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STUDY PLANE-PARALLEL MOTION MOVEMENT COMBINED SEEDING UNIT

ИССЛЕДОВАНИЕ ПЛОСКОПАРАЛЛЕЛЬНОГО ДВИЖЕНИЯ КОМБИНИРОВАННОГО ПОСЕВНОГО АГРЕГАТА

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Abstract: *Conducted analytical studies, resulted in the construction of a new mathematical model of plane-parallel motion combined simultaneous sowing unit and bandpass mineral fertilizers. If you use the original equation in the form of Lagrange II-the kind, the system was composed of six differential equations of motion, that describes the behavior of the combined unit with its plane-parallel motion. Defined analytical expressions for the forces, that act on the machine unit, can be solved on the PC.*
***KEYWORDS**: MACHINE, FERTILIZER, SOWING, POWER CIRCUIT, DIFFERENTIAL EQUATIONS OF MOTION, FORCE, SEED*

1. Introduction

Modern energy-saving Technologies, that are widely implemented currently in agriculture include the use of combined units that can not only reduce the agronomic timing of field work, but also reduce water loss by reducing the inter-operational periods of time, to reduce the impact of sealing machine units on the ground, to save fuel -smazochnye materials and so on.

2. Background and means for solving the problem

We have developed and successfully tested in the field work of combined machine. It consisting of tractor and combined seed drill, to which is connected applicator fertilizer and seeder. Operation of such dynamic systems require high quality rectilinear motion during the manufacturing process and, consequently, the stability of its movement.

The study of complex combined agricultural machine units is possible on the basis of the constructed mathematical models for this, including mathematical models of plane-parallel motion. A method for constructing such machine units are well represented in the works [1-4]. In this case, the main type of movement of agricultural machine (trailed, mounted and self-propelled) is their plane-parallel motion, because this type of motion is determined by the quality of performing the specified processes. Study of combined agricultural machine units and work aggregates are determined to many of the published scientific papers in press [5-8, 10]. Numerous studies have found, that the agronomic and operational and technical performance of the combined tractor units depends largely on the nature of their plane-parallel motion. Therefore, the study of plane-parallel motion of various agricultural machine units as needed when evaluating existing and the design of innovative combinations of such units [4].

The solution of the problem

To study the complex plane-parallel motion of combined machine units will be needed to build their mathematical models, create differential equations of plane-parallel motion that will eventually allow them to find a rational design and kinematic parameters of the sustainability of movement of machine, and, consequently, the quality of the process.

Therefore, we first develop a power scheme trailer combined sowing unit, which consists of aggregated tractor 1, to which is attached the fertilizer distributing drill 2, which produces a stripe of mineral fertilizers, behind which, with the help of the hitch 3 attached grain seeder 4 (Fig. 1).

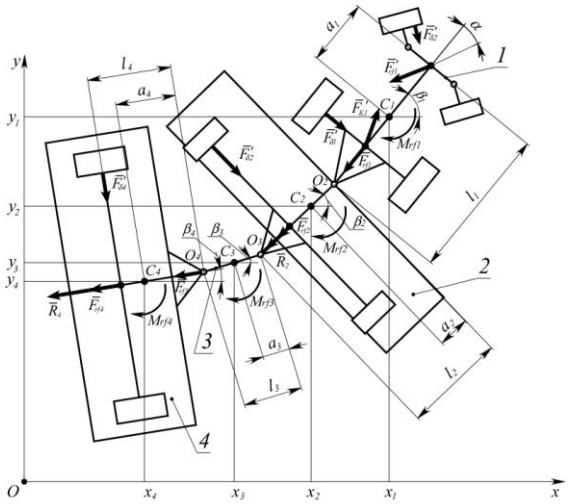


Fig. 1 – Power scheme trailer combined unit: 1 – tractor, 2 – fertilizer distributing seeder, 3 – hitch, 4 – grain seeder

$$
\left.\begin{aligned}
&m_1\ddot{x}_1+\sum_{i=2}^{4}m_i\ddot{x}_i=\sum_{i=1}^{4}F_{xi},\\
&m_1\ddot{y}_1+\sum_{i=2}^{4}m_i\ddot{y}_i=\sum_{i=1}^{4}F_{yi},\\
&I_1\ddot{\beta}_1+(l_1-a_1)\sum_{i=2}^{4}m_i\left(\ddot{x}_i\sin\beta_1-\ddot{y}_i\cos\beta_1\right)=\\
&=M_{C_1}-M_{rf1}+(l_1-a_1)\times\\
&\times\left[\sin\beta_1\sum_{i=2}^{4}F_{xi}-\cos\beta_1\sum_{i=2}^{4}F_{yi}\right],\\
&I_i\ddot{\beta}_i+m_ia_i\left(\ddot{x}_i\sin\beta_i-\ddot{y}_i\cos\beta_i\right)+\\
&+l_i\sum_{j=i+1}^{4}m_j\left(\ddot{x}_j\sin\beta_i-\ddot{y}_j\cos\beta_i\right)=\\
&=M_{O_i}-M_{rfi}+l_i\left(\sin\beta_i\sum_{j=i+1}^{4}F_{yj}-\right.\\
&\left.-\cos\beta_i\sum_{j=i+1}^{4}F_{yj}\right),\qquad\left(i=\overline{2,4}\right).
\end{aligned}\right\}\qquad(1)
$$

In this case, the first three equations in (1) describes the linear motion of the center of mass of the tractor the first three equation, along the axis Ox and Oy – x_1 and y_1 and angular motion β_1 around its center of mass. The fourth equation of system (1) written in general terms, describes the units combined unit turns around the property of their centers of mass. Thus, the index i varies from 2 to

4 and define the actual twists: Mineral spreaders – β_2, hitch – β_3 and grain drill – β_4.

For practical use of the system of differential equations (1) to determine further force factors, that it contains.

In this case, for analytical expressions for the part of the system (1) power factor using the power circuit (Fig. 1) and the main curves obtained when considering a plane-parallel movement of other tractor units [6-10].

First we define $\sum_{i=1}^{n} F_{xi}$ and $\sum_{i=1}^{n} F_{yi}$, that are part of the system of equations (1) Compiled using the power circuit (Fig. 1) can be written such vector equation:

$$\begin{aligned}
&\bar{F}_1 = \bar{F}'_{\delta 1} + \bar{F}'_{\delta 2} + \bar{F}_{rf1} + \bar{F}'_{rf1},\\
&\bar{F}_2 = \bar{F}_{\delta 2} + \bar{F}_{rf2} + \bar{R}_2,\\
&\bar{F}_3 = \bar{F}_{rf3},\\
&\bar{F}_4 = \bar{F}_{\delta 4} + \bar{F}_{rf4} + \bar{R}_4.
\end{aligned} \tag{2}$$

When designing these vector equation (2) on the axis Ox and Oy obtain the values of their projections on the first axis:

$$\begin{aligned}
&F_{1x} = F'_{\delta 1}\sin\beta_1 - F'_{rf1}\cos(\beta_1-\alpha) + F'_{\delta 2}\sin(\beta_1-\alpha) - F_{rf1}\cos\beta_1,\\
&F_{2x} = F'_{\delta 2}\sin\beta_2 - F'_{rf2}\cos\beta_2 - R_2\cos\beta_2,\\
&F_{3x} = -F_{rf3}\cos\beta_3,\\
&F_{4x} = F_{\delta 4}\sin\beta_4 - F_{rf4}\cos\beta_4 - R_4\cos\beta_4.
\end{aligned} \tag{3}$$

Further, we also obtain the projection forces behind the expression (2) on the axis Oy:

$$\begin{aligned}
&F_{1y} = -F'_{\delta 1}\cos\beta_1 - F'_{rf1}\sin(\beta_1-\alpha) - F'_{\delta 2}\cos(\beta_1-\alpha) - F_{rf1}\sin\beta_1,\\
&F_{2y} = -F_{\delta 2}\cos\beta_2 - F_{rf2}\sin\beta_2 - R_2\sin\beta_2,\\
&F_{3y} = -F_{rf3}\sin\beta_3,\\
&F_{4y} = -F_{\delta 4}\cos\beta_4 - F_{rf4}\sin\beta_4 - R_4\sin\beta_4.
\end{aligned} \tag{4}$$

That Is Why:

$$\begin{aligned}
\sum_{i=1}^{4}(F_{ix}) = F_{1x} + F_{2x} + F_{3x} + F_{4x} &= F'_{\delta 1}\sin\beta_1 - F'_{rf1}\cos(\beta_1-\alpha) +\\
&+ F'_{\delta 2}\sin(\beta_1-\alpha) - F_{rf1}\cos\beta_1 + F_{\delta 2}\sin\beta_2 - F_{rf2}\cos\beta_2 -\\
&- R_2\cos\beta_2 - F_{rf3}\cos\beta_3 + F_{\delta_4}\sin\beta_4 - F_{rf4}\cos\beta_4 - R_4\cos\beta_4,
\end{aligned} \tag{5}$$

$$\begin{aligned}
\sum_{i=1}^{4}(F_{iy}) = F_{1y} + F_{2y} + F_{3y} + F_{4y} &= -F'_{\delta 1}\cos\beta_1 - F'_{rf1}\sin(\beta_1-\alpha) -\\
&- F'_{\delta 2}\cos(\beta_1-\alpha) - F_{rf1}\sin\beta_1 - F_{\delta 2}\cos\beta_2 - F_{rf2}\sin\beta_2 -\\
&- R_2\sin\beta_2 - F_{rf3}\sin\beta_3 - F_{\delta 4}\cos\beta_4 - F_{rf4}\sin\beta_4 - R_4\sin\beta_4.
\end{aligned} \tag{6}$$

Similarly, we obtain:

$$\begin{aligned}
\sum_{i=2}^{4}(F_{ix}) &= F_{\delta 2}\sin\beta_2 - F_{rf2}\cos\beta_2 - R_2\cos\beta_2 - F_{rf3}\cos\beta_3 +\\
&+ F_{\delta 4}\sin\beta_4 - F_{rf4}\cos\beta_4 - R_4\cos\beta_4,
\end{aligned} \tag{7}$$

and

$$\begin{aligned}
\sum_{i=2}^{4}(F_{iy}) &= -F_{\delta 2}\cos\beta_2 - F_{rf2}\sin\beta_2 - R_2\sin\beta_2 - F_{rf3}\sin\beta_3 -\\
&- F_{\delta 4}\cos\beta_4 - F_{rf4}\sin\beta_4 - R_4\sin\beta_4,
\end{aligned} \tag{8}$$

as a:

$$\sum_{i=3}^{4}(F_{ix}) = -F_{rf3}\cos\beta_3 + F_{\delta 4}\sin\beta_4 - F_{rf4}\cos\beta_4 - R_4\cos\beta_4, \tag{9}$$

and

$$\sum_{i=3}^{4}(F_{iy}) = -F_{rf3}\sin\beta_3 - F_{\delta 4}\cos\beta_4 - F_{rf4}\sin\beta_4 - R_4\sin\beta_4. \tag{10}$$

Determine the values of resistance forces $\bar{F}_{rfi}$, $(i=\overline{2,4})$ when wheels roll without sliding. To this end, we describe the motion of the two wheels of the i-th level of machine-tractor unit. $\left(i=\overline{2,4}\right)$. Using the differential equations of plane-parallel motion of the wheels and the force diagram (Fig. 2), we can write the following system of differential equations:

$$\left.\begin{aligned}
m_{ki}\,\ddot{x}'_{C_i} &= \sum_{k=1}^{n} F^e_{kx'_i},\\
m_{ki}\,\ddot{z}'_{C_i} &= \sum_{k=1}^{n} F^e_{kz'_i},\\
I_{ki}\,\ddot{\varphi}_i &= \sum_{k=1}^{n} M_{C'_i}(\bar{F}^e_k),
\end{aligned}\right\} \tag{11}$$

Where m_{ki} – wheel weight i-th unit, I_{ki} – moment of inertia of the i-th wheel assembly about the axis of rotation, $\sum_{k=1}^{n}\bar{F}^e_k$ – the vector sum of all external forces that act on the wheel i-th unit.

Determine the acceleration of the center of mass of the left wheel $\bar{a}_l$. At first, we form such vector equation:

$$\begin{aligned}
&\bar{a}_l = \bar{a}_{C_i} + \bar{a}^{\varepsilon}_{lC_i} + \bar{a}^{\omega}_{lC_i},\\
&\bar{a}_{C_i} = \ddot{x}_i\bar{i} + \ddot{y}_i\bar{j},\\
&a^{\varepsilon}_{lC_i} = \varepsilon_i \cdot c_i c'_i,\\
&a^{\omega}_{lC_i} = \omega_i^2 \cdot c_i c'_i,
\end{aligned} \tag{12}$$

Where $\bar{a}_{C_i}$ – acceleration of the center of mass of the i-th level machine aggregate; ε_i – angular acceleration of the i-th wheel in the rotational motion around the center of mass of the i-th level of the unit; $\bar{a}^{\varepsilon}_{lC_i}$ – rotational acceleration of the center of mass of the left wheel of the i-th level of the unit around the center of mass of this link; ω_i – the angular velocity of rotation of the i-th wheel around the center of mass of the i-th level of the unit; $a^{\omega}_{lC_i}$ – centripetal acceleration of the center of mass of the left wheel of the i-th level of the unit around the center of mass of this link; $c_i c'_i$ – distance from the center of mass of the i-th level of the unit to the center of mass of the left wheel of this link.

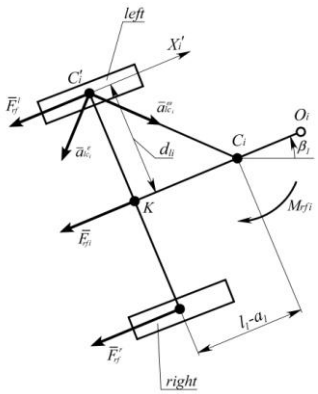


Fig. 2 *– Diagram of the forces that act on the drive wheels of the tractor when the plane-parallel motion*

Then:

$$\ddot{x}'_{li} = pr_{x'_i}\,\bar{a}_l = \ddot{x}_i\cos\beta_i + \ddot{y}_i\sin\beta_i + \dot{\beta}_i^2(l_i - a_i) - \ddot{\beta}_i\,d_{li}. \tag{13}$$

Where $\bar{a}_l$ – acceleration of the center of mass of the left wheel.

To get the right wheel is similar to:

$$\ddot{x}'_{ri} = \ddot{x}_i\cos\beta_i + \ddot{y}_i\sin\beta_i + \dot{\beta}_i^2(l_i - a_i) + \ddot{\beta}_i d_{ri}. \tag{14}$$

The condition of the wheels rolling without sliding is as follows: $\dot{x}'_{C_i} = r_{ki}\,\varphi_i$.

Location by double differentiation we find:

$$\ddot{\varphi}_i = \frac{\ddot{x}'_{C_i}}{r_{ki}}, \tag{15}$$

Where r_{ki} – wheel radius of the *i*-th level of the unit.

To the left wheel the third equation of (11) takes the following form:

$$I_{ki}\,\ddot{\varphi}_i = F^l_{rf\,i}\cdot r_{ki}. \tag{16}$$

Taking into account (15), we obtain:

$$F^l_{rf\,i} = \frac{I_{ki}\ddot{x}'_{li}}{r^2_{ki}}. \tag{17}$$

Substituting (13) into (17) yields:

$$F^l_{rf\,i} = \frac{I_{ki}\left[\ddot{x}_i\cos\beta_i + \ddot{y}_i\sin\beta_i + \dot{\beta}_i^2(l_i - a_i) - \ddot{\beta}_i d_{li}\right]}{r^2_{ki}}. \tag{18}$$

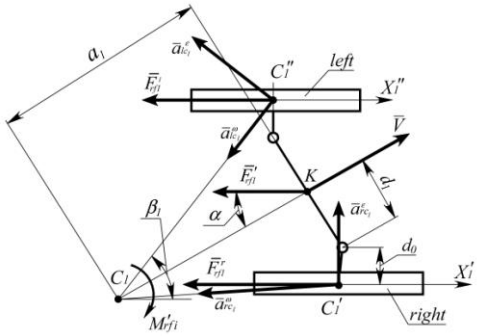


Fig. 3. *– Diagram of the forces that are applied to the steered wheels the machine set*

Similarly, we obtain:

$$F^r_{rf\,i} = \frac{I_{ki}\left[\ddot{x}_i\cos\beta_i + \ddot{y}_i\sin\beta_i + \dot{\beta}_i^2(l_i - a_i) + \ddot{\beta}_i d_{ri}\right]}{r^2_{ki}}. \tag{19}$$

Then:

$$F_{rf\,i} = F^l_{rf\,i} + F^r_{rf\,i} = \\ = \frac{I_{ki}\left\{2\left[\ddot{x}_i\cos\beta_i + \ddot{y}_i\sin\beta_i + \dot{\beta}_i^2(l_i - a_i)\right] + \ddot{\beta}_i(d_{ri} - d_{li})\right\}}{r^2_{ki}}. \tag{20}$$

We compute $M_{rf\,i}$ – moment of resistance of rotation of *i*-level unit *i*-th as the sum of the moments of resistance forces: the resistance of the left and right wheels relative to the center of mass of the *i*-th link:

$$M_{rf\,i} = M_k(\bar{F}^l_{rf\,i}) + M_k(\bar{F}^r_{rf\,i}) = -F^l_{rf\,i}\,d_{li} + F^r_{rf\,i}\,d_{ri} = \\ = \frac{I_{ki}\left\{\left[\ddot{x}_i\cos\beta_i + \ddot{y}_i\sin\beta_i + \dot{\beta}_i^2(l_i - a_i)\right](d_{ri} - d_{li}) + \ddot{\beta}_i(d^2_{li} + d^2_{ri})\right\}}{r^2_{ki}}. \tag{21}$$

Rear drive wheels of the tractor depending (20) and (21), with the proviso that $d_{ri} = d_{li} = d_1$ will look like this:

$$F_{rf1} = \frac{2I_{k1}\left[\ddot{x}_1\cos\beta_1 + \ddot{y}_1\sin\beta_1 + \dot{\beta}_1^2(l_1 - a_1)\right]}{r^2_{k1}} - \frac{2M'_e}{r_{k1}}, \tag{22}$$

$$M''_{rf1} = 2I_{k1}\ddot{\beta}_1\left(\frac{d_1}{r_{k1}}\right)^2, \tag{23}$$

Where: $M'_e = \frac{M_e\eta}{2}$; M_e – torque that develops engine tractor; η – factor which takes into account the type of tractor transmission.

Define $\bar{F}'_{rf1}$ and M'_{rf1} for the front steering wheels of the tractor (Fig. 3).

From the kinematics of plane-parallel rigid body motion acceleration define the center of mass right and left wheels according to the following expressions:

$$\bar{a}_{C''_1} = \bar{a}_{C_1} + \bar{a}^{\varepsilon}_{lC_1} + \bar{a}^{\omega}_{lC_1}, \\ \bar{a}_{C_1} = \ddot{x}_1\bar{i} + \ddot{y}_1\bar{j}, \tag{24} \\ a^{\varepsilon}_{lC_1} = \ddot{\beta}_1\cdot c_1c''_1, \\ a^{\omega}_{lC_1} = \dot{\beta}_1^2\cdot c_1c''_1.$$

Then the left wheel have:

$$\ddot{x}''_1 = pr_{x''_1}\,\bar{a}_{C''_1} = \ddot{x}_1\cos(\beta_1 - \alpha) + \ddot{y}_1\sin(\beta_1 - \alpha) - \\ -\ddot{\beta}_1\left[(d_1 + d_0\cos\alpha)\cos\alpha + (a_1 + d_0\sin\alpha)\sin\alpha\right] - \tag{25} \\ -\dot{\beta}_1^2\left[(a_1 + d_0\sin\alpha)\cos\alpha - (d_1 + d_0\cos\alpha)\sin\alpha\right].$$

Similarly, for the right wheel obtain:

$$\ddot{x}'_1 = pr_{x'_1}\,\bar{a}_{C'_1} = \ddot{x}_1\cos(\beta_1 - \alpha) + \ddot{y}_1\sin(\beta_1 - \alpha) + \\ +\ddot{\beta}_1\left[(d_1 + d_0\cos\alpha)\cos\alpha + (a_1 - d_0\sin\alpha)\sin\alpha\right] - \tag{26} \\ -\dot{\beta}_1^2\left[(a_1 - d_0\sin\alpha)\cos\alpha - (d_1 + d_0\cos\alpha)\sin\alpha\right].$$

From equation (17) to have left wheel:

$$F'^l_{rf1} = \frac{I'_{k1}}{r'^2_{k1}}\cdot\ddot{x}''_1 = \frac{I'_{k1}\left\{\ddot{x}_1\cos(\beta_1 - \alpha) + \ddot{y}_1\sin(\beta_1 - \alpha) - \right.}{1}\times \\ \times\frac{-\ddot{\beta}_1\left[(d_1 + d_0\cos\alpha)\cos\alpha + (a_1 + d_0\sin\alpha)\sin\alpha\right] -}{1}\times \tag{27} \\ \times\frac{\left.-\dot{\beta}_1^2\left[(a_1 + d_0\sin\alpha)\cos\alpha - (d_1 + d_0\cos\alpha)\sin\alpha\right]\right\}}{\left(r'_{k1}\right)^2},$$

Where r'_{k1} – the radius of the front wheels of the tractor; I'_{k1} – moment of inertia of the front wheels of the tractor relative to soybean rotation.

