogen, phosphorus, potassium and other chemical elements, soil acidity. During the study of the discipline "Mechanical and technological properties of agricultural materials" students study and investigate the physical and technological properties of the soil as a cultivation object, the mechanical and technological properties of fertilizers as the object of mechanized introduction into the soil, the properties of the seed material, the technological properties of pesticides, which are used for plant protection, etc.

The basic physical properties of soils, which are studied and researched by students are: granulometric and structural aggregate composition, stony, volumetric mass, porosity, humidity, color of soils. Special attention in the educational process of agroengineering is given to the technological properties of soils, which are manifested in the process of their cultivation and significantly affect the technical and economic indicators of agricultural production, cost and profit. These properties include: the ability of soils to loosen and crush, hardness, friction coefficient, soil resistance to deformations (permissible vice on the ground of mobile field aggregates, shear and cut resistance, internal friction and soil cohesion, soil strength, resistivity in plowing), adhesiveness, abrasiveness, ductility, elasticity, viscosity, fragility.

On the third year of studies the future agroengineering specialists have to consolidate and extend knowledge on the mechanical-technological properties of soils (hardness, volume factor, angles and coefficients of friction in the working and auxiliary parts of machines, etc.) through the analysis of the theory, experimental research in laboratory or field conditions, processing the received data and analyzing the results. For this purpose, they use special devices and equipment: a spring hardness tester, 2 millimeters of tape or a blank paper in the size of 70 x 500 mm (two sheets of paper can be used from a notebook, joined together), a hardening of a shock action, various soil samples for the study of their properties in laboratory conditions - 2 variants, the device for the experimental determination of angles and calculation of the coefficients of external friction of the soil.

Before beginning the research, students deeply analyze the basic concepts, terms and definitions. For example, let's list some of them.

The coefficient of soil texture – serves to evaluate it after cultivation. It is calculated as

$$K = m_1/m_2, \quad (1)$$

where m_1 and m_2 – mass of aggregates in size, respectively, 0,25 ... 7 mm and the rest of the soil.

Strength – differs depending on the type of deformation. For example, for clay soils the tensile strength is 5-6 kPa, and at compression – 65-108 kPa.

The hardness of the soil P – is the ability of soil to resist entering into it under pressure from any device in the form of a cone, cylinder or ball. The hardness of the soil characterizes the total resistance which is being overcome by tillage machines, performing the environmental destruction by means of different strains. The hardness of the soil is determined by special devices – rigid meter ones. A scheme of a rigid meter for the first time is offered by acad. V.P. Goryachkin. The principle schematic diagram of the hardness is based on the principle of action dynamometer and was improved in the future, and it is widely used. Average soil hardness:

$$P = \frac{Y_i k}{S}, \quad (2)$$

where Y_i – the average ordinate of the diagram at a depth on which the hardness is determined; k – stiffness of the spring of the rigid meter; S – cross-sectional area of the deformer.

Such rigid meters which were suggested by – Goryachkin, Vysotsky, Revyakin are the devices of discrete action and measure the resistance of the soil to the vertical entrance of the device tip.

Using the diagram of a rigid meter it is possible to determine the coefficient of volumetric grinding of soil.

$$q = \frac{F}{V} = \frac{F}{(S \cdot h_x)} = \frac{P}{h_x}, \quad (3)$$

where F – compression force; V – volume of soil in the phase of consolidation.

Friction during a soil cultivation can play both positive and negative roles. The negative role of friction is manifested in the working parts of soil-working machines; friction increases traction resistance of the machine, accelerates the wear of surfaces that interact with the soil. The positive role of friction is that it increases the grip of the wheels with the ground, improves the handling of the unit and reduces the towing. External friction is described by the Amont law, according to which the frictional resistance is proportional to the force of normal pressure N .

According to V.P. Goryachkin, the coefficient of friction for a pair of a metal-soil where $f = 0,5$, with the friction angle $\varphi = 26^\circ 30'$. If it is necessary to take into account the specific mechanical properties of the soil for different zones, then for the choice of coefficient of friction you can use the data proposed by G.N. Sineokov, which are shown in the table. 1

Table 1
Numerical data of the angles and coefficients of friction of the ground on the steel

Soils	Angle of friction	Friction coefficient
Sand and sandstone: loose	14°- 19°30'	0,25-0,35
connected	25°30'-35°	0,50-0,70
Easy and medium loose	19°30'-26°30'	0,35-0,50
Heavy loams and clay	31°-42°	0,60-0,90

The smaller value of the coefficient of friction for the given soil corresponds to lower humidity, the bigger – higher humidity. Friction is often accompanied by sticking of the soil to the metal surface. External friction and adhesion – are two different phenomena of the same process – slipping of the soil on the metal. However, the laws of friction and adhesion are different.

In the special methodological textbooks on the theoretical course of agricultural machines is presented the performance of laboratory work and the content of the report. This includes the following.

1. Describe the characteristics of the soil – hardness, volume of the cracking coefficient, angles and coefficients of external and internal friction, etc., to analyze their influence on the implementation of agricultural devices of technological processes.

2. Draw a diagram of a spring-loaded hardness meter, while revealing the mechanism of spring deformation and the kinematic scheme of information transmission from the spring to the self-recording device in 3, 4 characteristic positions. By analyzing the kinematic scheme of the work of the self-recorder, establish the relationship between the deformation of the spring and the displacement of the pencil from the conditional zero line.

Determine the hardness of the soil and examine its change according to one of the factors, namely: depending on the change in the mechanical composition of the soil, depending on the location relative to the edge of the field or depending on the change in soil moisture. Experimental studies should be carried out on one of the factors chosen from the above. To do this, use one tape for each of the 2 soil variants of the selected factor. To determine the hardness of the soil on each variant make 3 ... 5 measurements. At the same time on each of the 2 tapes will be shown the above number of graphs. Determining the depth of the tip of each centimeter of the ordinate and finding their average values to construct a graph, which is an average graph of the graphs, which are obtained experimentally. From the constructed graph of meant values, determine the hardness of the soil at depth 2; 4; 7; 10; 15; 20 cm. Construct graphs of averages and determine the hardness of the soil which should be for each of the 2 variants. Hardness of the spring of the hard-meter $K = K_v + K_m = 0,82 \text{ kN/m} + 1,33 \text{ kN/m} = 2,15 \text{ kN/m}$.

Total points of conducting researches on determination of technological properties of soil are 8.

On the 4th year in accordance with the discipline "Operation of Machines and Equipment" students study the scientific basis of effective use of technology, expand knowledge of the general characteristics of technological processes of soil cultivation, agronomic requirements for operations, etc. So, for example, plowing is used in the absence of wind erosion, and field-free cultivation is used in conditions of insufficient moisture and in the presence of wind erosion. On sloping lands, according to agrotechnical requirements, the movement of the unit must be carried out across the slope.

Master's training involves the formation of professional knowledge and skills of efficient use of land, water and other natural resources in accordance with the needs of agricultural production based on the study of the bases of mechanized technological processes of construction and maintenance of reclamation facilities, the structure and operation of reclamation machines, the combined effect of technological, technical and organizational factors, which enables restoration and further development of modern environmental remediation systems.

For example, let's consider one of the 11 laboratory and practical works performed by undergraduates – "Determination of the stability of the bulk part of anti-erosion structures on the slopes" [6]. Purpose of the study: to research the features to master the method of determining the stability of the bulk part of anti-erosion structures on the slopes in the development of technological processes of soil protection from water and wind erosion and increase its fertility.