For the right wheel:

$$F''^r_{rf1} = \frac{I'_{k1}\left\{\ddot{x}_1\cos(\beta_1 - \alpha) + \ddot{y}_1\sin(\beta_1 - \alpha) + \right.}{1}\times \\ \times\frac{+\ddot{\beta}_1\left[(d_1 + d_0\cos\alpha)\cos\alpha + (a_1 - d_0\sin\alpha)\sin\alpha\right] -}{1}\times \tag{28} \\ \times\frac{\left.-\dot{\beta}_1^2\left[(a_1 - d_0\sin\alpha)\cos\alpha - (d_1 + d_0\cos\alpha)\sin\alpha\right]\right\}}{\left(r'_{k1}\right)^2}.$$

Taking into account (27) and (28) we obtain:

$$F'_{rf1} = F''^r_{rf1} + F'^l_{rf1} = \\ = \frac{2I'_{k1}\left\{\ddot{x}_1\cos(\beta_1 - \alpha) + \ddot{y}_1\sin(\beta_1 - \alpha) - \right.}{1}\times \\ \times\frac{\left.-\frac{1}{2}\ddot{\beta}_1 d_0 - \dot{\beta}_1^2\left[a_1\cos\alpha - (d_1 + d_0\cos\alpha)\sin\alpha\right]\right\}}{\left(r'_{k1}\right)^2}, \tag{29}$$

$$M'_{rf1} = M_k(\bar{F}'^l_{rf1}) + M_k(\bar{F}''^r_{rf1}) = \\ = \frac{2I'_{k1}(d_0 + d_1\cos\alpha)\left\{\ddot{\beta}_1\left[(d_1 + d_0\cos\alpha)\cos\alpha + a_1\sin\alpha\right] + \right.}{1}\times \tag{30} \\ \times\frac{\left.+\dot{\beta}_1^2 d_0\sin\alpha\cos\alpha\right\}}{\left(r'_{k1}\right)^2},$$

Where M'_{rf1} – drag torque of the front steering wheels of the tractor, which is the sum of resistance to rotation torques of the left and right wheels relative to the center of mass.

Taking into account (23) and (30) we obtain:

$$M_{rf1} = M'_{rf1} + M''_{rf1} =$$

$$= 2I_{k1}\ddot{\beta}_1\left(\frac{d_1}{r_{k1}}\right)^2 + \frac{2I'_{k1}(d_0 + d_1\cos\alpha)\times}{1}\times \quad (31)$$

$$\times\frac{\times\left\{\ddot{\beta}_1\left[\left(d_1 + d_0\cos\alpha\right)\cos\alpha + a_1\sin\alpha\right] + \dot{\beta}_1^2 d_0\sin\alpha\cos\alpha\right\}}{\left(r'_{k1}\right)^2},$$

Where M_{rf1} – moment of resistance of rotation of the wheels of the tractor.

If some wheels will roll unit with sliding, for them the force of resistance (friction) are the maximum and determined by the following expression:

$$F_{rfi} = N_i\, f_i\ ,\ (i = \overline{1,4})\,, \quad (32)$$

Where N_i – pressure force of the i-th wheel on the ground; f_i – the coefficient of friction between the wheel and the ground.

The strength of the wheels on the ground pressure will be equal to:

$$N_i = \frac{m_i d a_i}{l_i}, \qquad \left(i = \overline{1,4}\right) \quad (33)$$

$$N_1' = \frac{m_1 d\left(l_1 - a_1\right)}{l_1},$$

Where N_1' – the pressure force of the front wheels on the ground.

Define the lateral forces that act on the tractor axles. According to [6]:

$$F_{ef\,i} = k_{wi}\varphi_{wi}\ ,\ \left(i = \overline{1,4}\right)$$

$$F'_{ef1} = k'_{w1}\varphi'_{w1}\,, \quad (34)$$

Where k_w – cornering power coefficient of resistance, which is typically determined experimentally; φ_w – slip angle bridges.

We define the slip angle of the front axle of the tractor:

$$\varphi'_{w1} \approx \frac{\dot{x}_1\sin(\beta_1 + \alpha) - \dot{y}_1\cos(\beta_1 + \alpha) - a_1\dot{\beta}_1}{\dot{x}_1\cos(\beta_1 + \alpha) + \dot{y}_1\sin(\beta_1 + \alpha) + a_1\dot{\beta}_1\sin(\beta_1 + \alpha)}\,, \quad (35)$$

or in general for other parts of the unit:

$$\varphi_{wi} \approx \frac{\dot{x}_i\sin\beta_i - \dot{y}_i\cos\beta_i + (l_i - a_i)\cos\beta_i\cdot\dot{\beta}_i}{\dot{x}_i\cos\beta_i + \dot{y}_i\sin\beta_i + (l_i - a_i)\sin\beta_i\cdot\dot{\beta}_i},\ (i = \overline{1,4})\,. \quad (36)$$

The force $F'_{k1} = 0$, because it is included in the determination of force F_{rf1}. Numerical analysis of this task should be carried out using a PC.

3. Results and discussion

Thus, we find all analytical expressions for the force factors that are composed system of differential equations (1), which describes the motion of a plane-parallel combined sowing unit consisting of aggregated tractor and hooked up behind him fertilizer distributing drills that band-pass method makes fertilizers and suspended on her grain drill.

In this case, the obtained analytical dependence expressed in terms of generalized coordinates, and, consequently, the system of differential equations of motion (1) after substituting the expressions obtained it will be closed, which gives every reason for its numerical solution on the PC.

According to the results of the numerical solutions of these have the possibility to build a combined motion path points sowing unit depending on its design and the kinematic parameters, and thus to determine their values, which provide a large rectilinear trajectories sowing unit etc.

4. Conclusion

Compiled earlier system of differential equations of plane-parallel motion combined sowing unit is fully prepared to address, is numerical modeling that will enable analytically determine the rational design and kinematic parameters that ensure its sustainable movement, and thus the quality of the implementation process.

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LABORATORY AND FIELD EQUIPMENT WORKINGOUT AND THE RESULTS OF EXPERIMENTAL STUDIES OF PRE- HARVESTING SUGAR BEET FIELD CONDITIONS

РАЗРАБОТКА ЛАБОРАТОРНО-ПОЛЕВОЙ УСТАНОВКИ И РЕЗУЛЬТАТЫ ЭКСПЕРИМЕНТАЛЬНОГО ИССЛЕДОВАНИЯ СОСТОЯНИЯ СВЕКЛОВИЧНОГО ПОЛЯ ПЕРЕД УБОРКОЙ

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Abstract: *Described in the scientific literature the results of experimental studies and performance test of the technological process of sugar beet harvesting conducted in recent years have shown that modern sugar-beet harvesters manufactured in Europe and America work with significant losses of sugar-bearing plant materials. These losses are due to generally poor topping quality of sugar beet on a root. Therefore, nowadays the search of technical solutions enabling to avoid these losses is of great to importance as it increases the yield of sugar-bearing plant materials per hectare of crops. The purpose of research is to reduce the losses of sugar-bearing plant materials in the course of separation process of sugar beet tops from heads of root crops on a root. While conducting research the methods of field experimental research on the measurement of physical parameters of the technological process were used, as well as methods of statistical processing of the measurement results with the use of computer. New experimental equipment was designed for the field experimental studies being equipped with modern electronic equipment with data transfer to a PC. As a result of the experimental investigation of the distribution heads heights above the ground of sugar beet roots confirmation has been received hypothesis that it does not deny the law of the normal distribution. The results of the multiple measurements enabled set limits of changes in their statistical characteristics, which are as follows: average statistical deviation σ = 20 ... 30 mm, the expectation m = 40 ... 60 mm. A new design of the laboratory equipment and results of the experimental studies, conducted on it, have given every reason to design and develop a new system of automatic adjustment of the height of cut tops, which can be used in designs of modern sugar-beet harvesting machines.*
KEYWORDS*: SUGAR BEET, HARVESTING MACHINES, EXPERIMENTAL STUDIES, LOSSES, SUGAR-BEARING PLANT MATERIAL, STATISTICAL DISTRIBUTION.*

1. Introduction

The sugar beet production has undergone a substantial reduction in the world. There are many reasons for it, and this mechanism is rather complicated. The most significant among them need to be highlighted:

- hard competition in performance with other sugar crops;
- import of cheap sugar and chemical substitutes;
- the lack of exports to foreign markets;
- high cost of sugar beet under economic conditions of many countries compared with cereals;
- the absence of substantial support sugar of sugar beet producers.

Despite this decreasing, the world's production of sugar beet and, accordingly, the technical means for its mechanization remains relevant and cost-effective. That is why we compare the sugar beet production costs in Germany and Ukraine. As a result it was found that a profit of about 400-600 Euro per hectare of crops. Despite this, the problem on sugar-bearing plant material loss is quite severe and requires immediate solutions. Our task is to reduce these losses.

2. Preconditions and means for resolving the problem

2.1. Analysis of recent research and publications

An analysis of numerous designs of working bodies for removing sugar beet tops has been considered in detail in the works of scientists: L.V. Pogoreliy, V.M. Bulgakov, N.V. Tatyanko, R.B. Hevko, V.Ya. Martynenko, M.M. Khelemendyk, Ya.I. Kozibroda, S.V. Siniy, et al. But nowadays there are no designs of topper that would satisfy the agro-technical requirements of sugar-bearing plant materials losses [1-6, 12-14].

We have concluded that modern machines mainly use cutting without copier, that is why it is necessary to determine the main factors of sugar-bearing plant materials losses to determine the main ways to reduce them.

2.2. Purpose of the study

Reducing the sugar-bearing plant materials losses in the separation process of sugar beet tops from root crop heads, creates the prerequisites for automatic correction of the foliage cutting height.

2.3 Materials and Methods

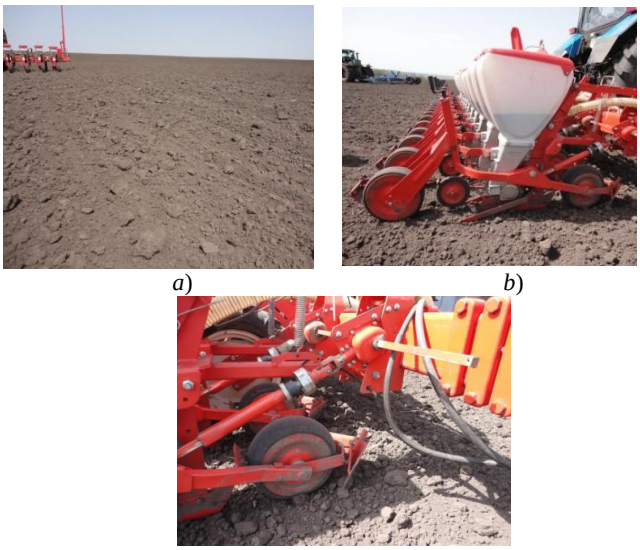
The object of this study is the process of topping on a root used cutting without copier. The study was conducted using methods of probability theory and mathematical modeling [10]. The results of the measurements have been processed by statistical methods using a personal computer. All experiments were carried out on the pre-developed plans experiments. Distribution of root crop heads was determined by means of specially designed laboratory equipment.

3. Results and discussion

To solve this problem of reducing the sugar-bearing plant materials losses we studied the availability of machinery in sugar beet producers, since the final state of height above ground distribution of root crop heads and their losses are formed during vegetation for the period from soil cultivation to the time of harvesting of root crops. It was established to ensure adequate machinery for soil preparation and sowing operations, as well as equipment for the protection and harvesting of sugar beet [7, 11].

Although, our task was to investigate the conditions of operation of equipment and quality of work in order to findout the problems. As for the sugar beet growth the primary parameters being formed by tillage operations are soil hardness and density, they were chosen as those under testing. The results of research showed that at sowing time these parameters did not meet to the agronomic requirements (fractional composition of the soil). In particular even the image (Fig. 1a), you can see a huge structural soil units being twice more than permissible requirements.

Therefore, the following colters and rollers operations (Fig. 2a and 2b) can not be performed according to agronomic requirements as for seeding depth, which results uneven heads height above ground of root crops. The above situation takes place in most companies. Thus at this production stage of sugar beet there is a problem that requires immediate solution, but it is impossible to do it quickly and effectively, as experience shows that any change in the technological or technical terms at the enterprise possesing of the acreage ten thousands hectares is possible to be realised for several years, but in most cases not possible at all. Despite the situation mentioned there is need to find ways of leveling influence of tillage on the harvesting process of sugar beet and weight loss of root crops.



a) *b*) *c*)

Fig. 1. *Typical condition of field surface before sowing sugar beet: a – poor quality of the soil processing in terms of soil aligned and lumpiness; b, c – the work of sowing drills sections under unsatisfactory conditions*

It was found that seeding quality indicators did not meet the agronomic requirements (sowing depth of the sugar beet crop ranges from 3.6 - 4.8 cm, which does not correspond to agro-technical requirements equal to 2 - 3 ± 0.5 cm).

We monitor machinery quality indicators for sugar beet harvesting. The main problems that were found in the course of study of the working environment are improper adjustment of topping and cleaning units of sugar-beet harvester. As a result, there were considerable excess of agronomic requirements as for the losses of sugar-bearing plant materials and residues of foliage as well as damage to root crops heads.

In the design of modern machines the rotor type topping units offen used that cut off the head of root crops at the same level relatively to the surface of the soil. Selecting this cutting height is made according to the well-known recommendations, but in practice it is often difficult to adhere to it, sometimes even impossible, taking into account the probabilistic nature of the distribution of the heads height above ground of root crops.

Despite the information given consumers of sugar-beet harvesting equipment always have the problem of choosing the rational cutting height values under specific production conditions (various characteristics of sugar beet heads height above ground). In most cases, this problem can be solved by empirical methods (visual assessment of the work quality after a few working trips), which have to be repeated several times. This leads to unproductive expenditure of working time, which reduces harvesting performance. Under this conditions improper cutting height selectionmay take place increase in sugar-bearing plant materials losses.

Table 1. *Holmer sugar-beet harvester performance under production conditions with extreme humidity of the soil*

Indicators number	Indicators	Value, %
1.	Correctly topped roots	16
2.	Under topped roots	34
3.	Over topped roots	24
4.	Uncut roots	22
5.	Over topped roots below the sleeping cells level	2
6.	Severely damaged roots	68
7.	Slightly damaged roots	14
8.	Angled topped roots	14
9.	Roots with green heads	18
10.	Roots with broken tips	96
11.	Sugar-bearing plant materials losses at the cut heads	5,2
12.	Sugar-bearing plant materials losses due to cut heads	3,8
13.	Total sugar-bearing plant materials losses	9
14.	Tops comtamination (according to the sugar factory data)	6…8

Therefore it is expedient to carry out the development of automatic regulator, which would provide solution to the problem of establishing the cutting height automatically in the process of sugar-beet harvester. For the development of this type of control it is necessary to determine the statistical distribution of the sugar beet heads height above ground. This problem has been considered by a number of scientistsis [6-9] and most of them prefer the normal law of distribution for it. The reliability of their results is in question because of the inability to obtain a large number of samples by manual sampling. Therefore, for assessment of parameters of the sugar beet field (plant distribution in a row, the distribution of heads height above ground, and the determination of losses when harvesting) laboratory and field equipment has been developed (Fig. 2).

Functional-block diagram of this equipment includes: input and output module, unit for measuring block control, sensor unit for the registration of sowing parameters. Algorithm of the program for control of measurement process height above ground of root crop heads is also developed. Structural scheme of laboratory and field equipment has been developed.

System of gyroscopes and accelerometers to study the fluctuations impact of sugar-beet harvester on the stability of working bodies was designed. Measuring unit design was developed as well as electronic module for control process of measurement locations parameter of sugar beet heads above the soil surface was worked out. The measuring unit contains the probes to indicate the presence of roots, probes to identify the position of the machine and height of roots head above the soil surface.



Fig. 2. *Laboratory and field equipment in course of experimental studies*

The basic causes of sugar-bearing plant materials losses (Table. 1):

- improper (unreasonable) adjustment of working bodies as well as technical and technological modes of operation of the equipment;
- untimely operations conduct in the process of sugar beet cultivation;
- baseless and unsutable selected technological scheme of machines that are used for production of sugar beet (by types of working bodies).

All the above factors affect the yield of sugar beet and yield harvesting saving. To overcome this shortcoming, we propose the development of an automated system to establish the cutting height of sugar beet without copier. To achieve this goal, we have conducted research on the aforementioned laboratory equipment and received mechanical and technological prerequisites for establishing a system to prevent sugar-bearing plant materials losses.

Study of distribution of heads height above ground of root crops relatively to the level of the soil surface as a result of a large sample (50.0 thousand measurements) were processed using the developed program in Matlab software on the computer. According to the results of research it was found that the statistical distribution of heads height above ground of root crops corresponds to the normal distribution law. Change limits of statistical characteristics are as follows: the mean deviation $\sigma = 20 ... 30$ mm, the expectation $m = 40 ... 60$ mm.

The following parameters of sugar beet harvesting qualityhave been established: sugar-bearing plant materials loss - 4%, untopped roots - 2%, roots damage - 3%.

Using the developed mathematical model [5, 8], we have been received sugar-bearing plant materials losses depending on the cutting height of sugar beet head without copier.

The experimental studies have shown that it is possible to predict the mass loss of roots and tops contamination under specific conditions, having previously obtained the statistical distribution parameters (m, σ) as well as using a mathematical model presented in [5, 8]. This enables to automatically create the system for evaluating parameters of root crops and adjust height of the sugar beet topping in order to reduce sugar-bearing plant materials losses up to the level of agronomic requirements equals to 2%.

4. Conclusion

1. A new experimental equipment that allows carrying out field studies for plants distribution of sugar beet in a row, the heads height above the soil surface and possible loss of sugar beet at harvest.

2. As a result of the pilot study of heads height distribution of sugar beet heads above the soil surface confirmed the hypothesis that it obeys the normal distribution. The limits changes in the statistical distribution of characteristics that show the average deviation $\sigma = 20 ... 30$ mm, the expectation $m = 40 ... 60$ mm.

3. Experimental studies established the following best indicators of quality of sugar beet harvesting: sugar-bearing plant materials losses – 4%, tops on the remains of roots – 2%, roots damage – 3%.

4. The results of the pilot study have created the prerequisites for the creation of electronic system that automatically correct tops cutting height on the sugar-beet harvesters of modern technical level.

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THE BATCH-COMBINED MINIMUM TILLAGE FARMING MACHINE

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Abstract:*The working members of the batch-combined machine for minimum tillage and crop tending are combined into two separate batches. By means of the first batch, there are performed simultaneously tilling and sowing operations, but the second is intended for surface tillage and crop tending. During just one field day, the machine is capable of performing 8…10 agricultural operations, and its working members can work in three modes: 1. Soil loosening without furrow slice overturning, when the main tillage unit (wedge) is in its working condition together with lateral knives (for the eroded soils); 2. Clod furrow slice pulverization and mixing, when the main tillage unit (wedge), lateral knives and rotary tiller are in their working conditions (for the non-eroded soils); 3.Cultivation of humid soils with a partial overturning of furrow slice, when the main tillage unit (wedge), lateral knives and rotary plough (instead of tiller) are in their working conditions. The cost of oil and lubricants and operating time are reduced by 2...2,5 times, and besides, the agrotechnical terms reduce considerably. The design formula for tillage output envisages both broken and unbroken soil strips. This formula can be also used for calculation of the machine output during cultivation, sowing, cutting the irrigation channels and so on. The proposed batch-combined machine can be also considered as energy-saving, resource-saving, environmental and advanced technology.*
Key words: TILLAGE; CULTIVATION; FERTILIZER; HERBICIDE; IRRIGATION; KNIFE;WEDGE; PLIOUGH; ROLLER; SUBSOIL PLOUGH

1. Introduction

As is known, multiple field days of tillage combines for performing agricultural operations lead to considerable soil consolidation and its dispersion. Thereat, soil strength increases, capillarity and moisture capacity go down and seeding time increases that in turn, causes reduction in yields. It is therefore necessary to develop and put into operation the combined tilling machines allowing performing several agricultural operation and processes simultaneously during one field day.

In the light of the foregoing, we have developed the so-called batch-combined strip tilling and crop tending machine, which is capable of performing 8…10 agricultural operations simultaneously during just one field day. These operations are as follows: ploughing (rotary tillage and loosening), expansion and deepening of tilled strip for the purpose of expansion of feeding canals and weeding; tilled soils harrowing; sowing; injection of friable mineral fertilizers into soil (both underground and surface ones); cultivation of border strip; making irrigating channels; injection of organic and mineral fertilizers into soil (both underground and surface ones); cutaway of backs from the walls of border strips and throwing them into the tilled strip); injection of herbicides or sprinkling of plants with pesticides; breaking of clods and packing; soil furrowing and cutting of track for tractors large bogie wheels.

2. Preconditions and means for resolving the problem

The working member of strip tilling of soil comprises the passive (the main ploughing device – wedge) and active (rotator plough) working members, which working separately or simultaneously, perform strip tilling of soil. In this case, there cultivated not the full area, but just a soil strip of a certain width (b=15…30 cm) and depth (a=15…25 cm), which is intended for seeding or planting (Fig.1). But in other unbroken strips, soil "rests" and it will be tilled in the following years.

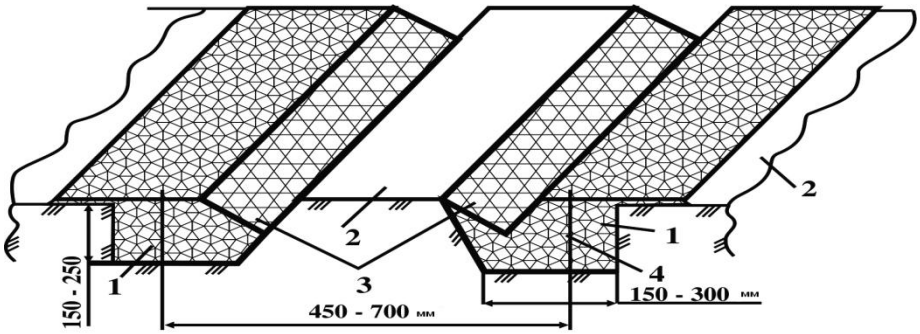


Fig. 1. *Scheme of strip tilling of soil*
1 – Broken strip; 2 – Unbroken strip; 3 – Irrigation mini channels; Seed.

It is known that the working members of soil tilling machines are shaped as a wedge, since for breaking of material by wedge by using the relatively less force, which is directed along the wedge, it possibly to obtain a large force, which breaks up material into several parts. Thus, the wedge is considered as an efficient working member, and that is why we have used the wedge as a main plough share.

Fig. 2 shows the scheme of strip tilling-sowing and crop tending batch-combined machine, the driving members of which are combined in the so-called two batches. The first batch's driving members 1 perform the tilling-sowing operations, and the driving members of the second batch – the cultivation of soil between the rows, cutting of irrigating mini channels, injection of fertilizers and herbicides, aerosol nutrition of plants and compaction of tilled strips.

The first batch's working members operate in the following manner: by means of adjustor nuts 18 and 21 of the main plough (wedge), after adjusting the soil entry angle, during the motion of the aggregate, together with lateral vertical 13 and tilled strip expanding knives 12, cut into soil and perform strip tilling of soil. In particular, by means of the main plough 11, there occurs horizontal cutting of soil layer, its vertical lifting, loosening and movement on its surface toward the cutter knives. The cutting of soil layer lifted by the main plough is completed by means of lateral vertical knives 13 vertically on the both sides (Fig.3), but the expanding knives cut – cutaway of backs from the walls of the border strips with a certain angle, and expanding of tilled strip at the side of soil surface. When the soil layer moving on the main plough, reaches the cutter's knives, there begins its breaking and throwing into empty soil, which is cut from behind. Throwing of clods is limited by metal net 25 fixed to bracket 20, on which after colliding of clod thrown by cutter's knives with net, it will be more broken thrown into the tilled strip, but the thin particle of soil, which will pass through the net, will lay on the surface of tilled soil and will provide an even top surface and thinness of particles. The filled out strip is harrowing by harrow 9 and then there occurs seeding. By means of anchoring seeder 8 and subsoil disrupter 10, which is fixed to the top of the main plough 11, the deepening of tilled strips' bottoms at the depths of 5…8 cm is completed.

Between the lateral knives 13, there is inserted the shaft 15, on which by means of splines there is mounted substitute in kind of clod (soil layer) ripper, an active working member 14, for example cutter or rotary plough. Besides, the driving shaft 15 with reduction gear unit 17 and cardan drive 16 sets in driving from power take-off shaft of tractor.

The designations of the first batch's working members and other elements are shown in Fig. 1.

The second batch's working members operate in the following manner: together with operation of the first batch's driving members, there operate the second batch's driving members as well. In particular, the soil cultivation in the border strips is carried out at a small depth (1,5…3 cm) by means of arrow-like universal hoes 26, or by herbicides 36. Two hoes are fixed to cutter 27, and one – to cross member of machine's frame 1.

The backs of border strip cutaway by means of tilled strip expander 12 (Fig.2, Fig. 3), are cut again by knife 27 with a certain width and angle, and then by means of blade 28 fixed to it, are throwing into the tilled strip that results in creation of cut irrigating mini channel 44 (Fig. 2), which can be used as an irrigator by tracks as well as for drop irrigation, for placing of drop rubbery hoses in it.

By means of needle-like gear breaking-ramming rollers 33, on the strip tilled surface there could happen breaking of clods and ramming, but with a lateral ramming roller (or sledge-like shield) 34 mounted on it, there is performed ramming of slopes of irrigating channels (or restriction of ground brought down into the irrigating track).

By means of guiding slot cutters 29, on tracks of tractor wheels in the border strips there could happen cutting of slots at a depth 25…30 cm (during the first passage – until 20 cm, during the second and third one – until 5,5 cm), which are intended for better orientation during motion and increasing service speeds during execution of following operations, during the repeated passage, as well as for better irrigation of soil near the roots by using the mini channels.

On tracks of tractor wheels, whereupon the soil the slots are cut, by means of plough working member 39 (Fig. 3), there could be cut the track with a depth of 4…6 cm and width of 20…30 cm, which is intended for quick finding and orienting of the moving direction of tractor aggregate during the repeated passage for execution of following operations (constant track).

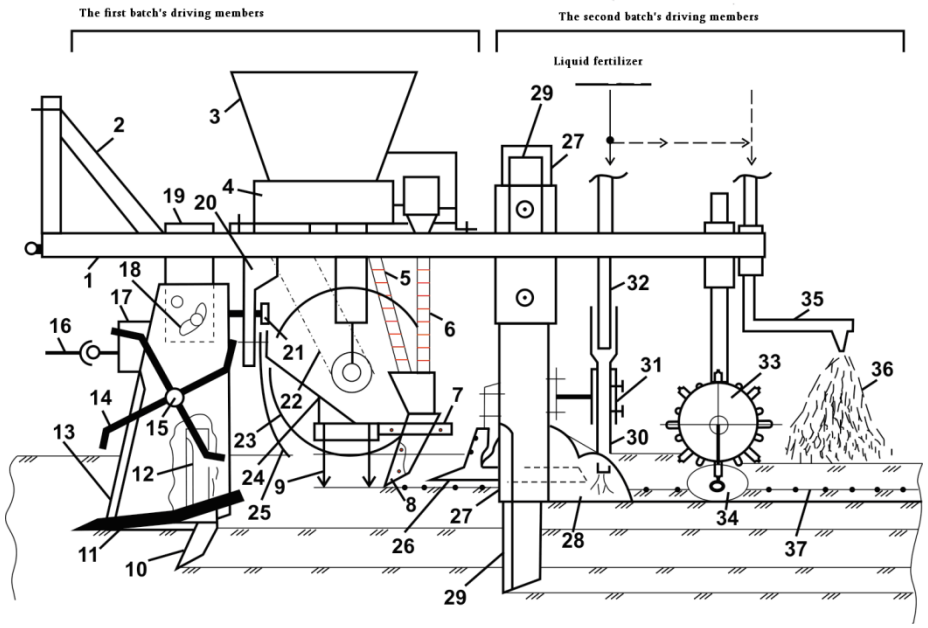


Fig. 2. *The Scheme of Batch-Combined Machine for Strip Tilling-Sowing and Crop Tending:*

The first batch's working members: 1. Frame; 2 – Suspension; 3 - Receptacle for seeds and fertilizers; 4 – Sowing device for seeds and fertilizers; 5 – Fertilizer pipeline; 6 – Seed pipeline; 7 – Seeder securing bracket; 8 – Anchoring seeder; 9 – Spike-tooth harrow; 10 - Subsoil disrupter; 11 – The main plough (wedge); 12 – Lateral expanding knives; 13 – Lateral vertical knives; 14 – Cutter knives; 15 – Cutter shaft; 16 - Cardan drive; 17 – Cutter reduction gear unit; 18 – Adjusting screw with oval slot for soil entry angle of the main plough; 19 - Securing bracket for plough member on the frame; 20 – Bracket; 21 – Foot screw; 23 – Journal and adjusting wheel; 24 – Harrow and seeder securing bracket; 25 –Clod throwing limiting net. **The second batch's working members:** 26 – Cultivator arrow-like universal hoe; 27 – Irrigating mini channel cutting knife with blade (28); 29 - Guiding slot cutter; 30 – Liquid fertilizer metal pipeline; 31 – Securing bracket; 32 - Liquid fertilizer rubbery pipeline; 33 – Needle-like-gear breaking-ramming roller; 34 – Ramming roller (or sledge-like shield); 35 – Sprayer bar; 36 – Pesticide; 37 – Seed (fertilizer).

Injection of herbicides 36 or aerosol nutrition of plants is carried out by means of sprayer 35.

By means of ploughing driving member of batch-combined machine, it is possible to carry out strip tilling at three modes as follows: 1. Loosening of eroded soil, with no overturning of clod, when the cutter 14 is turned off and is in operation, together with the main plough 11, lateral vertical knives 13, expanding knives 12 and subsoil disrupter 10; 2. Tilling of non-eroded soils, with breaking and mixing of clods, when the main plough 11, lateral vertical knives 13 and tilled strip expanding knives 12, subsoil disrupter 10, and an active driving member – cutter 14 are in operation; 3. Cultivation of humid soils by partial overturning of clod, when in operation are the main plough 11, lateral vertical knives 13 and expanding knives 12, subsoil disrupter 10 and rotary plough, which will be mounted on the shaft 15 at the place of cutter 14.

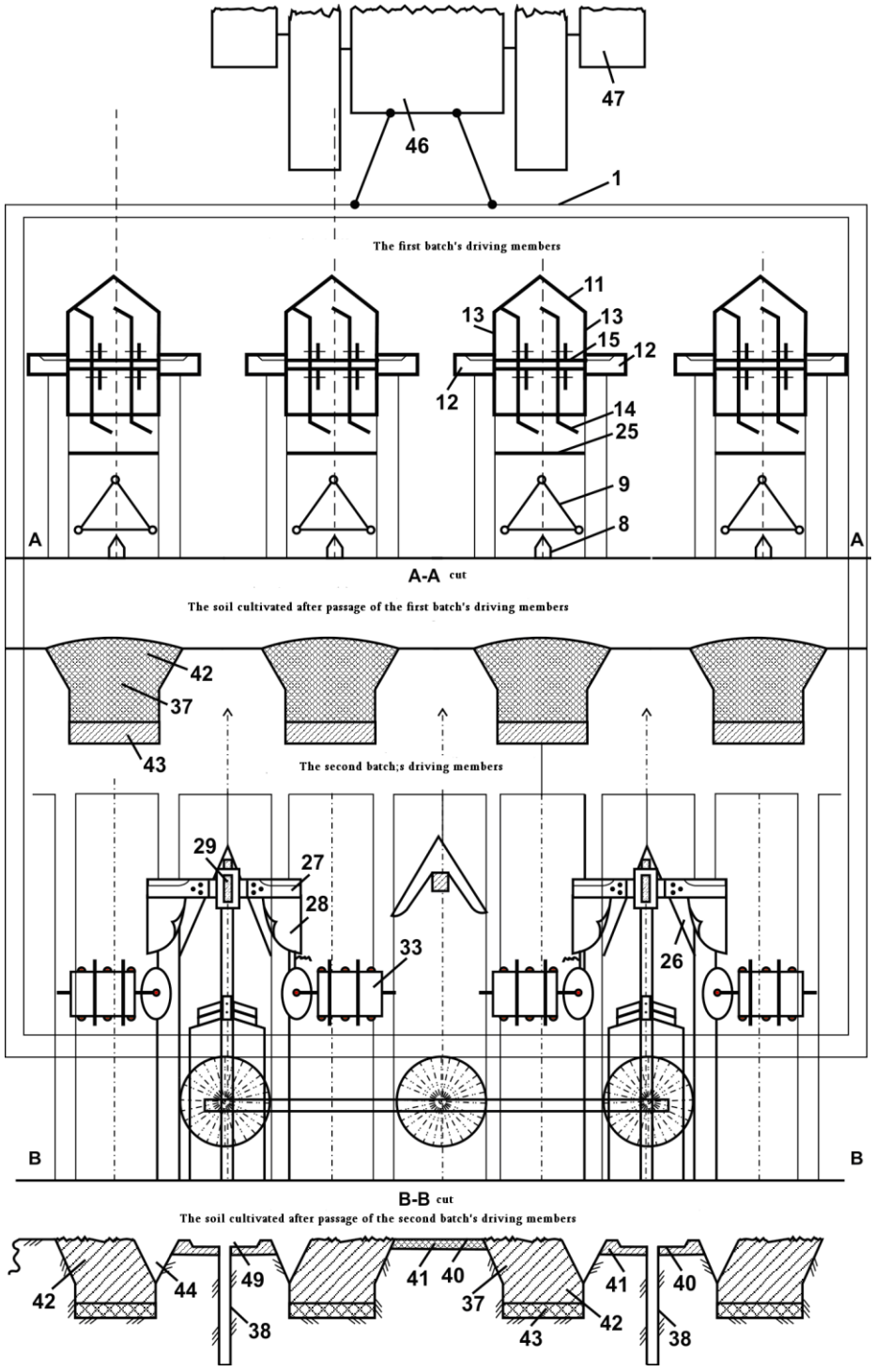


Fig. 3. *Mounting Arrangement of Driving Members of Batch-Combined Machine:*

1 – Frame; 8 – Anchoring seeder; 9 - Spike-tooth harrow; 11 – The main plough (wedge); 12 – Tilled soil lateral expanding knives; 13 - Lateral vertical knives; 14 – Cutter knives (cutter); 15 Cutter shaft; 25 - Clod throwing limiting net; 26 - Cultivator arrow-like universal hoes; 27 - Irrigating mini channel cutting knife; 28 – Channel cutting knife blade; 29 - Guiding slot cutting knife; 33 - Needle-like-gear breaking-ramming roller; 34 - Ramming roller (or sledge-like shield); 35 - Sprayer bar; 36 – Sprayed pesticide; 37 – Seed; 38 – Guiding slot; 39 – Track cutting device; 40 – Herbicide ribbon; 41 – Soil cultivated by cultivator hoes; 42 – Tilled strip; 43 – Soil broken by subsoil disrupter; 44 – Irrigating mini channel; 45 – Soil cut by track cutting device (39); 46 – Tractor; 47 – Spraying aggregate.

Based on the above stated considerations, it is possible to make the following conclusions:

In case using the wedge as a main ploughing unit, for soil loosening there is required a force, which is by several times less than when using other tilling working members, for example, when using ordinary ploughs. Hence, the cost of oil and lubricants and operating time are reduced by 2...2,5 times. That is why it is considered as energy-saving and resource-saving working member (machine).

When using the combined tilling working members we developed, the hourly efficiency at strip tilling of soil can be calculated the formula, which we also developed recently (according to Fig. 1)

$$W_ч=0,36V_p[B_0(n-1)+ B_p \cdot n),$$

where, V_p – is an operating velocity of machine, m/sec; B_0 – is unbroken row's width, m; B_p – one plough-share coverage width, m; n – number of ploughs. As is seen from the formula, the efficiency of the batch-combined tilling machines is considerably higher than during tilling with ordinary ploughs and consequently, lower is the cost of oil and lubricants and environmental pollution that makes them more profitable to farmers and country. So it should be considered not only energy- and resource-saving technology, but the nature-oriented technology (machine) as well.

3. Conclusion

Since the soil between the broken rows "rests" and it will be cultivated in the following years, the thickness of the fruitful in the surface layer of mellow humus layer will be preserved, and the development of the erosive processes will slow down that will result in an increase in productivity. That is why the proposed technology even in a greater degree is a nature-oriented technology.

Due to fact that the share of the eroded soil in the entire area of all arable lands is high, cultivation of soils of various complexity by means of the combined working members at the appropriate modes (there are given above three types of modes with regulation of the tilt angle of a main ploughing unit – wedge), it will be possible to avoid developing the wind and watery-erosion processes. In addition, the resistance of soil during its cultivation by agricultural machine will be reduced, that will result in reducing capacity power of tractor engine, as well as the cost of oil and lubricants required for strip tilling of soil. The released power of engine can be used for increasing the plough-share coverage and operating velocities of machine.

Thus, as a whole, such a soil tilling technology should be considered as energy-saving, resource-saving, nature-oriented rational and advanced technology.

4. Literature

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OPTIMIZATION OF TRIBOLOGICAL PARAMETERS IN THE DESIGN OF ROTARY TILLER BLADES

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Abstract *The argument of this paper is rotary the tiller blade, which undergoes severe surface wear during tillage of agricultural land. The study was conducted by comparing on H-shaped blades, of two different manufacturers, used in rotary tillers, mainly in the fields of Myzeqe, Lushnje. Our tests included the measurement of the abrasive wearing as weight loss of material of each blade to the end of lifecycle - recorded after every 10 hectares cultivated surface in field conditions. We experimented in laboratory the blade wearing through 'pin on disk' test. Another tribological parameter measured in the laboratory was the hardness in Vickers on cutting edge of the blade, before and after wearing. To make the targeted optimization, we initially computed a stressed situation on the blade cutting edge, and then processed through the SOLIDWORKS software, which generates a map of more stressed areas that lead to significant wear. By simulating with geometric parameters of tiller blades, we have sought the situation of stresses with less impact on wearing of tiller blades. This paper is also includes relevant recommendations.*
KEY WORDS*: TILLER BLADE, TRIBO-PAIR, SURFACE WEAR, WEIGHT LOSS, PIN ON DISC.*

1. Introduction and study purpose

In this paper, we focus on efficiency of agricultural machinery used for breaking the soil and preparing the seedbed for the planting of agricultural crops. The main phenomenon that significantly affects the decline of this effectiveness is the wearing of the working parts of these machines. Our study has taken in account the tribological phenomena that occur between the rotary tiller blades and agricultural land [1]. The tiller blades undergo severe surface wear, which means increased costs for agricultural land preparation and therefore food costs [2].

The study conducted by comparing on H-shaped blades, made from two low alloy steel brands of two different manufacturers, used in rotary tillers, MASCHIO H205, mainly in the fields of Myzeqe, Lushnje [3]. We started from a detailed study of the wear as a tribological phenomenon, with the aim of reducing the power requirement by improving the geometry of tiller blade. Thus, the proper design of the rotary tiller blades is essential for efficient operations; by optimizing their geometry, the power required will reduce [4]. At the end of this article are also made recommendations for the selection of appropriate materials for tiller blades.