Initially, the master students study and investigate the stability of the bulk part of anti-erosion structures on the slopes. It is worth noting that the issue of the stability of soil terraces is associated with the definition of the greatest steepness in which it is advisable to terrain the slopes. The determination of the stability of bulk slopes was studied by prof. I.N. Tsitovich, A.M. Panchenko and other scholars. In the theoretical substantiation of the stability of the bulk part of anti-erosion structures on the slopes, one can assume that the surface of the slip is previously known and it coincides with the surface of the slope.

The equilibrium of the forces acting on the bulk of the terrace is as follows:

$$T - N f - C_{ui} l = 0, \quad (4)$$

where T – tangential forces that arise in the plane of sliding; N – ковшання normal forces that arise in the plane of sliding; f – coefficient of internal friction of the soil; C_{ui} – specific soil grafting; l – the length of the surface of the slide (Fig. 1).

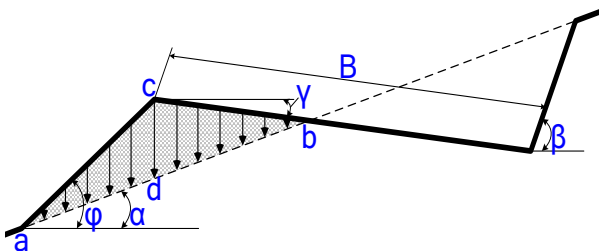


Fig. 1 Scheme for determining the stability of the bulk slope on the slope

When determining the equilibrium conditions, the shrinking array neglects the emerging lateral pressure. The greatest load in the body of the bulk part of the terrace will be under point C (Fig. 1), from where

$$cd = \frac{B \sin(\alpha + \gamma)}{\cos \alpha \left[1 + \sqrt{\frac{\sin(\beta - \alpha) \sin(\varphi + \gamma)}{\sin(\varphi - \alpha) \sin(\beta + \gamma)}} \right]}; \quad (5)$$

$$bd = \frac{B \cos \gamma}{\cos \alpha \left[1 + \sqrt{\frac{\sin(\beta - \alpha) \sin(\varphi + \gamma)}{\sin(\varphi - \alpha) \sin(\beta + \gamma)}} \right]}; \quad (6)$$

$$ab = \frac{B \sin(\varphi + \gamma)}{\sin(\varphi - \alpha) \left[1 + \sqrt{\frac{\sin(\beta - \alpha) \sin(\varphi + \gamma)}{\sin(\varphi - \alpha) \sin(\beta + \gamma)}} \right]}. \quad (7)$$

The equation (5 – 6) can be used to construct the shear of the distribution of the shear stress of τ_{3c} and the shear resistance τ_{on} of the forces acting in the slip plane

$$\tau_{3c} = \frac{G \sin \alpha}{F}, \quad (8)$$

$$\tau_{on} = \frac{G \cos \alpha}{F} + C_{ui} F, \quad (9)$$

where G – the mass of the moving wedge; F – area of contact of the bulk part of the terrace with the slope surface.

The mass of soil gravity depends on its consistency (Table 2).

Table 2

Consistence the soil	Loam			Supysok		
	$\gamma_{o6}, T/m^3$	φ°_2	$C_{ui}, N/cm^2$	$\gamma_{o6}, T/m^3$	φ°_2	$C_{ui}, N/cm^2$
Okay	2,15	25	6	2,05	28	2
Half-hard	2,10	23	4	2,00	26	1,5
Tumultuous	2,00	21	2,5	1,95	24	1
Flexible	1,90	17	1,5	1,90	20	0,5
Cecoplastic	1,85	13	1	1,65	18	0,2
Flowing	1,80	10	0,5	1,80	14	0

In the literature, the degree of stability of earthen slopes is characterized by the magnitude of the coefficient of stability k_{cm} . It is accepted that the coefficient of stability of slopes can be determined using the formulas used to calculate the stability of slopes by the method of circular cylindrical sliding surfaces, that is,

$$k_{cr} = \frac{N f + C_{ui} l}{F}. \quad (10)$$

To determine the forces N and F it is necessary to know the weight of the shifting wedge, which for 1 m of the length of the terrace can be determined by the formula:

$$G = \frac{\gamma_{o6} B^2 \sin(\beta + \gamma) \sin(\alpha + \gamma)}{2 \sin(\beta - \alpha) \left[1 + \sqrt{\frac{\sin(\beta + \gamma) \sin(\varphi + \alpha)}{\sin(\varphi + \gamma) \sin(\beta - \alpha)}} \right]^2}, \quad (11)$$

where γ_{o6} – volumetric weight of soil.

Substituting in (10) the values of N , F and l on their expressions, after transformations we obtain the formula for determining the coefficient of stability of the bulk slopes of the terraces:

$$k_{cr} = f \operatorname{ctg} \alpha + \frac{2 C_{ui} \left[1 + \sqrt{\frac{\sin(\beta + \alpha) \sin(\varphi + \gamma)}{\sin(\varphi + \alpha) \sin(\beta + \gamma)}} \right]}{\gamma_{o6} B \sin \alpha \sin(\alpha + \gamma)}. \quad (12)$$

Then the undergraduates are familiar with the order of the fulfilling of a work [6], execute it and draw up a report.

4. Conclusion

In the pedagogical technologies of the preparation of future agroengineers considerable attention is paid to the problem issues of soil and water conservation. During the entire period of studies, students study and research the mechanical and technological properties of soils as the main means of agricultural production continuously and consistently. In the project activity for the initial

parameters primary consideration is given to soils with their characteristics and parameters with the obligatory preservation of their fertility in the technologies of agricultural production of the crop production sector.

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ROLE OF MINERAL SUBSTRATES IN FORMATION OF HUMIC COMPOUNDS IN SOIL

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Abstract

The effect of mineral matrices of loam, quartz sand, sand + 30% kaolinite, and sand + 15% bentonite on the dynamics of transformation of plant residues (PRs) of corn and red clover was studied. It is shown that the dynamics of PRs transformation has a wave pattern and depends both on the nature of mineral matrices and on the composition and properties of PRs. The kinetic parameters of corn and clover decomposition were studied, using a two-term exponential polynomial. The turnover period for the labile pool of clover and corn in all substrate (8-10 days) is typical for the organic acids and simple saccharides. The turnover time of the stable clover pool (0.95 years) and of the corn (1.60 years) corresponds to the turnover time of plant biomass.

KEYWORDS: MINERAL MATRICES, HUMIC SUBSTANCES, CORN, CLOVER, DECOMPOSITION DYNAMICS

1. Introduction

The transformation of plant residues (PRs) in soils is complicated due to two opposite processes: mineralization and humification of organic matter (OM). Both processes are complex and contain many successive-parallel stages. These are biochemical decomposition of PRs and partly newly formed organic material, stabilization of the decomposed products on each step of the process, humification of more stable pools of soil organic matter and more slow mineralization of already stabilized humic substances. Thus, a continuous set of organic and organo-mineral compounds different by their resistance to decomposition by soil microorganisms is formed.

A large number of studies have been devoted to investigation of these processes in soils. Most of them are associated with the study of the nature of organic matter of soils, its composition and properties, as well as the biochemical mechanisms for formation of specific humic substances - humic (HA) and fulvic (FA) acids. The participation of mineral components of soils in the formation of humic substances is poorly studied till now.