For coming up here, first analyzed the phenomenon that occurs and then we defined tribological parameters, such as the hardness of the blades, loads on cutting edge of blades, speed and distance prescribed by each tiller blade (distance per working hours) throughout its life cycle, the type and content of the agricultural soil and geometrical parameters of the blade.

2. Tillage and tribological phenomenon on Rotary Tiller blades

Tillage is a process performed to obtain a desirable soil structure for a seedbed. This is a granular structure that allows rapid infiltration and good retention of rainfall, will provide adequate air capacity and exchange within the soil and minimizing resistance to root penetration. Rotary tiller is a tillage machine designed for preparing the land by breaking the soil with the help of rotating blades [2].



Fig. 1. *MASCIO H205 rotavator with 10 flanges and 60 blades; 1 - rotor, 2 – right blade, 3 – left blade, 4 – flange (on the left); The tiller blade 1 and 2 in study, from two different manufacturers made from two different steels brands, 'C' shaped & 'H' type [3].*

Our rotary tiller, MASCHIO H205 [3], is a specialized mechanical tool used to plough the land by series of blades ('C' shape, 'H' type) which are used to swirl up the earth (fig. 1). This rotavator is available in the size 2.00 m working width, which is suitable for

tractors having their power 30 to 60 hp. The work quality by using rotavator not only depends on the machine performance but also on soil conditions, blade geometry and velocity ratio. It often happens to interfere on the backside of the blade and the uncut soil, which may result in severe soil compaction and high power consumption. This is the main reason to cause vibrations, which are a result of the soil upon the tiller blades. The proper design of the rotary tiller blades is essential for efficient operations [5].

Both blades and tillage constitute a tribologic pair. These blades interacting with soil subjected to impact of soil crust / clods / stone and high friction, which develop high stress areas on blade tip or blade critical edges. Tribological phenomenon that is present throughout tillage and the life span of tiller blade is predicted by wear. Blades are under pulsating loads and subjected to high abrasive wear and fatigue. As this wear, the total cost of agricultural production inflates [6].

Our rotary tiller has 10 flanges with six blades for each flange. Each blade cuts a segment of soil as it removes downward and towards the rear. Because of the high peak torques developed during each cut, it is important to stranger the blades in the different courses, with equal angular displacement between them, so no two blades strike the soil at the same time (Fig.2).

We think that an appropriate geometric shape of the tiller blade will provide easy soil cutting by reducing the maximal loads (their high stress), consequently reducing blade wear. Let us have a look at the experiments and measurements that we have done for determining the blade wear on the field and laboratory, as well as some of the other tribological parameters associated with this phenomenon.

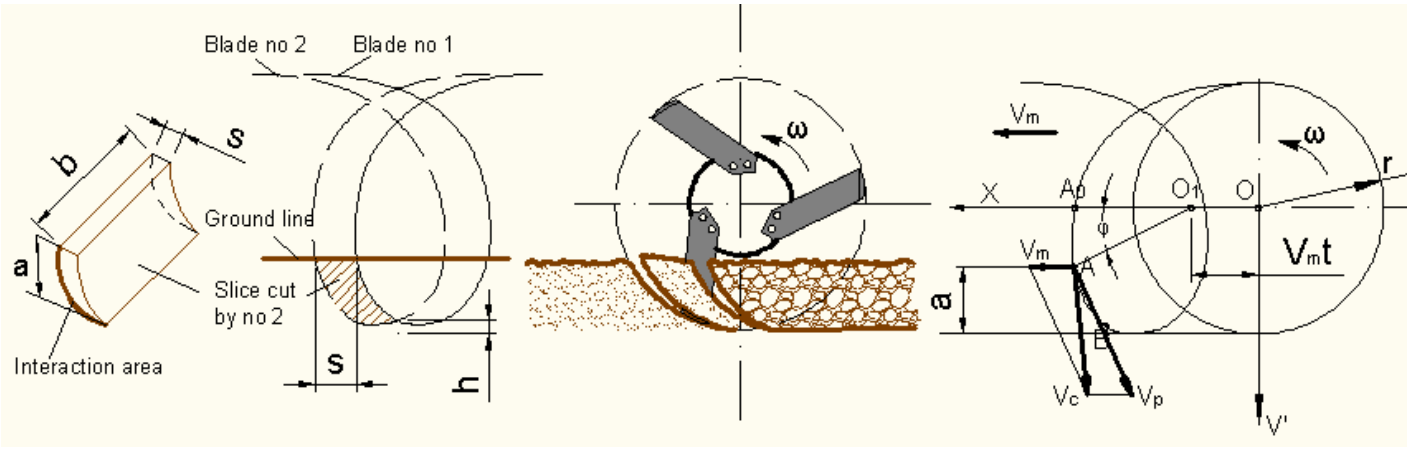


Fig. 2. *Parameters of the rotary tiller blade movement and forming of the slice cut [11]*

3. *Testing on ground and Laboratory*

3.1. Field test procedure

Based on the available data and feedback from users, it has been found that the blade is worn out after certain hours (100 – 300 hours) field usages depending on the soil conditions. Two are the factors that we have considered: the tillage or digging strikes of blade in soil and the linear distance described by tiller blade throughout their live span. Digging and strikes of tiller blades on soil will cause excessive loads and high stresses that are related with fatigue wear. The second factor related with high friction due to stones, gravel and sand in soil during the tillage and consequently the abrasive wear is also present. The blades undergoing severe surface wear of the tip and cutting edges.

Number of strikes by cutting edge of tiller blade is 8000 strikes / ha [1]. Our field test was measured after tillage of 45 ha; so, there are 360000 strikes of a tiller blade.

The linear distance described from a point of cutting edge of tiller blade when interacts with soil (fig. 2, bold contour), for a slice cut is 20 cm, for 15 cm tillage depth (diameter of rotor is 20 cm and diameter of tip of blade is 50 cm), will be 1600 m/ha and 72000 m per 45 ha.

Let us calculate the wear rate, *w*, for each of tiller blades, 1 and 2 [7], when their loss weight is respectively 95 gr and 158 gr:

$$w = \frac{\text{Volume of material removed from contact surface } (m^3)}{\text{Distance slid (m)}} = \frac{V}{L}\,(m^2) \quad (1)$$

$V_{Blade\ 1} = m/\rho = 1.2x10^{-5}m^3$ and $V_{Blade\ 2} = 2x10^{-5}m^3$, where specific weight, $\rho = 7900\ kg/m^3$.



Fig. 3. *Wear tiller blades 1 and 2, after tillage of 45 hectares (on the left) and blade 2 (on the right) as new product that weight 720gr, under it the same blade with full wear at the end of its lifecycle.*

Our tests included the measurement of the wearing as weight loss of material of each blades recorded after every 10 hectares cultivate surface in field conditions after tillage of 45 hectares.

Table 1. Wearing of blades that is defined with loss weight

Hectares / Blades product	10	10	10	10	5
Blade 1 (gr)	21	22.3	20.2	19.5	12
Blade 2 (gr)	40,6	36,5	35,7	33,1	12.1

It is observed a severe wear at the beginning of the life cycle of new blades. The wearing of blade 1 is far less than 2 ones.

3.2. Wear Testing with Pin-on-disk apparatus (G-99)

This test method describes a laboratory procedure for determining the wear of materials during sliding using a pin-on-disk apparatus [8]. Materials were tested in pairs imitating real conditions of tiller blade work mainly in clay soil or heavy loam. Pin is a prismatic specimen with a flat surface on the tip such that it will support the load over its entire cross-section, is positioned perpendicular to the other, usually a flat circular disk. The specimen of pin is taken from tiller blade and disc is an abrasive stone with corundum particles. The pin specimen is pressed against the disk at a specified load usually realized by means of an arm or lever and attached weights [9].

The pin was held against the counter face of a rotating disc with wear track diameter of 60 mm. The pin was loaded against the disc through a dead weight loading system. The wear test for all specimens was conducted under the normal loads of 20N, 40N and a sliding velocity of 2 and 4 m/s.

Wear tests were carried out for a total sliding distance of approximately 3000 m under similar conditions as discussed above. The pin specimens were 43 mm in length and 72 mm^2 and 78 mm^2 in the across section, respectively made from blades 1 and 2 materials.

The wear rate was calculated from the weight loss technique and expressed in terms of wear volume loss per unit sliding distance. The specific wear rates of the materials were obtained by [10]:

$$W = \frac{\Delta w}{L\rho F} \qquad (2)$$

Where W denotes specific wear rates in mm^3/N, Δw is the weight loss measured in grams, L is the sliding distance in meters, ρ, density of the worn material in g/mm^3 and F is the applied load in N.

Table 2. Weight loss of the steel specimens in grams

Weight loss of steel sample of pin							
		Sliding speed, 2 m/s			Sliding speed, 4m/s		
No	Specimen name	Initial weight (gr)	Final weight (gr)	Weight loss (gr)	Initial weight (gr)	Final weight (gr)	Weight loss (gr)
1	Blade 1	35.046	34.242	0.804	34.242	32.425	1.817
2	Blade 2	36.173	34.041	2.132	34.041	30.004	4.037

Results of laboratory tests attest measurements of wear of tiller blades during tillage in field.

3.3. Chemical composition and microstructure observation

It is clear that the severe surface wear is present on rotary tiller blades. We have already defined the types of wear and its wear mechanisms. The occurrence of different types of wear mechanisms may depend upon the chemistry, microstructure and hardness of material. To access which wear mechanism dominates between our two steel grades, let us do the analysis of chemical composition, microscopy and hardness test.

The chemical composition of rotary tiller blades made from low alloy steel given in Table 3, offers a good combination of mechanical properties, which are required to exhibit excellent resistance to fatigue loading and severe wear from high friction, as necessitated by tiller blades during field operation [6].

Table 3. Chemical composition (wt. %) of our tiller blades

	C%	Si%	Mn%	P%	S%	Cr%	Ni%	Mo%
1: **72MnCrB5-2**	0.221	0.252	1.4	0.023	0.0076	0.385	0.173	0.068
2: **33MnCrB5-2**	0.302	0.222	1.39	0.024	0.012	0.424	0.202	0.078
	Al%	Cu%	Co%	Ti%	B%	V%	W%	Pb%
1: **72MnCrB5-2**	0.016	0.265	0.015	0.042	0.0017	0.0075	<0.007	.0012
2: **33MnCrB5-2**	0.017	0.227	0.01	46	0.0018	0.0063	<0.007	<.001

Now we know that the properties of engineering components depend on the structure of material. Microstructures views show clear crystallographic compounds.

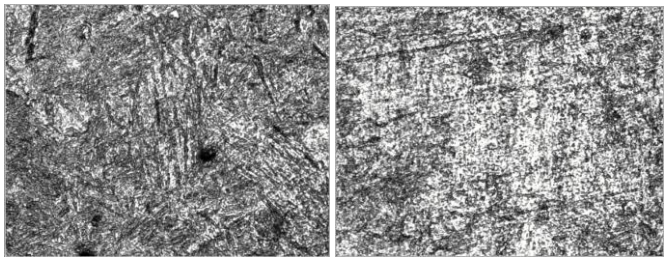


Fig. 4. *Microstructural views of new tiller blades 1 (on the left) and 2 (on the right); Samples are taken in cutting edges areas of each blade and corroded with 4% nital, 500 x. Tiller blade 1 has needle and bejnitic structure while the blade 2 has fine granulated structure with chrome carburets.*

These materials have high resistance against abrasion and are used for tools that work in high friction. Such is our case study of tiller blades.

3.4. Hardness Testing

Hardness is the most important tribological parameter. In a tribosystem is the soft material that undergoes a severe wear. In our tribo-pair, tiller blade made from low alloy steel and soil, can be thought that blades are many time stronger than soft soil. Nevertheless, it is not so, because there are too many stones, gravel and sand into the soil, which are harder than the steel of blades. Therefore, the blades that undergo a severe wear that often end with breaking, fracture or failure. Here there are shown the results of Vickers Micro-Hardness test, for new (unwearing) and wearing tiller blades. The test load is 10 N or 1 kg.

Table 4. Results in Vickers (HV) measured before and after wearing

Distance from cutting edge	0.5 mm	1.5-2 mm	7-8 mm	15 mm
Blade 1: Before	368.5	493.6	565	547
After	540	534	533	539
Blade 2: Before	533.6	593.3	564.6	530.6
After	567	600	577	575

These results show a reinforcement of surface in cutting edge blade due to its plastic deformation in the cold, during tillage operation when the blade shocked with the solid material in the soil. Reinforcement is quite obvious on the blade 1, while highest values of hardness encountered on blade 2 (600HV).

4. Design of rotary tiller blades

The design of rotary tiller blades depends on type and number of blades and the working conditions of rotary tiller. In this design, the 'H' type blades are considered for the rotary tiller according to the working conditions presented. The total power of machine, N_C, is distributed between the blades: N_C=40hp. Our rotary tiller was designed with the working width of 200 cm and having *i=10* flanges on the rotor shaft with six blades on each flange. The agricultural land in Myzeqe, Lushnje is between clay soil and heavy loam, non-rocky soil.

4.1. Calculation of forces on the blade

Two major forces are known to act on rotating blade used for tilling or digging operations. Tangential force, P_O, acts at the tip of the blade as shown in Fig. 5, through tangent of blade cutting edge [11]. Soil force, R_T, acts perpendicular to cutting edge of the blade. Soil force for analysis is considered as uniformly distributed load acting along the cutting edge.

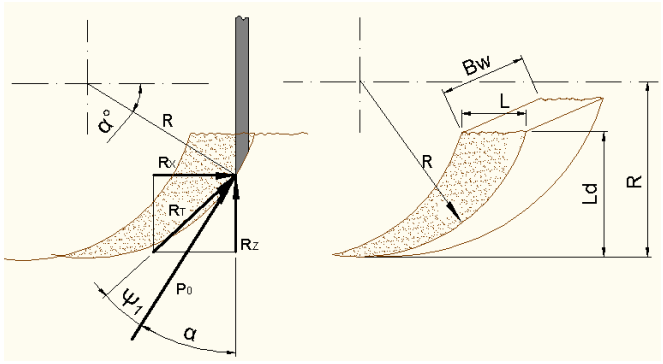


Fig. 5. *Major forces acting on a rotavator blade and dimensions of sliced soil [11]*

The maximum tangential force that occurs at the minimum of blades tangential speed is calculated by following relation (Bernacki et al,):

$$P_o = C_s \frac{75 N_c \eta_c \eta_z}{U_{min}} \qquad (3)$$

Where C_s, is the reliability factor; C_s=1.5, for non-rocky soils; N_C=40hp; η_c, is traction efficiency; η_c=0.9, because the directions of tractor forward speed and the rotational speed of rotor shaft are the same. η_z is coefficient of reservation of power taken 0.7-0.8, η_z=0.75; u_{min} is minimum peripheral velocity: $u_{min}=v\lambda$, λ=u/v; *u*, tangential speed of blades (m/s). *v*, forward speed (m/s). Forward speed is dependent to the tangential speed of blades (that is function of rotational speed of rotor, *n*) and the length of sliced soil, *L*.

In our calculations [1, 11, 12], *v=0.6 m/s, λ=2.13, L=36.85 cm, R=25 cm,* conventional rotor radius, *Z=3,* number of blades on each side of the rotor flanges; λ_{min}=1.42 *and* u_{min}=0.85m/s.

$$P_o = C_s \frac{75 N_c \eta_c \eta_z}{U_{min}} = 1.5 \frac{75x40x0.9x0.75}{0.85} = \mathbf{2382}kg$$

The soil force acting on the sharpened edge of each blade, R_T, is calculated:

$$R_T = \frac{P_O x C_p}{i Z_e n_e} = \frac{2382x1.5}{10x6x6/60} = \mathbf{595.5}\ kg \qquad (4)$$

Number, n_e is obtained through division of the number of blades which action jointly on the soil into the total number of blades; C_p=1.5, coefficient of tangential force;

The main forces on blade are the maximum tangential force, P_o = 2382kg = 23360N and the soil force, R_T = 595.5kg = 5840N.

4.2. Optimal design of blades by simulating with SolidWorks

Proper design of tiller blades is necessary in order to increase their working lifetime and reduce the farming costs. High rate of wear is the phenomenon, which will reduce the service life. Seeing under this prism, the blade geometry shape is directly related to the phenomenon but also to the quality of tillage. Often the farmers complain for bad quality of land preparation. That is true. Therefore, we think that an appropriate geometric shape of the tiller blade will provide easy soil cutting by reducing the maximal loads (their high stress), consequently reducing blade wear. Initially we simulated the maximum tangential force, P_o and soil force, R_T on the blade (fig.7). This figure shows comparison of results with FEM: stresses and deformations/displacements caused from complex loading [13].

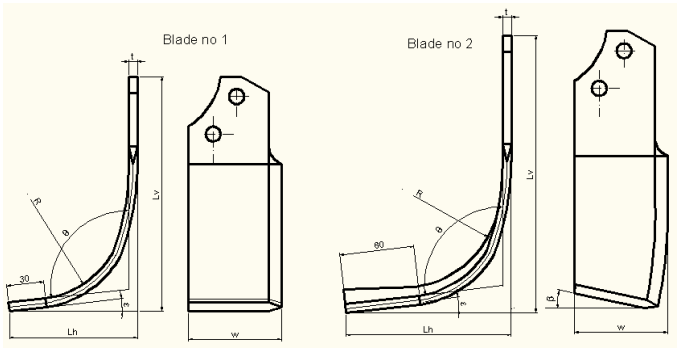


Fig. 6. *Blade schematic with designed parameters (values in Tab.5)*

Table 5. Parameters of different blades designed for the study

Parameters	Notations	Values	
		Blade 1	Blade 2
w	Blade span, mm	75	75
L_v	Effective vertical length, mm	188	222
L_h	Blade cutting width, mm	103	133
R	Curvature between L_v - L_h, mm	85	80
θ	Blade angle, degree	96°	97°
β	Clearance angle, degree	3°	12°
t	Blade thickness, mm	7	7
ε	Bending angle, degree	6°	7°

To do an optimizing of the blade design have to consider that blade parameters are functions of operating parameters, soil parameters and tool parameters. Two are geometric parameters, thickness *t* and curvature *R* that optimized tiller blades on plane 6, where software found the situation of stresses with less impact on wearing of tiller blades.

Table 5. Tribological parameters after optimizing of *t* and *R*.