Mineralization of organic matter (OM) in soils depends on its availability to microorganisms (external factor) and their inherent stability to decomposition (internal factor). The least stable organic compounds are decomposed for several hours or days, the most stable ones remain in the soil for years or even millennia (Alekseeva et al., 2009; Bertrand et al., 2011).

Finely dispersed mineral components, predominantly clay minerals, play an extremely important role in the formation of humic substances and their conservation in soils. They ensure physical and chemical mechanisms for the protection of humic substances from biodegradation. This is due to the decrease in the availability of organic substances for microorganisms as result of formation of stable organomineral compounds on the surfaces of soil microaggregates (Mikutta, 2006; Van Lutzow, 2006). Recent theoretical and experimental works confirm the important role of adsorption on the surface of clay minerals for stabilization of newly formed OM and in synthesis of humic substances (Birkel et al., 2006; Kaiser and Guggenberger, 2003; Lehmann et al., 2007; Pinsky et al., 2014). In particular, Travnikova et al. (1992) proposed that the condensation of PRs decomposition products to HAs occurs mainly through the formation of mineral-organic compounds, where organic component interacts with the surface of finely dispersed mineral.

The HAs thus formed are similar in composition and molecular weight to HAs and FAs and are bounded with the clay fraction of soils. These studies imply the direct participation of clay minerals in humus formation. Zavarzina (2006) revealed a direct effect of mineral matrix on enzymatic synthesis of humus-like substances from simple decomposition products of PRs. The consideration of soil humus as a complex of organomineral compounds attracts the increasing attention of researchers.

The aim of this work is to study the effect of mineral substrates of different composition on the mineralization and humification of the decomposition products of PRs of corn and clover under controlled conditions.

2. Objects and methods

In the experiments we used the aboveground mass of corn (*Zea mays*) and red clover (*Trifolium pratense*), which was preliminary dried and milled to the sizes 3-5 mm. Mineral matrixes were as following: pure quartz sand and carbonate-free covering loam (the soil forming material of gray forest soil from the Experimental Field Station of the Institute of Physico-chemical and Biological Problems in Soil Science Russian Academy of Sciences), the mixtures: sand + 15% bentonite and sand + 30% kaolinite. Mineral content of the loam was 59% quartz, 16% kaolin, 13% mica, 11% feldspar, and 2% smectite. The bentonite contained beidellite, montmorillonite, talk, some quartz, calcite, and mica. Different admixtures in kaolinite were less than 2%.

All mineral substrates were thoroughly mixed with the milled aboveground mass of corn and clover in the ratio 1:10, placed into glass vessels (200 cm³), watered to 60% of the water holding capacity (WHC). Soil microorganisms were inoculated into the substrates of each vessel by adding of 1 ml of gray forest soil – water suspension (1:100 w/v). After that, the substrates were incubated at 20°C and 60% WHC. Duration of experiments was 6-19 months. Sampling for the analyses was carried out after 5, 10, 20, 30, 60, 90, and 180 days from the beginning of the experiment with the clover set and after 7, 14, 20, 30, 60, 90, 180, 285 and 570 days – with the corn set. The experiments were run in three replicates. The content of organic carbon was determined by the Tyurin method (The theory..., 2006). Carbon mineralization losses were estimated from the difference between the contents of organic carbon in the beginning of the experiment (C₀) and in the respective sampling date. Biochemical composition of PRs is presented in Table 2.

Table 2. The some components in corn and clover biomass

Organic substances groups	% of ash-free matter	
	Corn	Clover
Ash	18	13
Wax resins	19.1	6.0
Proteins	4.9	14.8
Hemicellulose	32.6	23.8
Cellulose	26.0	20.4
Lignin	10.8	8.2

The elemental composition of the OM (C, N) in the samples of the incubated material was determined on an Elementar Vario EL III CHNS analyzer.

3. Results and discussion

3.1. Dynamics of plant residue transformation

The temporal changes in the relative content of carbon in PRs of corn and clover are presented in Fig.1. As a whole plant residues of

clover are mineralized faster than corn ones. For both cultures the least amounts of mineralized plant residues were observed in the loam, the highest amounts - in the kaolinite (for corn) and sandy (for clover) substrates.

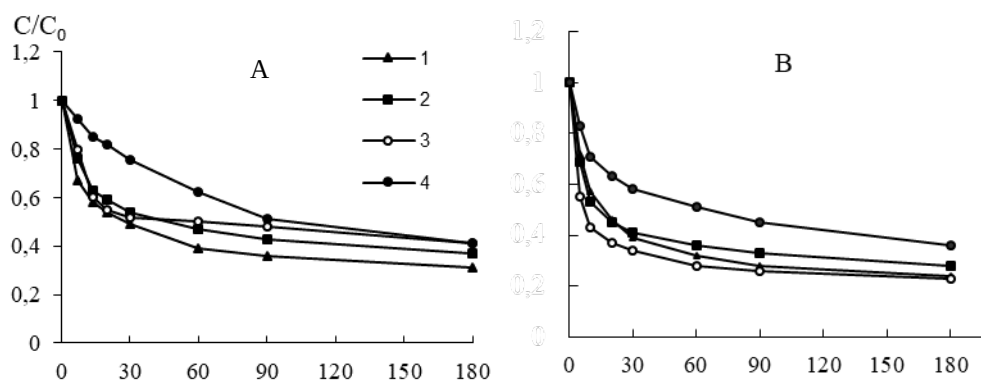


Fig. 1. The dynamics of mineralization of PR of corn (A) and clover (B) in the substrates studied: 1 – sand+30% kaolinite, 2 – sand+15% bentonite, 3 – sand, 4 – loam.

Mineralization of PRs of corn and clover (Fig. 1) conditionally includes three stages: fast, transitional, and slow. The fast stage lasts about one month, the transitional stage - from one to three months, the slow stage – more than three months. Decomposition of organic matter in substrates obeys an exponential law in time. In general, the clover residues are mineralized faster than corn ones due to the influence of biochemical composition of plant residues. For both cultures the least amounts of plant residues were mineralized in the loamy substrate, the largest - in the substrates containing kaolinite (corn) and sand (clover) due to the effect of mineral matrices.

During the transformation of the PRs, a change in the populations of microorganisms occurs at each stage in the transformation of OM, due to a change in the composition of nutrient substrates (Rybalkina and Kononenko, 1959). At the same time, a complex of humic substances with undecomposed plant residues and a system of universal succession complexes of microorganisms-destroyers is formed (Chertov et al. 2007). It may be one of the causes of the wave pattern of humification of PRs, clearly manifested in the change in the content of humic substances and in the C/N ratio in the process of decomposition in time (Fig. 2).

The effect of mineral substrate on the humification is also clearly manifested in the content of the formed HAs and FAs. On the loam, more significant amounts of HAs are accumulated during the entire period of incubation, except for the first month of the experiment, when the portion of HA on the sand was slightly higher. The dynamics of the HA in the incubated systems copy the dynamics of the humic substances: they have an undulating character with a tendency for a gradual decrease in their content during the experiment. The end of the first humification stage is more clearly indicated by the C_{HA}/C_{FA} ratio. Minimal values of this ratio were observed in both systems after three months of incubation. A decrease in the humification rate, most significant in the sandy substrates, was simultaneously observed. At the next stages of humification, HA are always predominant in the humic substances. The C_{HA}/C_{FA} ratio reaches its maximal values to the end of the experiment, which perfectly coincides with the main law of Orlov's kinetic theory of humification: the selection of thermodynamically and biochemically stable humic substances (Humic substances..., 1993).