Tribological parameters	Blades	Original	Optimal	Plane 6
Blade thickness (mm)	1	7	5.6	8.5
	2	7	6.2	8
Curvature R, (mm)	1	85	75	85
	2	80	70	90
Von Misses stresses (N/m^2)	1	11.13e+009	12.33e+009	10.81+e009
	2	6.887+e009	7.204e+009	6.573+e009
Displacements (mm)	1	27.67	32.45	18.08
	2	21.7171	24.55	19.5

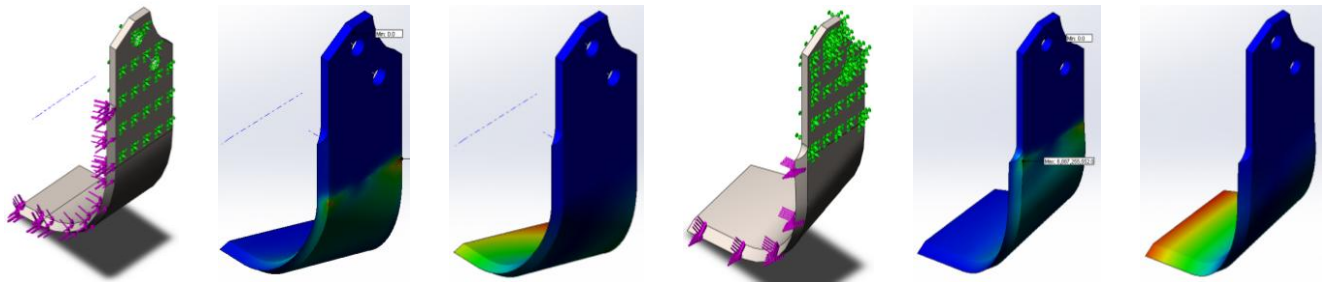


Fig. 7. *Comparison of result between blade 1 (on the right) and 2 (on the right): loading, stresses and displacements*

5. Results and Recommendations

- The results of testing on ground and laboratory show that tillage is a process that is realized with the help of rotary blades, which undergo a very large wear of its cutting edge. There are two forms of wear in tiller blades, abrasive and fatigue; dominate abrasive wear. This wear reaches approximately 1/4 of the initial weight up to the end of life. The results of wearing was determined by means of method of material weight loss.
- Chemical analysis determined the grades of steel: 72MnCrB5-2 and 33MnCrB5-2. While the microstructure observation shows respectively its needle and bejnitic structure for blade 1 and fine granulated structure with chrome carbures for blade 2. These materials have high resistance against abrasion and are used for tools that work in high friction. Presence of boron, B gives a significant increase in tempering/hardening of low alloy steels, providing a better behavior against wear. Relatively low carbon content (less than 0.35%) of these steels after quenching causes them not to reach too high hardness (less brittleness), but provides a combination of moderately high reinforcement with good tenacity and high resistance to abrasive wear.
- Results of hardness testing show that this property increases after a working period. It is a reinforcement of surface in cutting edge blade due to its plastic deformation in the cold, during tillage operation when the blade is shocked with the solid material in the soil. The reinforcement is obvious on the blade 1 and 2, while highest values of hardness are encountered on blade 2 (600HV). Experience confirms that blades with very strong surface are brittleness and come out of use very quickly or accidentally, as is the case of the blade 2.
- Our recommendation in this case related to the preparation of tiller blades is that they should be strong on the surface but plastic inside so they will face better the shocking with solid materials into the soil without failure.
- Our calculation of forces in blades show a complex stresses situations caused from tangential force acting at the tip of the blade (P_o=*2382kg*) and soil force acting perpendicular to the cutting edge of blade (R_T=*595.5kg*). Results generated from SolidWorks show a less stresses situation and deformations on blade 2 than on blade 1.

Conclusions

CAD method is an effective tool for the development of blade as this the main critical parts of a rotavator. It always exist the tribologic phenomenon, which often happens in these parts that encourages us to look for ways to reduce its impact on the tiller blade. CAD combined with finite elements method in SolidWorks are useful tools for analyzing stresses and deformations in design of complex geometries. Less wear of blades means less power of tractor and higher effectivity of preparation this agricultural land. The power required can be lowered by optimizing the blade and minimizing stresses. Above analysis reveals, that blade 1 undergoes high surface stresses, which reinforce their surface and make it more resistant against wear. Field study & hardness test confirmed these results.

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OPTIMIZATION OF THE FREQUENCY OF THE TECHNICAL SERVICE OF MACHINES WITH RELIANCE OF RELIABILITY

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Abstract: *A key element in the machinery management policy is its rational use by optimizing the periodicity of maintenance and repairs. The influence of the numerical characteristics and parameters of the reliability indicators distribution on the optimal periodicity of the maintenance has been investigated. Analytical dependencies for determining the complex reliability indicators of the objects at the optimal periodicity of the prophylactics are proposed.*
Key words: *STANDARDS, ASSET MANAGEMENT, MAINTENANCE, FAILURE, SERVICEABILITY, COST.*

The structure and nature of the machine maintenance and repair process is determined by the adopted usage strategy, which in its broadest form is a set of principles and rules that provide a defined management of the process of maintaining and restoring machine performance by maintaining an optimal operation of the machinery and prescribing the maintenance and repair work in accordance with its technical condition.

Therefore, the aim of this work is to study and optimize the periodicity of machine maintenance, taking into account their reliability characteristics.

The object of the study is the self-propelled agricultural equipment, and the subject of research is a mathematical model for optimizing the periodicity of its maintenance.

For companies and business organizations, whose the machine-tractor park failures lead mainly to a decline in their economic indicators, the optimization of the prophylactic actions should be done on the basis of the criterion " specific aggregate costs minimum" (C) [1]:

(1) $C= C(\tau) = C(\tau)/t = \{C_o(\tau) + C_p(\tau)\}/t,$

where $C_0(\tau)$ is the function of the cost of restoring the facility's operational capacity due to a failure;

$C_p(\tau)$ - the function of costs for conducting planned preventive actions.

The cost of restoring the work capacity of the site due to a failure $(C_o(\tau))$ and the costs for conducting planned preventive actions $(C_p(\tau))$ can be determined by the following relations:

(2) $C_o(\tau) = C_0 H_0(t); C_p(\tau) = C_p H_p(t),$

where C_0, C_p are the cost averages, respectively, for the removal of one failure and for a planned repair action to be carried out;

$H_0(t)$; $H_p(t)$ - the flow characteristics of the failures and the planned repairs.

If z is the work between the moments of restoration of the facility's working capacity, than $\{z_k\}$ forms a recurrent flow of restoration of the functionality of the objects [2, 3] with an average number of failures for a particular work $m=M\{m_b\}$, where m_b is the number of restorers of the facility's performance in the range (0,t).

In [4] using the full probability formula, the following expression for m_b is obtained:

(3)

$$m_b = \int_o^\tau [1-F(t)]dt + t_b F(\tau) + t_p[1-F(\tau)].$$

The expected number of restorers of the facility's performance within the range (0,t) for each stationary process is proportional to t [2], i.e. $H(t)=t/m_b$.

Then, taking into account that the two types of actions (due to a failure and planned) form a complete set of events, we get

(4) $H_o(t) = M(m_0) = H(t).F(\tau);$

(5) $H_p(t) = M(m_p) = H(t).[1-F(\tau)].$

If in (1) we substitute (2), (3), (4) and (5) with their equals, than

(6) $C=\{C_o F(\tau) + C_p[1-F(\tau)]\} / \{\int_0^\tau [1-F(\tau)]dt + t_b F(\tau) + t_p[1-F(\tau)]\}.$

To optimize the periodicity of planed actions, it is necessary to differentiate (6) and equalize the derivative to zero.

Then $\omega(\tau)\{\int [1-F(\tau)dt + p] - [F(\tau) + C_p/(C_o + C_p)]\} = 0,$

where $p=(C_0 t_p - C_p t_b)/(C_o - C_p)$.

In this case, if the density of distribution of work until failure (the resource) is by Weibull distribution

(7) $f(t)=(b/a)(t/a)^{b-1}\exp[-(t/a)^b]$; $\bar{t} = a\Gamma(1+1/b),$

then $\int_0^\tau [1-F(t)]dt = \bar{t}\Gamma\{[\tau.\Gamma(1+1/b)/\bar{t}]^b; (1+1/b)\} + \tau.\exp[-(\tau/a)^b],$

where a,b are the parameters of the Weibull distribution;

$\bar{t}$ is the average value of work until failure (the resource) of the object;

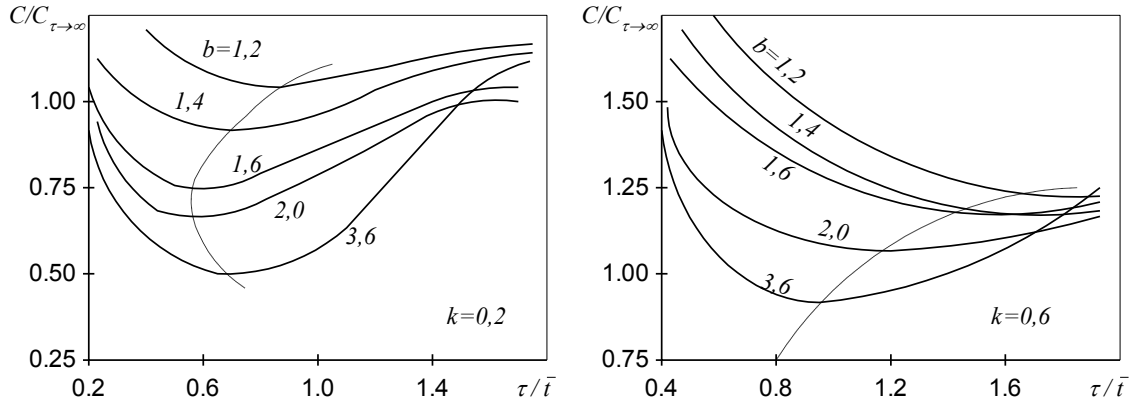
$\Gamma(z;x)$- the incomplete gamma-function of the arguments z and x [5].

Taking into account (7), we may get for (6) and (7) specific expressions, i.e.

(6′) $C=\{C_o F(\tau) + C_p[1-F(\tau)]\} / \{\bar{t}\Gamma(z;x) + \tau\exp[-(\tau/a)^b + t_b F(\tau) + t_p[1-F(\tau)]\};$

(7′) $\omega(\tau)[\bar{t}\Gamma(z;x) + \tau\exp[-(\tau/a)^b + p] - [F(\tau) + C_p/(C_o + C_p)] = 0.$

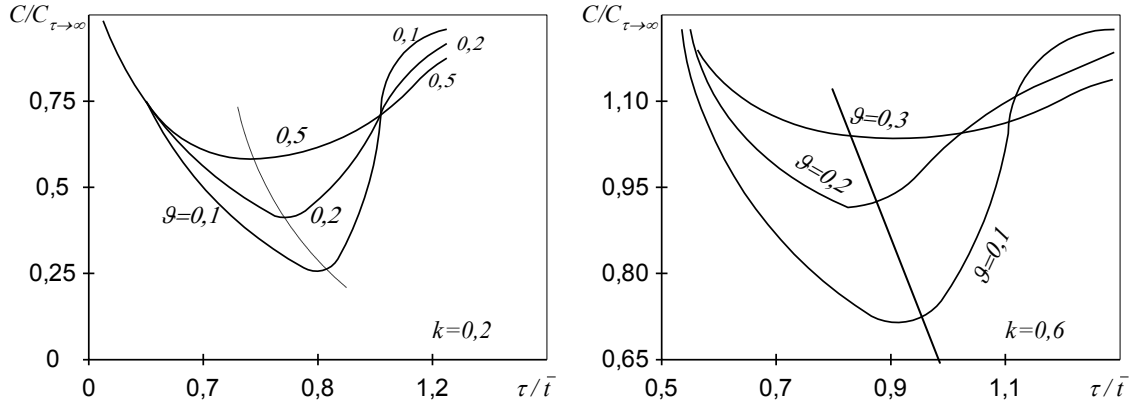
It follows from the analysis of (6) that the value of C is dependent on the costs C_0, C_p, the parameters of the work distribution law to the failure F(t) and the periodicity of the planned maintenance τ. The study was conducted for Weibull and normal distribution of the work until failure, and the graphical interpretation of the results is given in Figure 1-4, where $\tau/\bar{t}$ is the variation of the periodicity of the planed actions compared to the average work until failure; $\kappa=C_p/C_0$ is the cost-reduction ratio for planned repair actions, and the $C/C_{\tau\to\infty}$ ratio characterizes the change in the relative costs of scheduled maintenance services relative to relative costs without planned maintenance actions $(\tau \to \infty)$.



а) б)

Figure. 1. *The nature of the relative cost variation according to the periodicity of the planned actions in Weibull distribution of the work to the failure of the object: a) with a cost-reduction ratio for planned repair actions κ=0,2; b) with a cost-reduction ratio for planned repair actions κ=0,6.*

The analysis of the results obtained shows that the effectiveness of management of the level of reliability depends on the periodicity of the prophylactic actions. By decreasing the ratio k outlines more clearly the extremum of the function *C=f(τ)*, the achievement of which can be ensured by increasing the frequency of planned repairs. Therefore with the decrease of k due to the increase of C_o the need to carry out planned preventive actions, even at an invariable level of $\omega(t)$ of objects, will grow.



а) б)

Figure 2. *The nature of variation in relative costs depending on the periodicity of planned actions under normal law of distribution of workmanship to refusal of the object: a) with a cost-reduction ratio for planned repair actions κ=0,2; b) with a cost-reduction ratio for planned repair actions κ=0,6.*

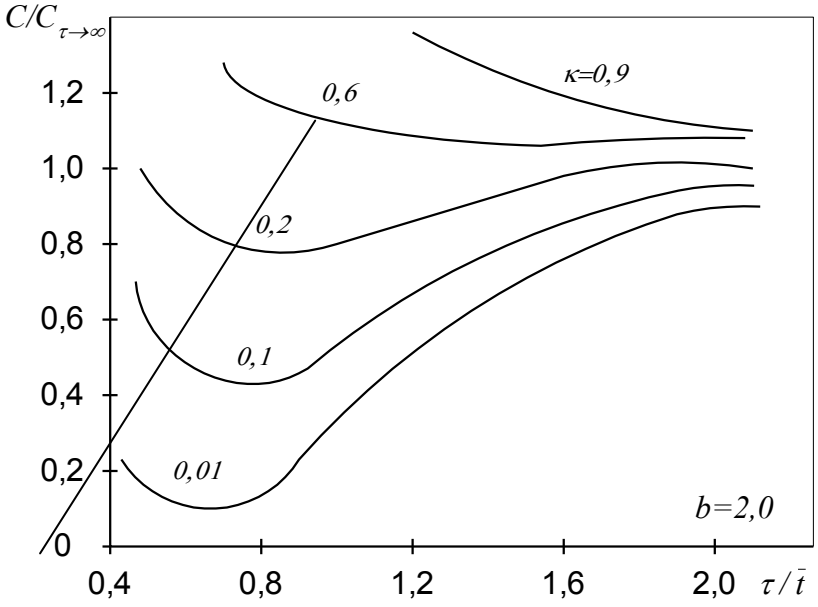


Figure 3. *Influence of the cost-reduction ratio for planned repair actions (κ) on the optimal periodicity of the planned service (τ)in Weibull distribution of the work to a failure.*

The reduction of C in conducting prophylactic maintenance with optimal frequency compared to the use of objects until failure may be significant, for example from 80% (k=0,02; b=2,4) to 2% (k=0,6; b=2,4). The rate of change of C largely depends on the parameter of the form b and in case of small values of b the implementation of the planned preventive actions from an economic point of view is meaningless, because in this case the distribution is close to the exponential distribution of the work until failure.

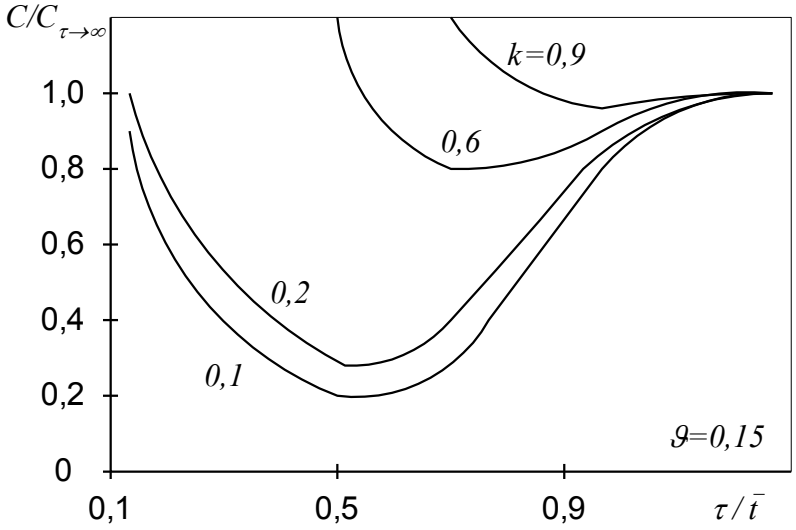


Figure 4. *Influence of the cost-reduction ratio for planned repair actions (к) on the optimum periodicity (τ) in normal distribution of the work to a failure.*

The expression (6) allows to investigate from another direction the influence of b and k on τ_{opt}.. Therefore, in Figure 3 and Figure 4, the change of function $\tau_{opt} = f(b;k).$ is shown. From the analysis of graphical dependence, it follows that the nature of the change in the τ_{opt} in the relation to the parameter b has a non-linear character, which confirms the economic efficiency of the organization of the prophylactic service of the technique with optimal frequency. Moreover, regardless of the value of k, when b $\to 1(V=1)$, $\tau_{opt} \to \infty$, and this means that it is effective to use objects until failure and not to carry out scheduled maintenance service actions.

To evaluate the level of reliability of the managed objects by optimizing the periodicity of prophylactic actions we use the complex indicators:

standby ratio

$$K_{\Gamma} = \left(t - t_p.m_p - t_p.m_o\right)/t_p.m_p,$$

and a technical utilization ratio

$$K_{\Gamma} = \left(t - t_p.m_p - t_p.m_o\right)/t\,.$$

Conclusions:

- The influence of the numerical characteristics and the parameters of the distribution of the reliability indicators on the optimal periodicity of the prophylactic actions was investigated.
- Analytical dependencies are proposed for determining the complex reliability of the objects at the optimal periodicity of conducting the prophylactic actions.

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OPTIMIZING THE PERIODICITY OF MACHINE MAINTENANCE WITH RESPECT TO THE UNDERUSED RESOURCE

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Abstract: *The intensity of aging and wear of the components /aggregates and assemblies/ of the machines is different and hence the necessity of carrying out repair service interventions has different periodicity and volume.*

A model has been developed to optimize the periodicity of maintenance of machine components, taking into account the losses from the underuse of their resource.

The influence of the parameters of the law and the economic indicators on the optimal periodicity of the maintenance was examined at the density of the distribution of work until failure to the Weibull distribution.

Key words: *RESOURCES, MAINTENANCE, PERIODICITY, OPTIMIZATION, PROBABILITY, FAILURE, SERVICEABILITY, COST.*

Deterioration of the quality and reliability of the machines is a completely natural and lawful process of degradation, after which faults occur. It is known that the intensity of aging and wear of the components / aggregates and units / of the machines is different and hence the need for carrying out repair service operations is of different periodicity and volume.

Complex mechanical systems, such as tractors and self-propelled agricultural machinery, are composed of a large number of elements. By strictly adhering to the optimal periodicity of repair service impacts, the efficiency of using the machines will be reduced as they reduce their productivity and increase the cost of labor and tools for diagnostics, maintenance and repair.

The aim of the study is to develop a mathematical model for optimizing the periodicity of machine maintenance. The objects of the study are tractors and self-propelled agricultural equipment, and the subject of the study is a mathematical model for optimization of the periodicity of maintenance.

As the maintenance period t increases, the value of the unused resource of the items decreases, and the probability of failure (and hence the probability of loss due to fault time) increases, i.e. unlike the works of Barlfw, Hunter, Proschan и Райкин [1-4;5], optimization of the periodicity of component maintenance will be made taking into account their underused resource, due to substitution for planned repair impacts, and costs associated with the faults of the elements.

Essence of the model. The optimization of the periodicity of maintenance t of the elements is limited to finding the meaning of t^*, which corresponds to the minimum of the function [6]:

$U(t) = C_n(t) + C_{np}(t) \Rightarrow \min$,

where Cn(t) is the function of the cost of not using the resource of the elements;

$C_{np}(t)$ – the function of costs due to the stay in the maintenance and repair facility.

Costs due to fault time of the object are:

$C_{np}(t) = C_0\, t_{np} F(t)$,

where C_o is the value of 1 h fault time, BGN/h;

t_{np} – fault time, h;

F(t) – failure probability.

The cost of non-use of the replaced element resource is determined at any point by the product of the value of the element and the share of area Sn/S, locked between the curve P(t) and the coordinate system (Figure 1), which characterizes the unused resource, namely [6]:

$$C_n(t) = C_z\{[\int_o^\infty P(t)dt - \int_o^\tau P(t)dt] / \int_o^\infty P(t)dt]\} = C_z\{[\, t - \int_o^\tau P(t)dt] / t\},$$

where Cz is the cost of the replacement element;

t – the mathematical expectation of the average cost resource;

τ - the optimal periodicity of maintenance.

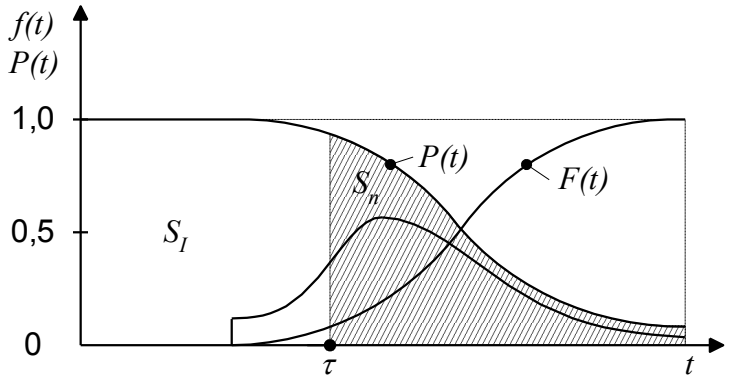


Figure 1. *The nature of the change in the elements' reliability characteristics P(t) and the density of their resource F(t)*

The total cost is expressed by the following function:

$$U(t) = C_z\,(1 - \int_0^\tau P(t)dt / t) + C_0 t_{np} F(t) \Rightarrow \min.$$

Let the density of the distribution of the work to failure (resource) to be according to Weibull distribution, where

$f(t)=b/a\,(t/a)^{b-1}\exp[-(a/b)^b]$, $\bar{t} = a\,\Gamma(1+1/b)$.

Here *a* is the scale parameter, and *b* - the shape parameter of Weibull distribution.

Under this condition

$$U(t) = C_z\{1-[\, \bar{t}\Gamma(k;s) + \tau \exp[-(\tau/a)^b] / -(\tau/a)^b\} + C_o t_{np}\{1-\exp[-(\tau/a)^b]\},$$

where $\kappa = \{\tau\Gamma(1+1/b) / \bar{t}\}^b$; $s=1+1/b$.

Then

$$U(\tau) = C_z\ \{1-\Gamma[(\tau/a)^b;(1+1/b)] + \tau \exp[-(\tau/a)^b] / \bar{t}\ \} + C_o t_{np}\{1-\exp[-(\tau/a)^b]\},$$

where $\Gamma(z;x) = 1/\Gamma(x)\int_0^z t^{x-1}e^{-t}dt$ is the incomplete gamma-function of the arguments *x* и *z* [7].

The function U(τ) is concave with a minimum that is determined by the condition dU(τ)/dτ.

If the derivative of the function is determined

$$U(\tau) = C_z\left[t - \int_0^{\tau} P(t)dt \right] / \bar{t} - C_o t_{np} F(t)$$

$dU(\tau)/d\tau = -C_z + F(\tau)C_z + C_0 t_{np} \bar{t} f(\tau)$ is obtained

or $[1-F(\tau)] / f(\tau) = C_0 t_{np} \bar{t} / C_z$.

Considering that the density of work to failure (resource) is distributed by Weibull distribution, then

$C_z / C_0 t_{np} = b(\tau/a)^{b-1}\Gamma(1+1/b)$.

Figure 2 gives the characteristics of variation of the optimal periodicity of maintenance according to the parameters of the distribution of reliability and replacement cost, loss due to fault time and length of fault time.

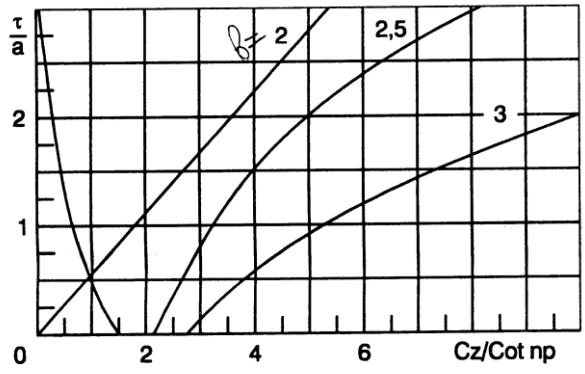


Figure 2. *Change of the optimal periodicity of the maintenance of the machine components at b=const*

The way in which graphical dependencies are used to determine the optimal periodicity is shown in the figure itself.

Figure 3-4 shows the influence of the individual factors of the model on the optimal periodicity of the component maintenance.

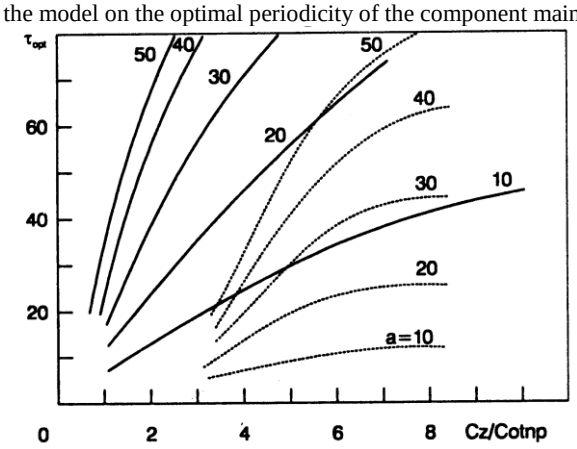


Figure 3. *Impact of economic performance on the optimal periodicity of maintenance:*
for b=2; ------ for b=2,5.

Conclusions:

A model has been developed to optimize the periodicity of maintenance of machine components, taking into account the losses of their resource underusage.

The influence of Weibull distribution's parameters on the optimal periodicity as well as the influence of economic indicators on the optimal value of the maintenance periodicity are examined.

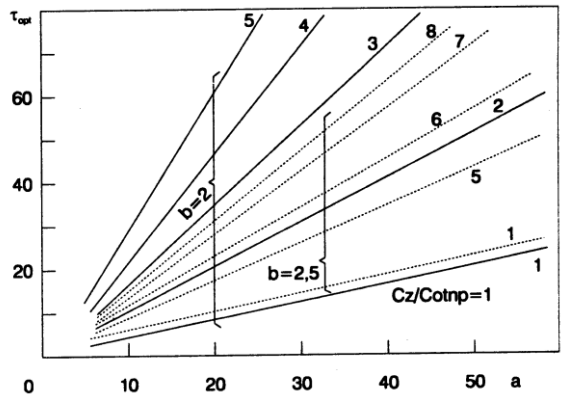


Figure 4. *Influence of the "a" parameter of Weibull distribution on the optimal periodicity of maintenance:*
for b=2; ------ - for b=2,5=

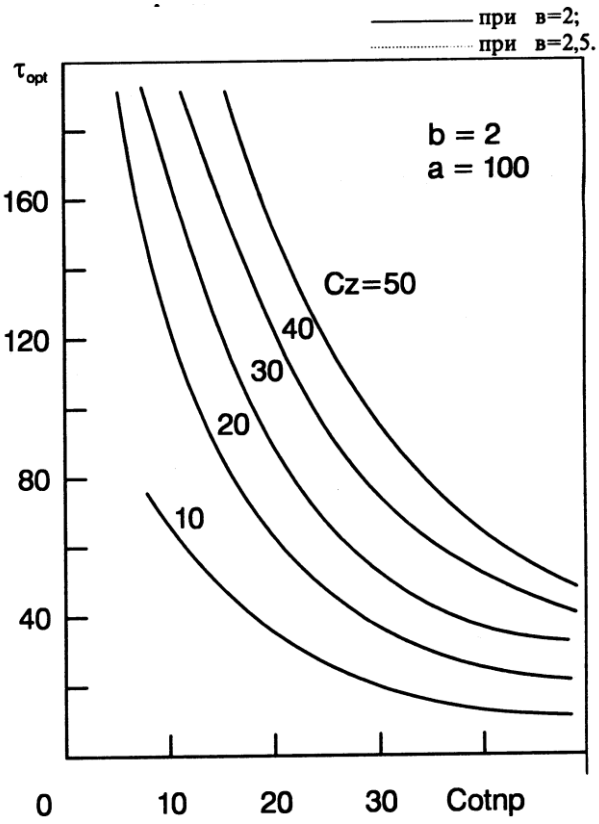


Figure 5. *Impact of the value of the fault time $C_0.t_{np}$ on the optimal periodicity at different values C_i*

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INNOVATIVE MOMENTS IN TRAINING BACHELOR DEGREE STUDENTS IN "CROP PRODUCTION"

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Abstract: *Dynamically developing plant growing continuously sets challenges to the system for training specialists, who have to be able to develop competitive and sustainable agriculture. In the conditions of market economy and various forms of land management, for the development of plant growing are needed managers and executives, who will be able to apply successfully the scientific principles of research, analysis, support and management of cost-effective agricultural production units. The degree programme Plant Growing provides preparation of such specialists. Education in Crop Science and Production offers such kind of training by application of innovation moments such as practical semester and development of integrated project.*
KEY WORDS: *STUDENTS, EDUCATION, BACHELOR DEGREE, PRACTICAL SEMESTER, INTEGRATED PROJECT*

1. Introduction

Even in modern societies plant growing is of lasting importance. This is so not only because plant growing provides jobs for millions of people and contributes substantially to the gross domestic product in agricultural countries, but also because it has the potential to change the life of a nation. Plant growing has the unique ability to encourage development." (source: World bank, Report on world development, 2008, „Plant growing and development"). Dynamically developing plant growing continuously sets challenges to the system for training specialists, who have to be able to develop competitive and sustainable agriculture.

In the conditions of market economy and various forms of land management, for the development of plant growing are needed managers and executives, who will be able to apply successfully the scientific principles of research, analysis, support and management of cost-effective agricultural production units. The degree programme *Plant Growing* provides preparation of such specialists.

2. Materials and method

The main goal of this training is the preparation of highly qualified specialists in the field of plant growing, who will be able to develop competitive and sustainable agriculture.

The purpose of this publication is to present the innovative moments in the curriculum in the course of study of students from the degree programme *Plant Growing* at the University of Ruse „Angel Kanchev".

The motives for training students in *Plant Growing* are related to the demands of practice, consistent with the world's leading scientific and educational trends for priority development of efficient agricultural production.

The philosophy of training students in this degree programme is striving for realisation of ideas and strategies such as:

- Continuous learning and skills at the different stages of development of agriculture and readiness for successful adaptation and realisation in a new market reality;
- Learning technologies, methods and tools that meet the global economic situation;
- Training in creative and innovative methods (i.e. technologies, adopting change as an irrevocable command of the knowledge age);
- Continuous acquisition of new knowledge, for applying it on both conventional and high-tech products;
- Developing entrepreneurial spirit, built on adequate levels of creative and professional competence (broad, specific and special).

The demands for opening a professional field 6.1. Plant Growing and Bachelor degree in Plant Growing at the University of Ruse "Angel Kanchev" are related not only to the above-mentioned global changes in attitudes for agricultural development, but also to the increasing demand for food and the national and regional strategies for development of this vital branch, [1].

First, on a national and regional scale, there exists the problem of the shortage of highly qualified specialists with appropriate agricultural education and adequate theoretical and practical preparation. A tendency for significant growth in average age of those engaged in agriculture can also be seen.

At the same time, analysing the experience of home and foreign universities and the tendencies in the educational system in the field of plant growing internationally, we arrived at the conclusion that it is high time to initiate decisive improvement of practical training of students with the aim to help their fast adaptation in real production conditions. The analysis of curricula shows that the idea for practical training is not new in the world educational system.

In the process of developing the education materials, we have studied the experience of the Agrarian University in Plovdiv, the Thracian University in Stara Zagora, the technical University in Varna, the Forestry technical university in Sofia and the Shumen University "Bishop Konstantin Preslavski".in the training in the Bachelor and master degree programmes, [2].

From the compulsory subjects in the curricula, 19 (about 50%) are studied in all universities. They are mathematics, Botany Part I, Organic Chemistry, Soil Science, General Agriculture Parts I and II, Biochemistry, Microbiology, Agrochemistry, Agrometeorology, Genetics, Physiology of Plants, Entomology, Plant Growing Part I and II, Phytopathology, Agricultural Economics, Perennials Part I and II (horticulture and viticulture).

Five of the universities under survey suggest the subjects Selection and Seed Production, Mechanisation in Plant Growing, Vegetable Growing, Land Reclamation and Irrigation.

Four of the universities have included the subjects Inorganic and Analytical Chemistry, Botany Part II (Systematics), Power Machines, Livestock Breeding Part I, Mechanisation in Plant Growing Part II, Informatics.

The experience of foreign universities offering the degree program „Plant Sciences" BSc (Instituto Superior de Agronomia with the technical University in Lisbon, Portugal); University College Dubin, Ireland; Harper Adams Agricultural College, Newport, UK; University of Thessaly, Volos, Greece; Cornell University, USA; University of Newcastle, UK, Jowa State University, USA, has been studied too [3].

The University of Newcastle, UK is ranked among the first five larger universities in Great Britain, offering education in

the field of agriculture. [Source: Guidebook, 2013]. The main scientific principles on which the training is based are lectures, lab classes and practical classes. The visits to University and other farms for agricultural production are used to boost the theoretical studies.

Jowa State University, USA, offers its students to choose from 129 subjects, related to plant growing and grouped in five main fields such as agricultural, economic, environmental, philosophical and sociological, from which they can accumulate the necessary credits. Of these, 23 subjects (17%) are practical.

When developing its curriculum, the University of Ruse offers three innovative aspects:

- From the very first semester, the emphasis of student training is put on soil and water resources, which are fundamental for the agricultural science. The subject Soil Physics provides basic information about this vital resource, which is extremely hard to renew. The knowledge about using the soils and water is complementary throughout the whole process of study to semester 7.
- In semester 6 generalist supervised practical training is conducted. The students chose their field of interest and then they are given an assignment for the practical semester. Every student is supervised and monitored by two mentors;
- Developing an integrated course project during the supervised practical training in semester 6. The students do a profound study in their chosen field, participate in laboratory and practical research, which they develop in an individual or group integrated course project. Training is conducted in the experimental facilities at the Institute on Agriculture and Seed Science "Obrazcov Chiflik" – Ruse and/or at "N. Pushkarov" Institute of Soil Science – Sofia, as well as in some elite farms or seed producing houses. The practice semester can be conducted at other institutes with the Agricultural Academy. The aim is through doing research together with professional researchers to consolidate the knowledge of creating and using new sorts of plants and implementing them into advanced production technologies, which will be demonstrated at the diploma thesis defence or during the state exam. The course project will be controlled through colloquiums in weeks 5 and 7 and a defence in week 15 of the semester.

In accordance with the highlighted integrative and interdisciplinary approach of education in the degree programme of *Plant Growing*, education fields are formed, which consist of groups of disciplines such as: - foundation; - agricultural; - livestock breeding; - technical; - economic and computer science; - foreign languages; - educational practice – training in a broad field and graduating.

On developing the curriculum, the competitive environment in the education institutions has been analysed. In Bulgaria all curricula for bachelor degree programmes in *Plant Growing* tend to include practical training, but it is organised after the end of even semesters in the so called "summer practice". There is a shortage of master degree specialists in processing and storage of produce, selection and seed production, land reclamation and irrigation, bio agriculture and plant protection.

In the course of study the students learn purposefully fundamental subjects like: Bio mathematics; Physics of the Soil; Inorganic and Analytical Chemistry; Biology; Botany; Organic Chemistry; Soil Science; Experiment Work; General Agriculture, Foreign Language; Biochemistry, Microbiology. Through individual work in these subjects, students learn to meet the increased requirements for working on their own and being entrepreneurial.

Specialised and profound knowledge is acquired through the subjects Agrochemistry, General Agriculture, Agrometeorology, Energy Equipment in Agriculture, Genetics, Plant Physiology, Entomology, Livestock Breeding Parts I and II, Mechanisation in Agriculture Parts I and II, Information Technologies in Agriculture, Plant Growing Parts I and II, election and Seed Production, Phytopathology, Fodder Production, Economics of Agriculture, Perennials – Viniculture and Horticulture, Vegetable Production, Using Machinery in Agriculture, Technologies and Systems for Agricultural Production, Land Development, Land Reclamation and Irrigation.

These subjects are complemented by practice in production facilities during the summer period after the second and the fourth semesters for consolidating the knowledge on taxonomy of plants.

Graduating with Bachelor's degree in *Plant Growing* the students have specialised in one of the profiles of plant growing like cereal, leguminous, forage crops, vegetable, industrial crops, medicinal and essential oil crops, perennials and specific crops.

With this Bachelor degree, students can apply for a Master degree programme both at the University of Ruse and in other universities in Bulgaria, offering similar degree programmes. The fundamental knowledge they have acquired will be complemented with a number of specialised subjects in the field of their choice.

Thus prepared, they will be able to:

- apply modern technologies for production in the field of plant growing;
- manage various units, differing in scope and nature of production;
- apply the experience and achievements of specialist in areas related to agriculture;
- apply information technologies in agriculture;

3. Job opportunities

The graduates in professional field Plant Growing and Bachelor degree programme Plant growing can work in the sphere of agriculture in Bulgaria, which is characterised by various forms and scale of production. They will be able to perform the following activities:

- Managing different sizes own, rented or mixed farms with agricultural production.
- Organiser (technologist) of plant production in cooperatives, associations or other forms of cooperation units, which have the same activities.
- Experts in state and/or public institutions, dealing with the problems of plant growing at the level of their competences.

4. Conclusions:

- The University of Ruse "Angel Kanchev" as well as the other universities, teaching students in this degree programme, maintain high quality of education and teaching staff. By developing and implementing a reliable system of quality, cost effective training and research is provided. Identifying and applying good practices is the key to higher achievements, which is the continuous aim of the teaching staff in the University.
- Achieving standards in the quality of education and the qualification of the teaching staff is a guarantee for fulfilling our mission and goals. The approved criteria for responsibility and self-criticism of the academic community guarantee high quality of education and of the teaching staff.

- Managing the quality of education and of the teaching staff is a shared responsibility of administrators, students and lecturers. When building the University policy, concerning the quality of education and of the teaching staff, the opinion of the students is the leading criterion.

- The University of Ruse "Angel Kanchev" has well-developed diverse education and research, advanced facilities and a sufficient number of high quality qualified staff with academic ranks.

- The innovation approach applied in structuring and developing teaching documentation and the continuous analysis of the competitive environment guarantee in real time the fulfilment of the strategy for developing the professional field.

- The University of Ruse "Angel Kanchev", through its Agrarian and Industrial faculty, has full capacity for teaching in the professional field 6.1. Plant Growing from higher education area 6 – Agrarian Sciences and Veterinary Medicine, thus becoming a complex centre for science and research in Northern Bulgaria, completely meeting the criteria for timeliness, innovation and efficiency.

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TECHNOLOGICAL AND ECONOMIC ASPECTS OF DRIP IRRIGATION OF RASPBERRIES

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Abstract: *Drip irrigation provides a fairly even mode of moisture in the soil and, along with this, favorable air, heat, microbiology and nutrition. As a result, there is an increase in yields and an improvement in the quality of production.*

In order to determine the impact of drip irrigation, on the size of the yield and the economic indicators, in the cultivation of raspberries in the soil and meteorological conditions of the area of the village of Chelopechene - Sofia researches of an everbearing variety "Lyulin" were carried out. Various options have been tested - from fully satisfying the daily needs of the culture by water, irrigation with 20% and 40% irrigation norms to non- irrigating conditions.

The results obtained in years with different security of meteorological factors show that the drip irrigation of raspberries has a positive effect on the economic indicators of its cultivation, the costs of creating the raspberry crop, the irrigation system and the cultivation of the crop are redeemed for two or three years.

KEYWORDS: *DRIP IRRIGATION, RASPBERRY CROPS, IRRIGATION REGIME, YIELD, EXPENSES, PAYBACK PERIOD.*

Introduction:

Raspberry is a crop of great economic importance due to excellent technological and taste characteristics and high productivity. These qualities it exerts exclusively in irrigation conditions, which is explained by its biological features.

The micro-irrigation of raspberries is increasingly used, due to the possibility of effective control of the processes in the irrigation system and in the irrigated plantation (Bucks et al.,1982). This method fully meets the requirements for sustainable agriculture and organic production of fruit, incl. ensuring high yields and quality of production, reduction of unwanted side effects (Branson et al.,1981). It has been established from our and world science that from the applied techniques and technologies for irrigation of berry and fruit crops most suitable for their biological requirements is drip irrigation (Drupka,W.,1979, Кирева, Р., В. Петрова, 2014).

Drip irrigation enables irrigation water combined with the necessary fertilizers to be delivered directly into the root system of the plants. This type of irrigation saves considerable water consumption, as well as the operating costs of watering the irrigation system and maintenance of the irrigation system. The drip irrigation system is realized by the installation of irrigation pipes /irrigation wings/. These pipelines are fed by submerged or underground distribution pipelines. Drip irrigators are built along the irrigation line and the water in the irrigation leaves drops into the root system of the plant. Drip irrigation technology is adapted to the type of crop, field features, water source, and planting pattern.