Thus, the studies showed that the dynamics of the PRs mineralization and humification in different mineral environments is largely similar and is determined by the undulating development of the microbial community. The rate and qualitative characteristics of the processes at the constant temperature and moisture conditions of the incubation depend on the composition and properties of the mineral matrix; therefore, they are significantly different.

Table 1. Change in the group composition of humus during the incubation of plant residues of corn in different mineral substrates.

Time of incubation, month	C_{HS}	C_{FA}	C_{HS}/C_{FA}
	% of C_0		
sand			
0.5	4.1	3.3	1.2
1	6.0	3.7	1.6
3	2.9	3.1	0.9
6	3.5	2.3	1.5
9.5	3.7	1.9	1.9
19	2.7	1.0	2.7
loam			
0.5	4.2	3.6	1.2
1	5.7	4.7	1.2
3	4.3	4.7	0.9
6	4.3	3.4	1.3
9.5	5.1	3.2	1.6
19	3.4	2.1	1.6

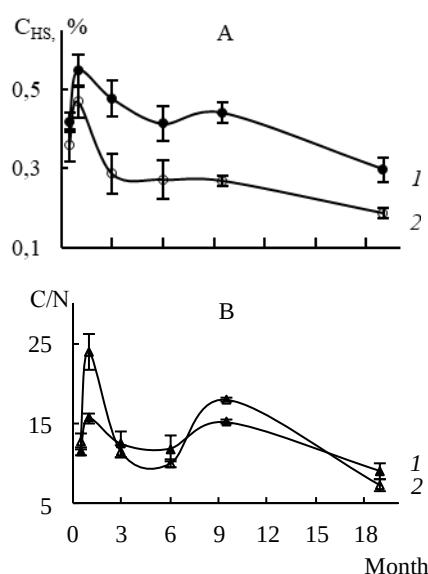


Fig. 2. Changes in the content of humic substances (A) and C/N ratio (B) during the humification of corn residues in loam (1) and in sand (2).

3.2. Kinetics of plant residue decomposition

The model selected for the quantitative description of plant residue mineralization involved two OM pools in the substrate: labile (LP) and decomposition-resistant ones; the decomposition process follows the first-order kinetic equation (Jenkinson and Rayner, 1977; Kuzyakov, 2006):

$$(1) \quad \frac{dC}{dt} = -(k_1 C_1 + k_2 C_2),$$

The analytical solution of the linear equation at the known initial content of organic carbon in the system ($C = C_0$ at $t = 0$) is the two-term exponential function:

$$(2) \quad \frac{C_t}{C_0} = A e^{-k_1 t} + B e^{-k_2 t}$$

where C_t is the residual organic carbon maintained in the soil at the time point t , A – is the share of labile matter, B – is the share of the resistant substances ($B = 1 - A$). The values of kinetic parameters calculated from equation (2) are presented in Table 2.

Table 2. The kinetic parameters of organic matter transformation in mineral substrates with different composition after six month incubation

Parameter	Sand + 15% bentonite	Sand + 30% kaolinite	Sand	Loam
Corn				
A	0.484±0.012	0.490±0.019	0.483±0.024	0.468±0.030
B	0.516±0.012	0.510±0.019	0.517±0.024	0.532±0.030
$k_1 \cdot 10^{-1}$, day ⁻¹	0.99±0.13	1.29±0.30	1.00±0.05	0.22±0.03
$k_2 \cdot 10^{-3}$, day ⁻¹	2.02±0.27	3.16±0.53	1.16±0.18	1.61±0.25
T ₁ , day	10	8	10	46
T ₂ , year	1.4	0.9	2.4	1.7
Clover				
A	0.567±0.015	0.600±0.011	0.632±0.018	0.385±0.013
B	0.433±0.015	0.400±0.011	0.368±0.018	0.615±0.013
$k_1 \cdot 10^{-1}$, day ⁻¹	1.56±0.11	1.15±0.15	2.33±0.14	1.12±0.20
$k_2 \cdot 10^{-3}$, day ⁻¹	2.58±0.40	3.19±0.32	3.11±0.40	3.10±0.28
T ₁ , day	6	9	4	9
T ₂ , year	1.1	0.9	0.9	0.9

The turnover time is related to the mineralization rate by the relationship $T = 1/k$. The turnover period for the labile pool of clover (4-9 days) in all substrates and corn in sand and substrates with kaolinite and bentonite (8-10 days) is typical for the organic acids and simple saccharides. In the loam substrate, the turnover period for the LP of the corn is about 46 days due to stronger stabilization of the LP components. The turnover period of the stable pool of clover (0.95 year) is essentially less than that of corn (1.6 year) and generally corresponds to the turnover period of plant biomass. Calculation of the rate constants of decomposition of labile and resistant carbon pools at incubation during 19 months has shown that k_1 values of mineralization of PRs of corn in sand substrate was 0.69 day⁻¹ ($T_1 = 15$ days), in loam substrate - 0.032 day⁻¹ ($T_1 = 31$ days). The values of k_2 were similar to both substrates and were 0.0015 day⁻¹ ($T_2 = 1.9$ years) in sand and 0.0012 day⁻¹ ($T_2 = 2.3$ years) in loam substrates and practically did not differ from the values obtained at incubation during 6 months. Concluding, the deceleration of the total rate of mineralization with time occurs mainly at the expenses of the labile pool.

4. Conclusion

It is shown that mineralization of PRs of corn and clover includes three stages: fast, transitional and slow. The fast stage takes about one month, the transitional stage – from one to three months, the slow stage – more than three months. Decomposition of organic matter in substrates obeys an exponential law into time. In general, the clover residues are mineralized faster than corn ones. For both

The analysis of the data obtained demonstrates that the kinetics of mineralization of PRs of corn and clover is adequately described by the binomial exponential polynomial. With that the share of LP of organic carbon in clover biomass is higher (57-63%) than that in corn one (47-49%). That is connected with the peculiarities of biochemical composition of PRs. In the loam substrate, the share of labile pool in clover biomass decreases to 39% that is explained by higher ability of the loam to stabilize the products of clover decomposition by means specific adsorption.

The rate constants of decomposition of labile and resistant pools in all cases differ: $k_1 \gg k_2$. The least rate of LP decomposition of corn is typical for the loam substrate, and maximal one – for the substrate with kaolinite. In the latter case $k_{1\text{clover}} \gg k_{1\text{corn}}$. Evidently, labile compounds of corn are stabilized by the loam stronger and are slower decomposed by microorganisms compared to the clover. The highest rate of PRs decomposition of corn and clover is typical for the substrate with kaolinite. Hence, the kaolinite accelerates the decomposition process of PRs of both cultures, and OM of the clover in a higher level.

cultures the least amount of plant residues was mineralized in the loamy substrate, the largest amount - in the substrates containing kaolinite (corn) and sand (clover).

The dynamics of HS formation, HA and FA content, their ratios, and the C/N indexes are of wavy pattern. This is the result of changes in the structure of microbial community under the changes in the nutrients composition.

The kinetics of mineralization of PRs of corn and clover in the investigated mineral substrates is satisfactorily described by a two-termed exponential polynomial. The decomposition constants of labile and stable pools are different in all cases: $k_1 \gg k_2$. The lowest decomposition constant of the corn labile pool is observed in the loamy substrate, and the highest rate in the kaolinite-containing substrate, and k_1 (clover) > k_1 (corn). Apparently, the labile OM components of corn are more strongly stabilized by loam than those of clover and are more slowly decomposed by microorganisms. The highest decomposition rate of corn and clover stable pools is observed for the kaolinite-containing substrate. Hence, kaolinite accelerates the decomposition of OM in both cultures, especially in clover.