Studies conducted so far on irrigation of raspberries indicate that it is very important to increase the yields of the raspberry before the ripening of the fruit and throughout the harvesting period (Kuiesza, W., 1973, Oosten, A.,1976). According to the same authors, the most negative influence on the yield is the drought two weeks before the harvesting of fruits and during ripening. In maintaining a limited water deficit in the soil, the yield of raspberries increased by over 9.6% and in dry years by 27.6% compared to non-irrigated variants (Mackenrron, 1982).

Full studies of the irrigation regime of raspberries are carried out solely by (Иванов, Ал.,1998,) and some of the drip irrigation parameters for have been established. For the massively inflowing everbearing raspberries, such research is lacking. In view of this, we have directed our study to determine the impact of drip irrigation on the amount of yield and economic performance in growing raspberries "Lyulin".

Materials and method

The field experiments were conducted in the experimental field of the Pushkarov Sofia Institute in the period 1999-2001. The soil is leached cinnamon forest, slightly sandy loam in the plow layer, formed on the base of an old delluvial cone of silt materials. It is poorly stocked with nitrogen, on average with phosphorus and well with potassium. On average, for the layer 0 - 60 cm the soil has the following water-physical properties: Saturation = 22,1%, wilting point – 12,3% on the weight of absolutely dry soil, volume weight at Saturation – 1,47 g/cm^3. For the soil layer 0 - 100 cm the same indicators have values: Saturation – 21,8%, wilting point – 12,3% and volume weight – 1,50 g/cm^3.

Various variations of irrigation have been tested:

- first variant - without irrigation;
- second variant - irrigation with 100% irrigation rate;
- third variant - irrigation with 80% irrigation rate;
- forth variant - irrigation with 60% irrigation rate.

The irrigation rate is calculated using the formula (Frecman and Garzoli, 1980).

To monitor soil moisture dynamics, soil samples are taken under variation 2 (100% irrigation rate) at a depth of 0 - 60 cm over 10 cm, which are processed by the weight-thermostatic method.

The scheme of the drip irrigation installation and the parameters of its main elements are designed to ensure a uniform distribution of the irrigation rate along the rows of raspberries. The installation is made of irrigation wings 20 mm diameter double-walled drip irrigation pipes type "Agrodrip" and water inlet through 30 cm.

Technology and agrotechnics for the creation and cultivation of raspberry crops developed by Experimental plant on berry breeding – Kostinbrod was used for the experiment. The irrigation was carried out by"Drozbah" irrigation system.

Results and discussions

The results from the triennial studies show that the number of irrigation and the irrigation rate are the meteorological conditions (precipitation) in individual years.

Regarding the amount of precipitated rainfall for the period April - September 1999 и 2001 are characterized respectively as a wet and medium-wet year with the provision of rainfall factor in the multi-year series 19,2% and 33,1% respectively, and for 2000 – as very dry with – 98,6%.

Table 1: *Rainfall during raspberry vegetation period (1999 – 2001)*

Periods	Total rainfall (mm)			Rainfall factor security (%)		
	1999 г.	2000 г.	2001 г.	1999 г.	2000 г.	2001 г.
Month IV - IX	398	182	358	19,2	98,6	33,1
Average multi-annual	365	363	362	-	-	-
Month VII - VIII	152	28	75	7,3	96,6	70,8
Average multi-annual	108	107	017	-	-	-

The sum of precipitations during the growing season of the crops for 1999. is 33 mm higher than the average multi-year values, and for the July-August period by 44 mm. In 2001, which is characterized as moderately humid, rainfall in April - September is almost the same as in the mid-year series - 358 mm and in July - August it is 75 mm (Table 1).

In the very dry year (2000) the sum of rainfall for the period April - September is 182 mm, which is 50% lower than the average multiannual values. Particularly dry during this year are the months of July and August, with the sum of rainfall being 28 mm, much lower than the average multiannual values for the same period of 107 mm. These rainfall was extremely inadequate for the development of raspberries, which predetermined a large number of waterings.

The results of triennial studies show that the number of irrigation and irrigation rates is determined by the weather conditions (precipitation) in individual years. The number of irrigation varies from 12 to 17 and the irrigation rate from 2160 to 4500 m^3/ha.

On average, during the rape season, 18 irrigations are made with average irrigation rate 180 m^3/ha and irrigation rate 3240 m^3/ha, with the highest number of pollutions being realized during the many dry years (2000), where the number of irrigations reaches 25, and the size of the irrigation rate reaches 4500 m^3/ha.

The results obtained for the raspberry yield during the different humid years show the impact of drip irrigation on its size. The greatest increase in yield was obtained in 2000, when it was about three times higher than the non-irrigated variant (Table 3). The least increase with 2470 kg/ha was obtained during the wet year 1999, with an average increase of the yield in the three years of 6000 kg/ha.

The irrigated regimes during the years also affected the yields obtained. Highest yields were obtained for variant with 100% irrigation rate - 10 760 kg/ha, and lowest for non-irrigated variants - 4 470 kg/ha. Lowering the irrigation rate by 20 and 40% has led to a reduction in yields of 11 and 22%. The reduction in yield is not drastic and such irrigation regimes can be used in the event of a water shortage.

Table 2: *Yield of the raspberry on variants end years*

Variant	1999		2000		2001		Average for the period 1999-2001г.	
	kg/da	%	kg/da	%	kg/da	%	kg/da	%
No irrigation	7 120	100	3 840	100	2 480	100	4 470	100
100% M	9 590	135	13 930	365	8 710	351	10 760	241
80% M	8 950	126	12 250	319	7 690	310	9 630	215
60% M	8 350	117	9 830	256	6 890	278	8 350	187

For the normal development of raspberry, given its biological water needs, it is necessary to ensure that the soil is wetted on a continuous strip along the rows, requiring overlapping of wetted areas from the individual water inlets in the pipeline. The research has shown that the use of an Agrodip type installation with irrigation wings and 30cm water inlets, supplying a water quantity of 2,7 l/h, the requirements of the field conditions of the Test field are met and the installation is suitable for supplying the required amount of water cultivated crop. The cost of creating one dka of raspberry plantation amounts to 3600 Lv/ha (on an experimental field). The analysis of the economic indicators shows that the investments made for the establishment of the plantation and the construction of the drip irrigation installation are redeemed in the third year (Table 3). In case a loan is obtained for the creation and cultivation, for example, the size of its area multiplied by the cost of its creation and the construction of the irrigation installation, area (ha) in 10000 Lv/ha, at 10% annual interest rate and one year grace period, there is the possibility to pay the loan for three, five or seven years, which will allow for the first year to make a profit.

Conclusions:

1. On average, for the duration of the experiment, the highest yield of 10760 kg/ha was obtained with the optimal irrigation variant and the lowest in the non-irrigated variant - 4470 kg/ha

2. The greatest increase in yield was obtained in 2000, when it is about three times larger than the non-irrigated option, the least increase of 2470 kg/ha was obtained during the moist 1999, as an average for the three studied years the increase of the yield is with 6000 kg/ha.

3. The investments made to create a raspberry crops and for the construction of the drip irrigation system under the terms of the survey shall be redeemed for three years.

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Table 3: *Economic indicators of the production of raspberry "Lyulin"variety*

Year	1998		1999		2000		2001		Average Irrigation 1998-2001	Average Non-irrigation 1998-2001
Indicator	Irrigation	Non-irrigation	Irrigation	Non-irrigation	Irrigation	Non-irrigation	Irrigation	Non-irrigation	Irrigation	Non-irrigation
1. Costs for setting up the plantation, lv/ha	3600	3600	-	-	-	-	-	-	-	
2. Costs for construction of a drip irrigation installation, lv/ha	6200									
3. Production costs, lv/ha	3520	2900	6160	4750	8970	3150	5590	2020	6910	4470
4.Yield, kg/ha	1200	1200	9590	7120	13930	3860	8710	2480	10760	3640
5. Average purchase price, lv/kg	1,2	1,2	1,2	1,2	1,6	1,6	1,7	1,7	1,5	1,5
6. Income, lv/ha	1440	1440	11500	8540	22280	180	14800	4210	16140	6700
7. Profit, lv/ha	-11880	-5960	5340	3790	13310	3030	9210	2190	9230	2230

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 DENAMICS*

1. *Introduction*

The transformation of plant residues (PRs) in soils is complicate 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; Pinskiy 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 (*Zéa máys*) and red clover (*Trifolium praténse*), 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 caolinite 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 cm^3), 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^{o}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 (C_0) 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.

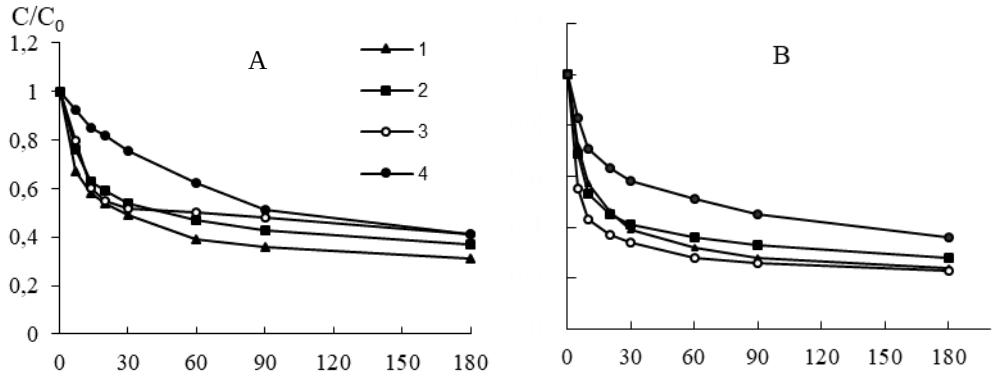


Fig. 1. *The dynamics of mineralization of PR of corn (A) and clover (B) in the substrates studied: 1 – sand+30% kaolinite, 2 –sand+15% bentonite, 3 –sand, 4 – loam.*

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-destructors 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).

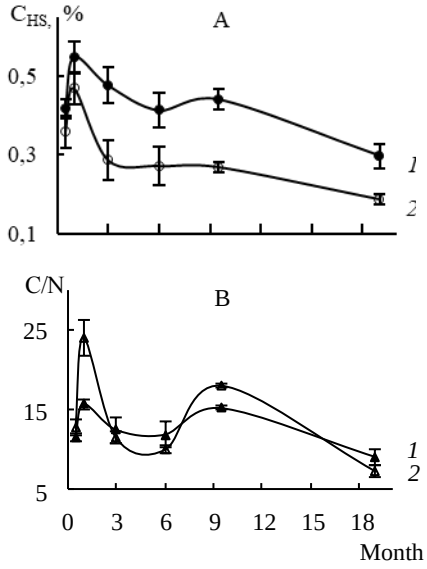


Fig. 2. *Changes in the content of humic substances (A) and C/N ratio (B) during the humification of corn residues in loam (1) and in sand (2).*

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

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

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) $$\frac{C_t}{C_0} = Ae^{-k_1 t} + B^{-k_2 t}$$

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.

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: $k_1 >> k_2$. 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 $k_{1clover} >> k_{1corn}$. 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.

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 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: $k_1 >> k_2$. 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.

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EFFECT OF USING A COMPLEX OF AGRO-TECHNICAL PRACTICES ON PLANOSOLS

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***Abstract**: The problem of updating agricultural technology, particularly in the field of agriculture, is important for agriculture. Alternative technology solutions that meet the performance criteria are a prerequisite for successful economic activity.*

The aim of the study is to determine the effect of the application of an agro-technical complex of events, which successfully supports the soil fertility of the Planosoils and the sustainable level of productivity of the field crops.

In the field experiment in the station for irrigation agricultural Pazardzhik Valley, in three-polar crop rotation maize-barley-rape are studied three factors - soil tillage system, mineral fertilization and ways of managing plant residues.

The study found that the moisture content of the soil was mainly influenced by the type of treatment applied (loosening as a main plow and plowing as a pre-sowing) and the use of plant residues. The over compaction found in the beginning of the experiment in the 25-40 cm layer is partly overcome by performing a deep rupture to the depth of 35 cm. Despite the short period of the study, there was a certain decrease in the content of digestible potassium forms. The results show the activation of the microbiological activity after planting of the plant residues - an increase of the amount of the cellulose microorganisms and of the ammonifiable bacteria, the most noticeable in the high fertilization rate and the intensive treatments. The main part in the formation of crop rotation productivity is mineral fertilization. The impact of the tillage system is more marked in the first year of maize and especially during the third year of rape. Lack of fertilization influences yields significantly in rapeseed compared to maize and barley.

***KEY WORDS:** AGRICULTURAL PRACTICES, SOIL TILLAGE, FERTILIZATION, PLANT RESIDUES, PRODUCTIVITY*

INTRODUCTION

The problem of updating agricultural technology in agriculture, grain-production in particular, is important for production. Alternative technology solutions that meet the performance criteria are a prerequisite for successful business activity. In order to achieve sustainable agriculture, it is necessary to make periodic changes in the technologies for growing individual crops and adding additional calories of energy in the form of fertilization, plant protection, watering and growing in environmentally disadvantaged areas (Arvidsson et al., 2003; Stoynev, 2004; Basitov, 2008). Agro-technical solutions also play a vital role as a major part of production technology. For a major agro-technical practice to be carried out, a number of requirements have to be met and the most accurate solution to be taken (Mitova et al 1999, Terra et al 2006, Karlen et al., 2013)

The rationalization of agro-technical practices allows the reproductive potential of crops to be more fully used at a good level of soil fertility (Dimitrov and Mitova, 1998, Nikolova et al., 2001, Zarkov and Koteva 2005, Terra et al., 2006; Toncheva et al., 2015).

The aim of the study is to determine the effect of the application of an agro-technical complex of practices, which successfully to supports the soil fertility of the planosols and the sustainable level of productivity of the field crops.

MATERIAL AND METHODS

In a field experiment conducted in the Experimental Station on Irrigated Agriculture, Pazardzhik in three-field crop rotation system maize-barley-rape in the conditions of irrigated agriculture, three factors were studied - soil treatment system (scheme 1), mineral fertilization norms (scheme 2) and plant residues management methods - by introducing the plant residues into the soil with the treatment (option O_1) and by removing them, by baling or chopping, and extracting them outside the test area (option O_2).

According to the requirements of the crops and the agro-ecological conditions, differentiated processing systems are used with variants of basic, pre-sowing and inter-row machining solutions. In the experiment, three levels of fertilization - zero and two fertilization norms with nitrogen and phosphorous fertilizer, potassium fertilization was carried out for the third crop in the crop rotation - oilseed rape.

***Scheme 1.** Systems for soil cultivation in crop rotation*

Crop	Option O_1	Option O_2
Maize for grain	tillage 25-30cm	disc harrow 10-12 cm tillage 25–30cm
Barley (winter)	tillage 15-18 cm	disc harrow 10-12 cm
Oilseed rape	disc harrow 10-12 cm loosening 35-40cm	tillage 20-25cm

Scheme 2. Fertilization variants

Crop	Fertilization variants		
	T_0	T_1	T_2
Maize	no fertilization (фон P_7)	$N_{20}P_{15}K_0$ Superphosphate, ammonium nitrate	$N_{25}P_{20}K_0$ Ammophos, Ca- ammonium nitrate
Barley	no fertilization	$N_6P_8K_0$ Superphosphate, ammonium nitrate	$N_8P_{10}K_0$ Ammophos, Ca- ammonium nitrate
Rape	no fertilization	$N_{15}P_{12}K_6$ potassium sulfate Superphosphate, ammonium nitrate	$N_{20}P_{15}K_6$ Eurobio NPK fertilizer, Ca- ammonium nitrate

The following indicators have been monitored: productivity - main and additional crop production and total crop rotation productivity calculated in kg/da; water-physical: moisture content by weight% and density in g/cm^3 - by Kaczynski's weight method, every10 cm in depth up to 60 cm depth with 100 cm^3 volume rings; hardness - with a weight-down

hardness meter with a cone angle of 30°, every 5 cm to a depth of 40 cm; general porosity of the soil - by ratio of bulk and relative mass of the soil;

agrochemical - mobile forms: nitrogen - by the method of Bremner and Keeney; phosphorus - by the method of P. Ivanov; potassium by the method of P. Ivanov; soil solution reaction (pH) - potentiometrically in water and potassium chloride; carbonates - using the Scheibler method, organic matter content in the soil - by Tyurin;

microbiological indicators: main groups of soil micro-organisms - ammonifying bacteria, actinomycetes, mineral nitrogen digesting bacteria, microscopic fungi, cellulose digesting microorganisms. The samples are taken from the surface layer of the soil (0-30 cm) near the roots of the plants; total biological activity (soil respiration) - determined by the method of Alef and Nannipieri.

The amount of plant residues is determined from 0.5m^2 area in three replicates; layer distribution of residues - by wet soil sieving of ¼ m^2.

The sum of the rainfall during the growing season of the crops is for maize 2014 (IV-IX) - 569,3 mm, for winter barley 2014/2015 (X-VI) - 627,7 mm and for oilseed rape 2015 / 2016 (IX-VI) -447.3 mm.

RESULTS AND DISCUSSION

The tested agrotechnical factors influence the condition of the soil parameters and the productive potential of the cultivated crops.

Effect on soil's physical characteristics: After maize sowing, a consistent differentiation of water content in the soil was established. In the surface layer, as a result of moisture evaporation, the content is 75-87% of Saturation, in the layer 20-30 cm is about 90% and in the deeper layers within the boundaries of Saturation. Substantial differences due to soil treatment have not been established. Only one irrigation with a rate of 80 m^3/da was made to maintain a presumptive humidity of 75% of Saturation.

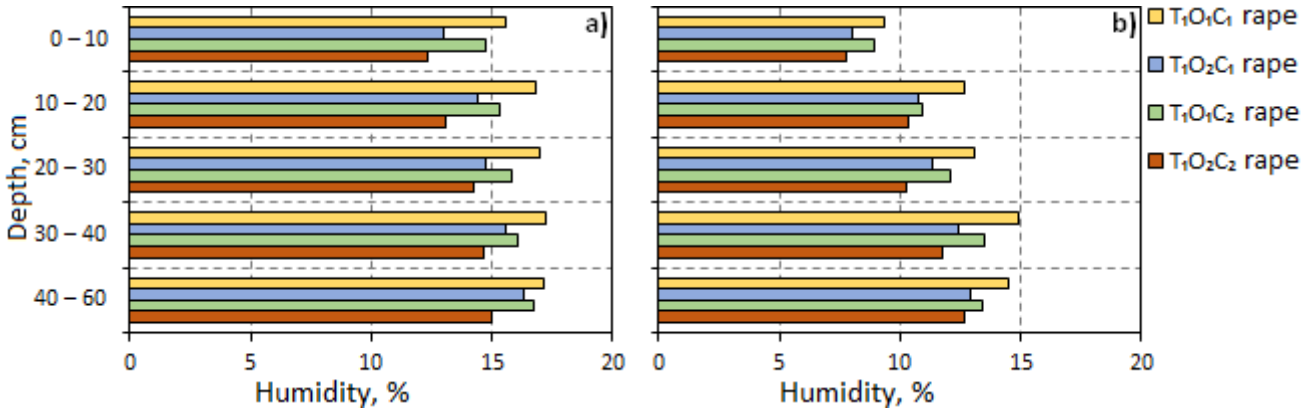


Fig. 1.*Content of soil moisture in weight% 2015/2016 – rape [a) germination, b) before harvesting]*

When inspecting the barley until the wax ripeness phase begins, the moisture content of the test area decreases with the measured values from 11.22% to 16.06%. There is a tendency of higher moisture content in the soil of the lots with tillige of the vegetation residues - the value differences are from 1.10% to 2.03%.

The moisture content of the Planosols in the autumn after rape sowing is from 12.36 to 17.23% (Fig. 1,a). A watering with a 20 m^3/da rate was made to accelerate germination. The measured soil moisture values in the pre-harvest test were from 9.35% to 14.87% (Fig. 1,b). The humidity in the 0-40 cm layer for the loosening area is higher than the plowing trough - from 1.3% in the surface layer to 2.47% in the 30-40 cm layer due to different evaporation rates and the retention of moisture to the depth of loosening.