The turnover time of the clover labile pool (4–9 days) in all substrates and that of corn in sand and kaolinite- and bentonite-containing substrates (8–10 days) is typical for organic acids, amino acids, and simple sugars. In the loamy substrate, the turnover time of the corn labile pool is about 46 days due to the stronger stabilization of the labile pool components. The turnover time of the clover stable pool (0.95 years) is significantly lower than that of

corn (1.60 years) and largely corresponds to the turnover time of plant biomass.

Acknowledgments

The work was supported by the Russian Foundation for Basic Research (project nos. 16-04-00924a, and 16-34-01172 mol-a).

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TO THE STUDY OF PHYTOPLANKTON OF URBAN PONDS IN THE SOUTH-EAST OF THE REPUBLIC OF TATARSTAN IN RUSSIA

К ИЗУЧЕНИЮ ФИТОПЛАНКТОНА ГОРОДСКИХ ПРУДОВ ЮГО-ВОСТОКА РЕСПУБЛИКИ ТАТАРСТАН РОССИИ

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The purpose of this work was to determine quantitative indicators and assess the quality of water of ponds located in the central part of the cities of Aktanysh, Leninogorsk and Bugulma of the Republic of Tatarstan of the Russian Federation by phytoplankton organisms. Phytoplankton samples were taken in June 2016, 10 stations were selected from each reservoir - coastal and deepwater, confined to different habitats.

Collection and processing of phytoplankton samples were carried out according to conventional hydrobiological methods (Method of study..., 1975). When determining the taxonomic affiliation of each species, determinants of freshwater algae were used (Hollerbach, Polyansky, 1951; Zabelina et al, 1951; Kiselev, 1954; Matvienko, 1954; Popova, 1955; Dedusenko-Schegoleva et al, 1959; Kosinskaya, 1960; Dedusenko-Schegoleva, Gollerbach, 1962; Gollerbach et al, 1963; Palamar-Mordvintseva, 1982; Diatoms ..., 1988, 1992; Genkal, 1992; Tsarenko, 1990.)

In the phytoplankton samples from pond in Aktanysh, 30 algae taxons were determined below the genus of six divisions. Numerically species were dominated by the green ones - 14 taxons (47% of the total number of species), diatoms - 7 species (23%), followed by euglenic - 4 species (13%), blue-green and golden algae - 2 species (7 %), 1 species belongs to the department of dinophyte (3% of the total number of species encountered in the

pond). The number of species from the stations of research varied from 13 (at st. 1) to 23 species (at st. 3).

The phytoplankton abundance at the research stations varied from 214.83 t. cells / l at the station 3 to 1679 t. cells / l at station 5.

The following representatives predominated among the species: at stations 2, 5, 6, the species from the Euglena texta department (Duj.) Hubner predominated with a contribution to the total number on the station - 19, 47, 16%, respectively; at station 3 prevailed species from the department of green Coelastrum reticulatum (P.A.Dangeard) Senn., 1899 accounting for 18% and Volvulina steinii (Playfair) - 19.5%; At st. 10 - dominated the green alga Scenedesmus quadricauda (Hegew.) Hegew. - 21%; also, on station 6 the green Chlorella sp. dominated, forming 20% of the total value. The total biomass in the stations varied from 1.907618 mg / l at the station 3 to 16.45238 mg / l at the station 10.

In biomass, the predominant species were: at stations 2, 3, 10, the green alga Volvulina steinii (Playfair), forming 61, 82 and 64% of the total biomass, respectively; at stations 5, 6 euglene Euglena texta (Duj.) Hubner predominated in biomass (54% and 44%, respectively); also on st. 10 blue-green Oscillatoria limnetica dominated in biomass (20%).

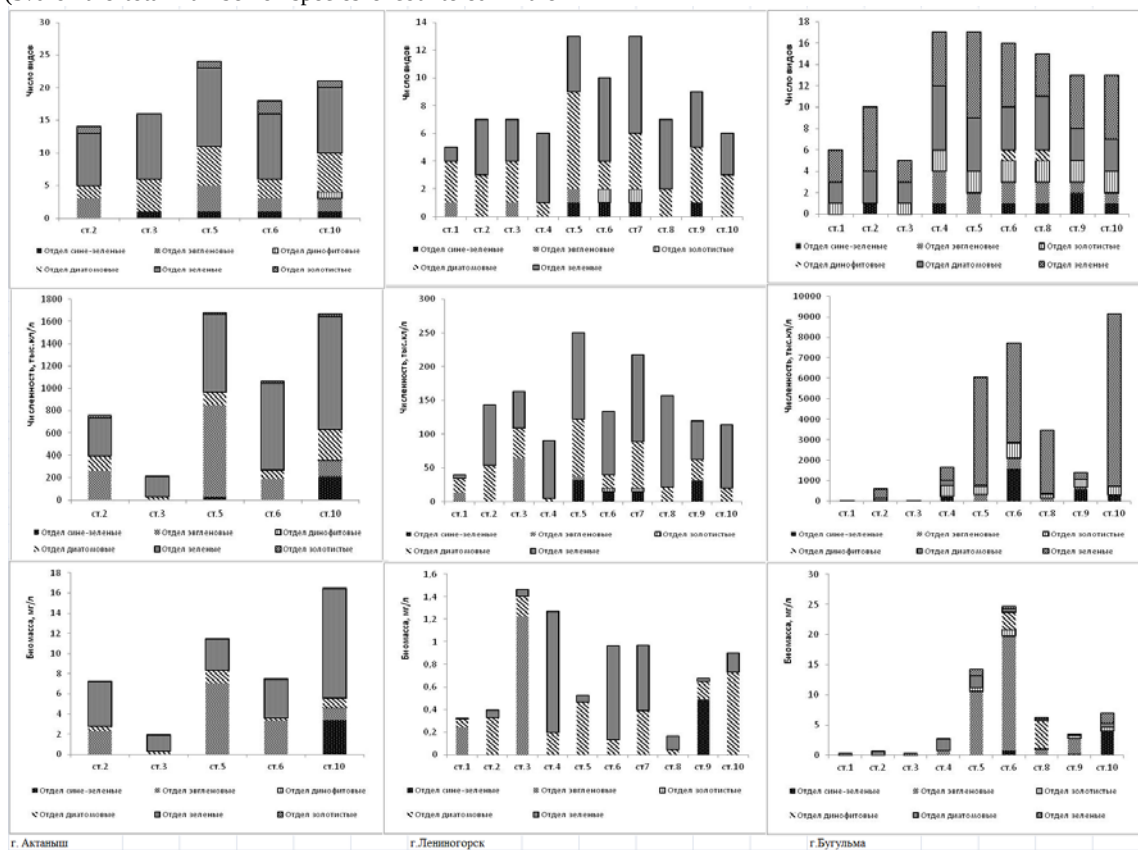


Fig. 1. Dynamics of changes in quantitative indicators (number of species, specimen, number, thousand cells / liter and biomass, mg / l) in the studied reservoirs of Aktanysh, Leninogorsk, Bugulma, respectively

On the whole, the reservoir is characterized as highly trophic, with a moderately high content of organic matter corresponding to the period of the vegetation season in the reservoirs of the Central Russia (the spring peak of "flowering" has already passed and the summer has not yet come). In mass predominant species are representatives of green algae (small-celled colonial forms), quantitatively also among the dominants the euglenic division is distinguished, which also indicates a high content of organic matter.

The representation of the diatom department indicates a flowage. Lack of diversity and massiveness of blue-green algae - indicates that the flowering period is not captured by research.

In 10 samples of the phytoplankton from pond in Leninogorsk, 29 algal taxa were determined below the genus of five divisions. The number of species is dominated by the green ones - 12 representatives (41% of the total number of species), diatoms - 11 species (38%), followed by euglenic, blue-green and golden algae - 2 species (7% each).

The number of species from the stations of research varied from 5 (at st. 1) to 13 species (at stations 5 and 7).

The number of phytoplankton at the stations of research varied from 38.88 t. cells / l on st. 1 to 249.51 t. cells / l at st. 5.

The number of species dominated: at stations 1, 3 - *Euglena schmitzii* Gojdicis euglena algae (33% and 39%, respectively); at stations 2 and 4, the green alga *Coelastrum reticulatum* (P.A. Dangeard) Senn (33% and 38%, respectively); at st. 5 - green alga *Pediastrum boryanum* (Turp.) Menegh. (34 %); at st. 6 - the species from the department of green *Chlorella* sp. Beij predominated (29%); at st. 7 and 8 - the largest species was the species from the department of green *Tetraëdron minimum* (A. Br.) Hansg. (28.6% and 50%, respectively); at st. 9 and 10 the representative from the department of green algae - *Dictyochlorella globosa* (Korsch.) Silva, prevailed, forming 26 and 35% of the total population, respectively. Also, at the station 9 prevailed blue-green alga *Oscillatoria limnetica* Lemmermann (26%); at st. 10 - *Raphidocelis subcapitata* (Korsch.) Nyg predominated (30 %). The total biomass in the stations varied from 0.33485 mg / l at the station 1 to 1.463761 mg / l at the station 3.

In biomass prevailed: at stations 1, 3 - euglena alga *Euglena schmitzii* Gojdicis (73% and 84%, respectively); at st. 2 - a species from the department of diatoms *Synedra ulna* (Nitzsch) Ehrenberg (66%); at stations 4, 6, 7, 8 - green *Volvulina steinii* (Playfair) - (84%, 84%, 57%, 59%, respectively); at st. 5 - diatom *Cyclotella comta* (Ehrb.) Kütz. (39%); at st. 9 prevailed blue-green alga *Oscillatoria limnetica* Lemmermann (73%); on st. 5 - diatom *Synedra acus* Kützing (75%). Also, in biomass at st. 1, the euglenous alga *Trachelomonas intermedia* Dang dominated (51.2%); at st. 2 - blue-green *Microcystis aeruginosa* (Kütz.) Kütz. (37.9%); at st. 3 - diatom *Stephanodiscus hantzschii* (25.6%).

In general, over the water body, clearly the prevalence of chlorococcal algae.

At stations 1 and 3 - the representatives of euglene both in numbers and in biomass clearly dominate. Blooming blue-green is not yet observed, but at the station 9 - the filamentary form dominates.

Representation of diatom species, as well as their dominance in biomass at stations 2, 5, 10 - indicates the flowage of the reservoir, favorable for them temperature regime - the water temperature is not high relative to the season and climatic conditions.

In the samples of phytoplankton from the pond in Bugulma, 28 taxons of algae were determined below the genus of six divisions. The number of species is dominated by the green ones - 11 representatives (39% of the total number of species), diatoms - 8 species (28%), followed by euglenic - 4 species (14%), blue-green and golden algae - 2 species (7 %), 1 species belong to the department of dinophyte (3%).

The number of species from the stations of research varied from 5 (at station 3) to 17 species (at stations 4 and 5).

The phytoplankton abundance at the research stations varied from 45.44 t. cells / l at the station 1 to 9145.66 t. cells / l at st. 10.

In terms of numbers, the following prevailed among species: at st. 1 - species of *Navicula* sp. from the department of diatoms and *Chlorella* sp. from the department of green algae (each share - 25% of the total number at station); at stations 2, 5, 6, 8 and 10 - green alga *Volvulina steinii* (Playfair) - (52%, 70%, 57.5%, 80% and 79.5%, respectively); at st. 3 prevailed species from the department of green - *Dictyochlorella globosa* (Korsch.) Silva and *Raphidocelis subcapitata* (Korsch.) Nyg. (28.6% and 50%, respectively); at st. 4 - the species from the department of golden algae *Mallomonas majorensis* predominated (30%); at st. 9 - representative of golden algae *Dinobryon divergens* Imhof. Also, at the station 6 the dominant was the blue-green *Oscillatoria limnetica*, forming 20% of the total value.

The total biomass at the stations varied from 0.234613 mg / l at the station 3 to 24.7027 mg / l at the station 6th.

In biomass among the species, the following species dominated the stations: at stations 1,2 and 4, the species *Navicula* sp. from the department of diatoms (86.3, 28.3 and 24.7%, respectively); at st. 3 - green *Raphidocelis subcapitata* (Korsch.) Nyg. (35%); at stations 5, 6 and 9, the euglena alga *Euglena texta* (Duj.) Hubner (74, 76 and 72%, respectively); at st. 8 - dinophyte *Peridinium* sp. (71%); at st. 10 - blue-green *Oscillatoria limnetica* (56%) and green *Volvulina steinii* (Playfair) (21%).

Also, at the station 2 as a dominant, diatom *Pinnularia* sp., was contributing 28% of the total biomass value; at st. 4 - diatom *Cocconeis placentula* Ehrb. (23%).

In general, small-cell colonial forms predominate in the water body, mainly from the green department - spring "flowering" as a response to the supply of nutrients with surface runoff in spring, along with a large number of representatives of the diatom department, which may indicate the presence of groundwater recharge.

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SOIL TILLAGE INFLUENCE ON THE AGGREGATE STABILITY

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Abstract: *The Importance of the Problem "Stability of Soil Aggregates" The assessment of soil quality indicators and their interpretation should be considered as a process in which all soil resources are assessed in terms of soil functions and the changes that would occur in these functions as a result of Natural or specific stresses and / or certain human activity. The process of formation of soil aggregates or organominerals complexes from primary particles and humic and other bounding substances, is called aggregation. It is the first step in the development of soil structure. Humified organic matter, with its long polymer chains and electric charge balanced by polyvalent cations, is a very effective cementing agents. Structural stability is the ability of a soil to retain its arrangements of solids and void space when external forces are applied. External forces can be natural or anthropogenic. The aggregate stability depends on the bonding agents involved in cementing the particles together.*

KEY WORDS: SOIL QUALITY INDICATORS, AGGREGATE STABILITY

Introduction

Soil has 5 specific features that are of particular importance:

- maintain biological activity, diversity and fertility;
- regulate and distribute water and soil solution;
- perform filtering, buffer, degradation and immobilization activities, as well as detoxify organic and inorganic materials, including industrial and urban waste, and absorb atmospheric overlaps;
- to store and carry out cyclical nutrients and other elements within the Earth's biosphere;
- maintain socio-economic structures and preserve the archaeological values associated with human activity, [17].

Definition of Soil Aggregate Stability: Soil aggregates are groups of soil particles that are tied to each other more tightly than other nearby particles, [16,17, 18].

The stability of soil aggregates directly affects the dynamics of erosion processes, air and water movement in the soil and the development of the root system of plants. It is desirable that soil aggregates be resistant to the destructive action of raindrops and surface water runoff. Broken aggregates that break down from water or raindrops can break and fill the pores and seal the surface of the soil against water penetration into it. This breakdown helps to form a soil crust, defines another way for water movement in the soil and restricts the germination of the seeds.

Material and method

The binding agents involved at each stage of aggregation can be grouped in three main categories: transient - such as polysaccharides and microbial products; temporary - roots, fungal hyphae and microbial byproducts; persistent - humic substances, organo-mineral complex, dehydrated humic materials and humic-sesquioxides complex [13, 14, 15].

The strength of the soil aggregates refers to the ability of aggregates to withstand disruptive forces such as traffic, intensive raindrop impact, annual soil tillage, root development. The information related to the soil's response to tillage or machines passing on the surface is important to calculate the aggregate strength. From one side, the factors affecting the soil strength are the water and organic matter content, size of the soil particles, texture and clay minerals, [16, 17]. From another side the soil strength depends on the contact points between the aggregates. The repeat cycles of drying and wetting play a major role in aggregation through shrinking and swelling that lead to formation of aggregates, table 1.

Table 1. Components of an aggregates:

Components	Size range	
Clay	2	µm
Domain, quasi crystal, or Packets	2-5	µm
Microaggregate	5-500	µm
Aggregate	0,5 – 5	mm
Compound structure	➤ 5	mm

The process of seedbed preparation is the most destructive for soil porosity process. The pore space and size distribution due to the change of the soil volume is serious. In fact, due to repeat annual ploughing only 2% of the soil volume is occupied by pores, [17]. Also, the machinery traffic have significant impact on the soil structure. The strategy to use crop residue and reduced number of passes throughout the soil surface is also useful tool to protect the soil structure, [5].

The Aggregate strength may be determined by the raindrop technique. i.e. by evaluation of the kinetic energy required to disrupt the aggregates. Dry soil aggregate strength may be evaluated by a procedure that evaluate the crushing strength, [6].

It is of particular importance to emphasize that the assessment of soil quality indicators includes the chemical, biological and physical properties and processes that take place on this basis. To interpret the results of the assessment, all measurements should focus on the sustainability of the processes over time and the long-term use of soil resources, [18].

The distance between soil aggregates determines the size of the pores for holding and exchanging air and water. Stability of soil aggregates refers to the ability of aggregates to remain undisturbed by applying an external force that is in most cases associated with the impact of water, [16]. The stability of soil aggregates is not the same as the stability of aggregates in a dry state, which is used to determine wind erosion.

Optimal conditions indicate a wide variety of pores. It includes both large pores formed between aggregates and micropores. Macropores are extremely important for water movement and air exchange. These pores also include the areas of instability through which the roots of the plants must penetrate. If the soil volume has a low bulk

density or a large area of pores, aggregate stability is not particularly important. For example, sandy soils have low stability of their aggregates but are water and air-permeable.

Factors influencing the stability of soil aggregates

Stability of soil aggregates influences soil texture, dominant soil clay, soluble iron and catholytes, soil organic matter content, and the size and size of microbial populations. Some soils swell when adsorbing water. Expansion and contraction of clay particles can change the soil and form cracks, which in turn can change the structure of soil aggregates. The calcium ion associated with clay generally helps aggregation, while the sodium ion helps to destroy it.

Soils with a content of more than 5% iron oxide show excellent stability of soil aggregates.

Soils that have a high organic content have high stability of their aggregates. Regular introduction of organic matter (OM) favors this process as active microbiological activity is observed. Soil microorganisms produce various organic compounds that help preserve soil aggregates. The type of microorganisms is important. Mycelium mycelium consolidates soil aggregates to a greater extent than microorganisms.

Stability of soil aggregates increases when the soil is captured or planted with alfalfa.

Measurement of soil aggregates stability

There are a number of methods to measure the stability of soil aggregates. The standard method of the National Center for the Study of soil (NRCS - USA) can be used in the field or laboratory testing. This procedure involves repetitive trials with aggregates in distilled water.

- The alternative procedure does not require weighing the sample. The measurements were carried out with an oven-dried soil which is passed through a mesh with a pore diameter of 2 mm and held in a sieve with a pore diameter of 1 mm thick. The size of these 1-2 mm aggregates is placed in a small open container with a sieve at the bottom. This container is placed in distilled water. After 20 minutes, this container is removed and the amount is dried. The dried soil is removed and the soil aggregates are destroyed visually. These materials, which are at least different from the original aggregates, have the highest stability.

- Soils containing sludge, often show low stability of the soil aggregates, if considered after drying than in field studies, as water destroys the structure.

Determination of a sustainable fraction in the soil

In order to determine the sustainable fraction of the soil, soil samples can be taken in advance. As field studies, soil density has to be measured and determined.

Sequence of actions:

- The soil sample is taken from a depth of not more than 0.10 m.

- Soil is then taken from the samples taken to determine soil pH and wet sifting.

- Determine the content of organic matter in the soil sample.

Wet sieving method

Determination of the soil aggregates stability after wetting is based on the principle that unsustainable aggregates break down more easily than persistent when immersed in water.

The appliance has 8 caps mesh screens (each sieve has 60 holes). They are filled with soil 5 mm below their upper edge. So filled they are immersed for a certain time in water and subtracted. At the end of the procedure, only the insoluble mineral part (sand) and plant residues remain in the cups.

The ratio between the mass of resistant aggregates versus the total mass of the sample (the soil used for the analysis) gives the stability index.

Sequence of execution

Take a soil sample and measure 4g soil with a soil aggregate fraction of 1-2mm. These soil aggregates are placed in the chalk sieve of the apparatus. The mass of the materials in each cup is determined after weighing them on an electrical balance. Remove the mass of the cup from the weighted mass. The dispersion mass in the second cups where the spray solution is placed is 0.2g. This mass must be pulled out of the weight of the weighed material.

The resistant fraction is equal to the mass of soil obtained in the dispersion cups, divided by the sum of the masses measured in the dispersion cups and the distilled water cups.

The result obtained shows the resistance of soil aggregates expressed as a percentage.

Four concurrent analyzes are performed, with the average value being the final result.

Results and discussions

Soil tillage play an important role in the aggregate stability building and destruction as well.

A number of experiments are carried out during the period 2014-2017 in the fields of Ruse, Dobrich and Silistra districts.

The aggregate stability tests are carried out after ploughing, disking, strip till and no till techniques.

It is suitable to made dispersion analysis. One-factor DISPERSION ANALYSIS FOR SUSTAINABILITY OF SOIL AGREGATES – 2015 is presented, [7, 8, 9.

Factor A - sampling point. Six locations are selected and soil aggregates are measured. They are - A1 – Ryahovo, Ruse District; A2 – Voynovo, Silista District; A3 – Izvor, Shumen District; A4 - E. Joseph, Ruse District; A5 Cherven, Ruse District; A6 – Slaveevo, Dobrich Desitric

The results related to the unsustainability of the soil aggregates is: table 1.

Table 1. Statistical analysis of the unsustainability of the soil aggregates

Effect	Univariate Tests of Significance for $Y_{\text{hey.ct.}}$ (Spreadsheet1)				
	Sigma-restricted parameterization Effective hypothesis decomposition				
	SS	Degr. of Freedom	MS	F	p
Intercept	30715,70	1	30715,70	293,1535	0,000000
A	4759,13	5	951,83	9,0843	0,000189
Error	1885,98	18	104,78		

The type of the dispersion model is:

$$SS = SS_A + SS_E = 4759,13 + 1885,98$$

Factor A – the geography place which refers to the specific soil type has a significant impact on unsustainable aggregates, which is confirmed by the probability value $p = 0.000189$, which is significantly less than the significance level $\alpha = 0.05$.

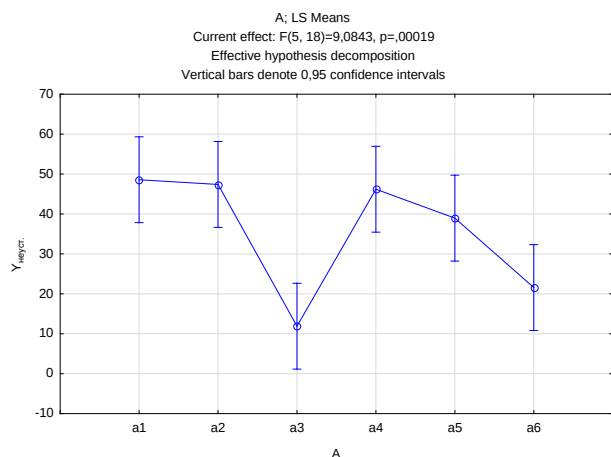


Fig.1. Graph presentation of the aggregate unstability by geography location.

Results related to the aggregate stability

Type of dispersion model: $SS = SS_A + SS_E = 4759,13 + 1885,98$

Factor A has a significant impact on unsustainable aggregates, which is confirmed by the probability value $p = 0.000189$, which is significantly less than the significance level $\alpha = 0.05$, table 3.

Table 3. Statistical analysis of the soil aggregates stability

Effect	Univariate Tests of Significance for $Y_{\text{yct.}}$ (Spreadsheet1)				
	Sigma-restricted parameterization Effective hypothesis decomposition				
	SS	Degr. of Freedom	MS	F	p
Intercept	98997,70	1	98997,70	944,8433	0,000000
A	4759,13	5	951,83	9,0843	0,000189
Error	1885,98	18	104,78		

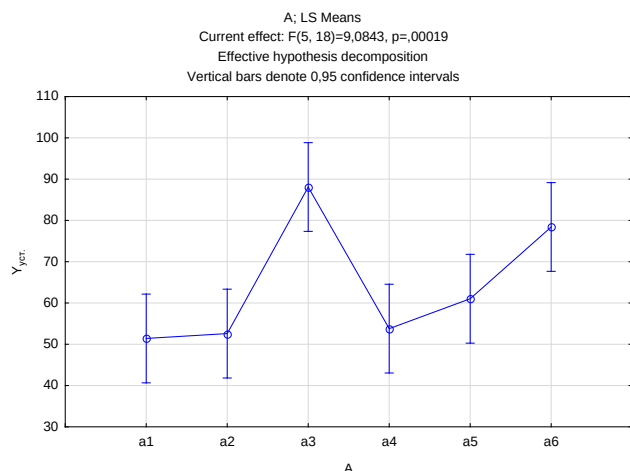


Fig.2. Graph presentation of the aggregate stability by geography location.

From the graphs, it can be seen that in the third level the factor A differs significantly from the other levels.

Multifactory dispersion analysis for sustainability of soil aggregates

Factor A - the same as for single factor analysis and the same levels

Factor B - year of sampling. B₁ - in 2014; B₂ - in 2015

Table 2. Analysis of the soil aggregates stability

Effect	Univariate Tests of Significance for $Y_{\text{yct.}}$ (Spreadsheet1)				
	Sigma-restricted parameterization Effective hypothesis decomposition				
	SS	Degr. of Freedom	MS	F	p
Intercept	150543,7	1	150543,7	1876,532	0,000000
A	5960,4	5	1192,1	14,859	0,000000
B	3245,3	1	3245,3	40,452	0,000000
A*B	2224,0	5	444,8	5,544	0,000693
Error	2888,1	36	80,2		

Type of dispersion model:

$$SS = SS_A + SS_B + SS_{AB} + SS_E = 5960,4 + 3245,3 + 2224 + 2888,1$$

Both factors, as well as their mixed interaction, have a significant impact on the percentage of sustainable aggregates. This is confirmed by their much lower probability p values than the level of significance of 0.05.

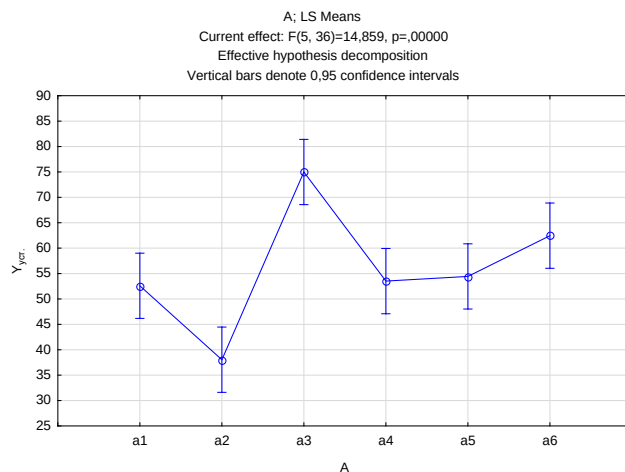


Fig.3. Graph presentation of the aggregate stability by geography location.

Examined separately for each factor, the results show that factor A at its third level is significantly different from other levels. Factor C on its second level gives higher scores for the percentage of persistent aggregates. The graph of the mixed interaction of both factors indicates that factor B with its second level results in improved performance at all levels of factor A.

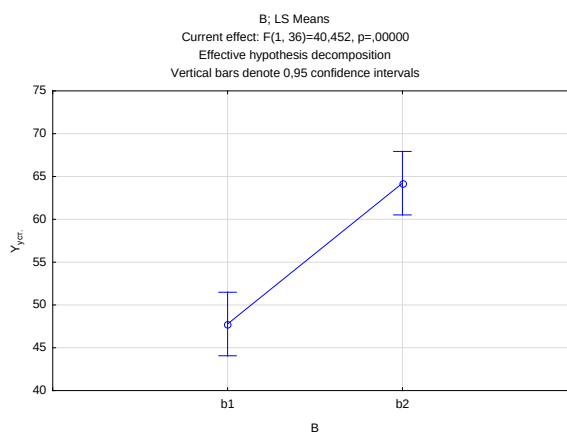


Fig.4. Influence the year when the samples are taken

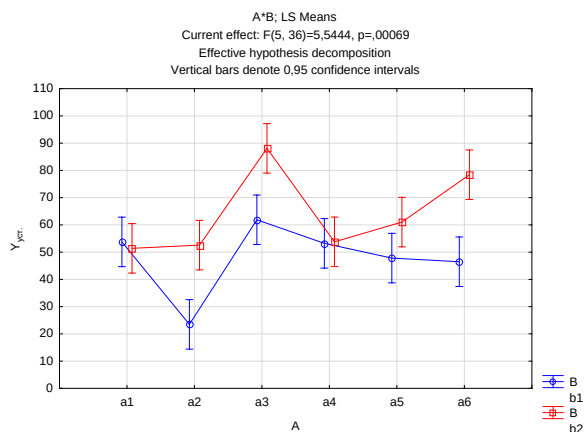


Fig.5. Joint influence the factors A and B on the soil aggregate stability

Conclusions:

Aggregate stability depends on many factors, but the most important are the organic matter content, traffic and soil type.

Due to the fact that Bulgarian soil map is presented by many soil types, the aggregate stability can be managed after analysis of the physical properties in each location.

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