In the first year, the high moisture content has an impact on soil density. In the wax ripeness phase, when the humidity is about 80% of the Saturation, an increase in the values of this parameter in the 0-20 cm layer was recorded, the differences with post- germination readings being in the range 0.08-0.13 g/cm^3. Although less expressed, there is an increase in volume density for the layer 30-40 cm. Prior to harvesting of the barley, the bulk density was high for the entire studied layer 0-40 cm, which ranged from 1.63 g/cm^3 to 1.76 g/cm^3. In order to overcome this overfill of the layer for option O1, rupture is included up to a depth of 40 cm.

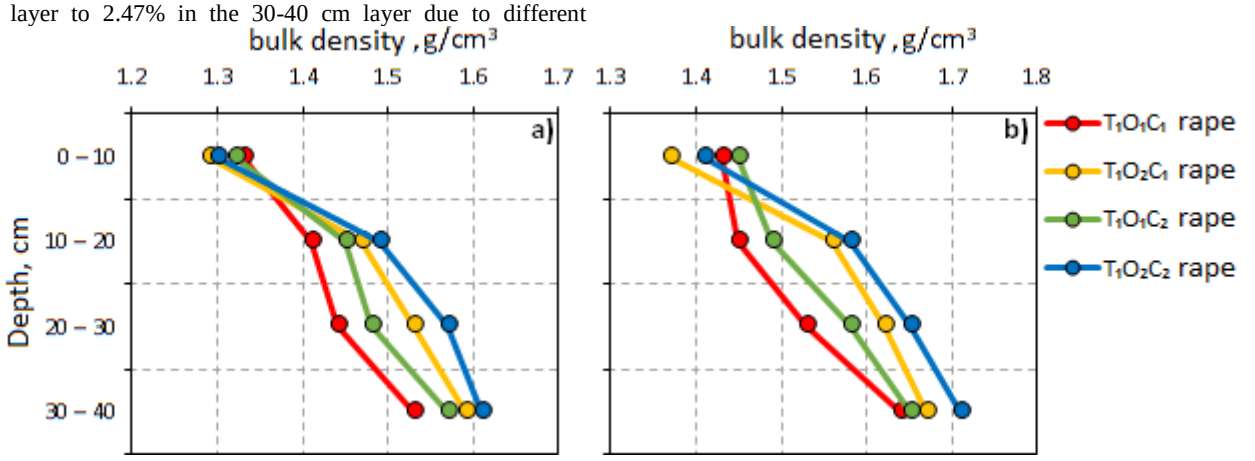


Fig. 2.*Soil bulk density g/cm^3 2015/2016 г. – rape [a) germination, b) before harvesting]*.

In the third year in the rape rosette stage it was found that after loosening to a depth of 35 cm the soil bulk density in the layer 10-20 cm was lower with 0.06-0.07 g/cm^3 of the lots with the residue and 0.05-0.09 g/cm^3 in the removal variants compared to the plowing at 20-25 cm (Figure 2, a). Prior to harvesting rape, the bulk density was high for the entire studied layer 0-40 cm (Figure 2, b).

Combining the effect of loosening with the use of plant residues from previous crops helps to lower the parameter values compared to those with plowing 0.08-0.11 g/cm^3 for the 10-20 cm layer and 0.07-0.09 g/cm^3 for the 20-30 cm layer, respectively for variants O_1 and O_2.

Taking into account the soil hardness, similar trends have been established with those of the bulk density. In the third year of rape growing, it was found that, after loosening, the values for this parameter were about 20 kg/cm^2 lower in the 20-30 cm layer compared to the tillage lots. Until the harvesting of the crop, the values increase significantly after the drought.

Effect on agrochemical characteristics of the soil: From the analysis of the taken field baseline samples, the content of digestible nitrogen in the soil layer of 0-30 cm was good and at a depth of 30-60 cm from satisfactory to good. A comparative uniformity of content from individual sampling was established. The content of mobile forms of phosphorus marks the same trend. From the agrochemical analysis it was found that potassium had a satisfactory quantity and no fertilization with this macroelement was planned.

After the completion of the vegetation of the first crop of crop rotation - grain maize, it was found that, despite high nitrogen fertilization rates and pre-existing soil reserves, the ammonia and nitrate nitrogen content was lowered. It can be assumed that a part of the nitrogen labile compounds are washed in depth of the soil profile as a result of the abundant supply of rainwater. From a content of 13.0-21.9 mg/100g of soil in the plow horizon, phosphorus decreases to 7.8-13.7 mg/100g of soil. With smaller differences, the content of digested potassium is also decreased. After barley vegetation, it is found that there is a satisfactory supply of digestible nitrogen. There is no reduction in nitrogen as a result of the denitrification activity of the micro-organisms. The content of digestible forms of phosphorus in the high fertilizer variants T_1 is higher with 1.2-1.7 mg/100g of soil compared to variants T2. The potassium content decreases in all tested variants.

In the third year, from the samples taken at the end of rapeseed's vegetation, the highest content of digestible nitrogen is in the variant with zero fertilization and use of the plant residues from the previous crops (T_0O) - 22.8 mg/kg, probably due to fewer harvested plants and lower yields. In the variants with plowing of plant residues the level of digestible phosphates increases - from 11.4 mg/100g after plowing to 16.1 mg/100g soil after loosening to 35 cm (Table 1). There is a tendency of decrease of phosphorus in the under layer in variants without plant residues (O_2).

Potassium decreases in the variants with removal of the plant mass - by 2.5; 4.6 and 5.6 mg/100 g of soil according to the fertilization options. This fact confirms the positive role of plant mass usage for improving the soil diversity diet - Planosols. The reaction of the soil solution is slightly acidic, and in the variants using the physiologically neutral and alkaline mineral fertilizers T_2 there is a slight tendency to raise the pH.

Table 1. *Agrochemical characteristics of Planosols in rape growing in 2016.*

Variant	Depth of the layer in cm	pH		∑ N-NH_4+NO_3	P_2O_5	K_2O	Hummus
		H_2O	KCl	mg/kg	mg/100gr		%
$T_0O_1C_1$	0-30	6,1	5,4	22,8	10,1	22,0	1,99
$T_0O_1C_1$	30-60	6,3	5,6	17,3	3,2	16,7	1,08
$T_1O_1C_1$	0-30	6,2	5,3	18,1	11,2	25,5	1,88
$T_1O_1C_1$	30-60	6,3	5,4	11,5	8,0	14,8	1,56
$T_2O_1C_1$	0-30	6,4	5,6	20,2	16,1	26,5	1,80
$T_2O_1C_1$	30-60	6,5	5,7	13,2	12,0	13,9	1,43
$T_0O_2C_2$	0-30	6,1	5,3	20,7	10,1	19,5	1,77
$T_0O_2C_2$	30-60	6,2	5,4	16,7	8,6	12,3	1,78
$T_1O_2C_2$	0-30	6,1	5,2	21,3	11,0	21,9	1,97
$T_1O_2C_2$	30-60	6,1	5,3	14,8	8,7	17,2	1,54
$T_2O_2C_2$	0-30	6,3	5,4	22,4	11,4	20,9	1,72
$T_2O_2C_2$	30-60	6,2	5,4	18,4	8,6	11,3	1,43

Effect on microbiological activity in the soil: In the Planosols, the highest amount of ammonifying bacteria was recorded in both treatments at the fertilization rate T_2. In the jointing phase of the barley growth, an increase in the amount of cellulose-producing microorganisms was detected in all variants when plowing plant residues.

Table 2. *Number of main groups of microorganisms in rapeseed rhizosphere at harvesting – 2016*

Variant	Ammonifying bacteria	Actinomycetes	Mineral nitrogen digesting bacteria	Microscopic fungi	Cellulose decomposing microorganisms
$T_0O_1S_2$	7.47 d	1.4 c	3.87 c	6.4 d	9.73 c
$T_1O_1S_2$	12.53 bc	3.67 b	9.07 b	7.47 cd	16.0 b
$T_2O_1S_2$	10.2 cd	0.53 c	5.33 c	25.07 a	9.93 c
$T_0O_1S_1$	11.2 cd	3.0 b	8.27 b	9.4 c	9.2 c
$T_1O_1S_1$	15.33 b	1.47 c	5.13 c	7.0 d	14.93 b
$T_2O_1S_1$	52.67 a	10.07 a	15.27 a	22.67 b	96.4 a

During the third year when in the deposition area was introduced plant mass from 669.4 to 1004.8 g/m^2 and good conditions were created for activating the activity of microorganisms in the soil. In the rosette formation stage in the rape rhizosphere an increase in the amount of cellulose microorganisms was registered in all variants with plawing of plant residues - higher in those with mineral fertilization.

In the ripe phase, the amount of ammonifiers is increased in all variants when plowing plant residues and the most noticeable at the higher fertilization rate (Table 2). Cellulose decomposing microorganisms increase at both fertilizer levels - more significant in higher T2. A general tendency for the experiment is the increase of the microbiological activity in the lots of the area with the plowing of the residues from the previous crops.

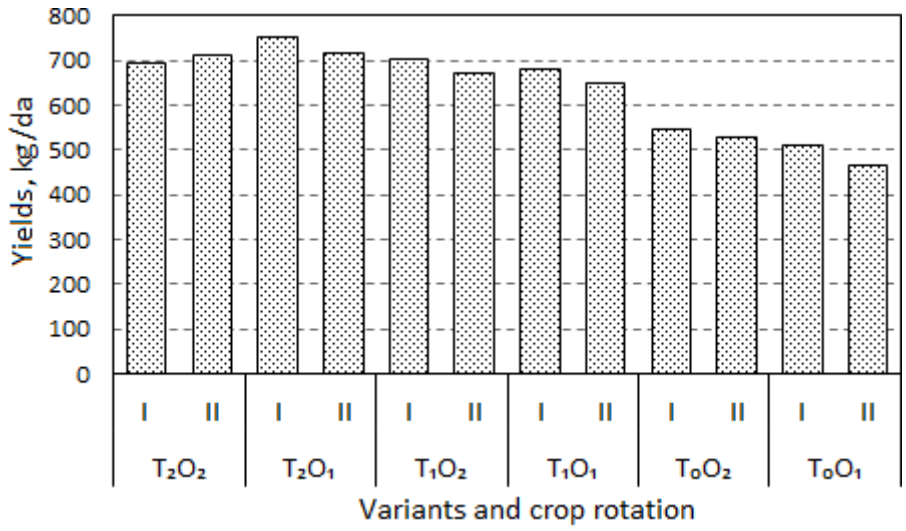


Fig. 3. *Yields grain maize kg/da experiment at Experimental Station on Irrigated Agriculture, Pazardzhik*

Effect on crop productivity: For the conditions of the studied area, yields are influenced by agro-technical factors.

In the first year of cultivation - grain maize, relatively high yields were obtained, with a yield of 694 to 751 kg / da (Figure 3) being obtained for the highest T_2 fertilization rate. The higher norm logically leads to an increase in yield, with differences between the fertilizer lots T_2 and T_1 from 37.8 kg/da to 71.1 kg/da.

Table 3. *Dispersion analysis of maize yield 2014.*

Source of variation	Sum of the squares	Sum of the squares %	Degrees of freedom	Average quadratic deviation	F-test	Level of significance
Fertilizing (F)	39801,812	80,363	2	19900,906	51,919	,000***
Processing (O)	2610,031	5,270	1	2610,031	6,809	,023 *
F*O	2516,271	5,080	2	1258,136	3,282	,073 -
Error	4599,722	9,287	12	383,310		
Total sum	49527,836		17			

Statistical data processing indicates that fertilization has the most significant impact on yields. Soil treatment has a negligible effect on yields. The impact of the interaction between the agrotechnical factors tested is also very low.

Table 4. *Dispersion analysis of barley yield 2015.*

Source of variation	Sum of the squares	Sum of the squares %	Degrees of freedom	Average quadratic deviation	F-test	Level of significance
Fertilizing (F)	34101.080	75,888	2	17050.540	79.505	0.000 ***
Processing (O)	2500.000	5,563	1	2500.000	11.657	0.002 **
F*O	1901.042	4,231	2	950.521	4.432	0.021 *
Error	6433.738	14,318	30	214.458		
Total sum	44935.860		35			

In the second year the increase of the yield is mainly due to the fertilization carried out. For barley, at three fertilization levels and two soil treatment systems, the dispersion analysis of the data shows that on the yields a significant effect on have both fertilization (probability of error p<0.1%) and soil treatment (at p <0.2%). The mutual influence of the two studied factors is also statistically proven (at p <5%).

For the rapeseed also the greatest impact on agro-technical factors has the fertilization. The highest yields are fertilization variant T_2 - in option O_1 after loosening 260 kg/da, and in option O_2 212,2 kg/da (Fig. 4). Compared to the non-fertilizing variants, the increase in the yield is 60.2% and 55% respectively for options O_1 and O_2. The application of loosening as the main treatment increases the yields compared to the plowing - 41.1 and 19.6 kg/da for the T_2 and T_1 fertilizer lots, and with 15.8 and 16.8 kg/da respectively for the residue removal area. With zero fertilization the differences are negligible.

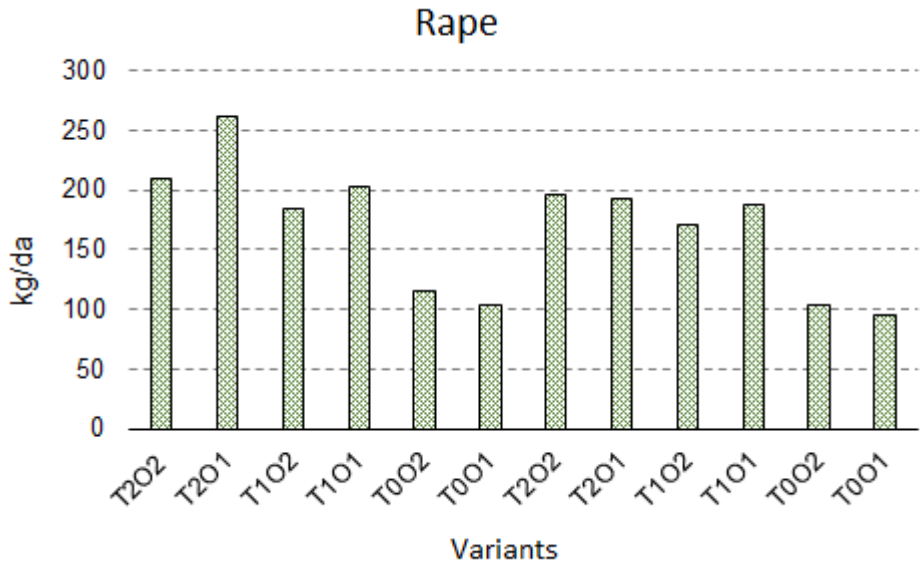


Fig.4. *Rape yield kg/da, Experimental Station on Irrigated Agriculture, Pazardzhik 2016.*

From the dispersion analysis, it can be seen that for rape, statistically fertilization has the highest impact on yields (p<0.1%). There are statistically proven differences between the average yields obtained from the different fertilization variants, as the fertilization rate increases as well as the yields (Table 5). Soil treatment has less impact on the yield value (p<1%), but as has been shown in other studies, it supports the effective impact of other agro-technical factors.

Table 5. Dispersion analysis of rape yield – 2016.

Source of variation	Sum of the squares	Sum of the squares %	Degrees of freedom	Average quadratic deviation	F-test	Level of significance
Fertilizing (F)	78261.744	85,408	2	39130.872	112.565	0.000 ***
Processing (O)	995.403	1,086	1	995.403	9.863	0.002 **
F*O	1946.832	2,125	2	973.416	4.300	0.027 *
Error	10428.838	11,38175,	30	347.628		
Total sum	91632.816		35			

Rape seed yield is also influenced by the use of plant mass. In variants O_1 (with the plowing of the available plant mass) and O_2 (with removal from the experimental area) differences in yields were obtained - with loosening and high fertilization rate of 48.8 kg, and after plowing with 23.4 kg, at the lower fertilizer rate of 16.4 kg and 13.5 kg respectively, and the smallest differences were recorded in the non-fertilizing variants - 8.5 kg and 11.0 kg, respectively.

CONCLUSIONS

Effective growth of crop yields of three-field crop rotation system maize-barley-rape is ensured by applying a treatment system including more intensive treatments, optimal fertilization, and plowing residual plant mass in the soil. The most significant is the impact of applied mineral fertilization with nitrogen and phosphorus. Lack of fertilization influences yields more significantly in rapeseed compared to maize and barley. The soil treatment system also has an impact on the level of yields obtained, better evidenced when growing oilseed rape.

The moisture content of the soil is mainly influenced by the type of treatment applied (loosening as a base and plowing as a pre-sowing) and by the use of plant residues. The excessive compaction found in the beginning of the experiment in the 25-40 cm layer is partly overcome by performing a deep loosening to the depth of 35 cm.

In spite of the short period of the study, there was a certain decrease in the content of digestible potassium forms and a slight increase in soil pH.

The results show the activation of the microbiological activity after plowing of the plant residues - an increase of the amount of the cellulose decomposing microorganisms and of the ammonifying bacteria, the most noticeable in the high fertilization rate and the intensive treatments.

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SUSTAINABILITY OF AGRICULTURAL PRODUCTION AND ITS IMPACT ON THE POLICY AND ENVIRONMENT

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Abstract :*The World Commission on Environmental Sustainability (1987: 43) identified sustainability as addressing current needs without compromising on the possibilities of taking the resources of future generations. Although this definition seems sufficiently well formulated, it has about 40 different definitions of the concept of sustainability in the context of policy actions and their implementation throughout the process.*
KEY WORDS: *SUSTAINABLE AGRICULTURE, ECOLOGY, AGRICULTURAL PRODUCTION SYSTEMS*

1. Introduction

The World Commission on Environmental Sustainability (1987: 43) identified sustainability as addressing current needs without compromising on the possibilities of taking the resources of future generations. Although this definition seems sufficiently well formulated, it has about 40 different definitions of the concept of sustainability in the context of policy actions and their implementation throughout the process.

2. Materials and method

O'Connor (1994: 153) divides the definition of "environmental sustainability" into three main categories such as to maintain the capitalist accumulation system, to maintain the necessities of human existence and to maintain the way of life by changing some of the facts. Maintaining distortions in the definition of sustainability also disturbs the political process and enables people with an interest to sustain the accumulated potential or lifestyle or change their already structured policy.

The only definition so far with minor changes is to maintain the need to live by applying two complementary components:

- to maintain the necessary level of environmentally friendly environment that ensures a sufficiently high quality of life;
- to create socio-economic conditions for people to reproduce.

However, there is socio-economic and environmental instability in the passage of labor from one sphere to another, as well as in the creation of some or other goods. This also implies another way of structuring societies and their activities. In these cases, the environment (in particular soils and waters) is treated as consumer goods that are subject to supply and demand.

The central player in this social system is an industrial company that seeks to reduce land investment (or rent) and labor (or wage) participation, but to increase its revenue when selling products.

This in practice means that the market becomes a basic social structure of modern society and a basis for the potential ideology of liberalism, socialism and other societies that are simply strategies for managing basic social structures.

Industrial firms are looking for ways to make costs internally and profit internationalize. The policy of a number of governments is aimed at defining and defending a political strategy to adapt the state approach to managing the efforts to internationalize the capitalist system.

The liberal system proclaims the self-regulatory functions of the market through the supply-demand relationship, the social system offers strong state support and intervention to protect the workforce from exploitation, and the third that labor must be sacrificed for the benefit of the nation. The neo-liberalism as an ideology proclaims the use of global resources on the planet as a strategy of capitalism.

The practical application is that in the first place companies are pursuing decentralization (dismantling or even dissolving) of production units to take advantage of the use of informal labor (those who are not united in trade unions, women, sometimes children, people are not good enough of education and, respectively, low pay).

When decentralization merges with the idea of using global resources, it leads to the creation of a new labor distribution - production is transferred to the workforce from the third world, and the consumption of the finished product - to the population of the first world.

At that time, the governments of the First World maintain and reconstruct the industry in their countries, while at the same time exhausting other resources and polluting the environment elsewhere on the planet.

Despite the benefits that some local forms of globalization offer in certain regions, the logical framework of global capitalism and transnational companies is anti-thetic and occupational and directed against environmental stability because they are built to exploit nature and the workforce (O'Connor 1998).

Some terms are not definable. 'Sustainable Society', 'Sustainable Industry', 'Sustainable Agriculture' and others are one of them. In such a rapidly changing world, how can something be sustainable? What do we want to keep? How can we set such an ambiguous goal? Is not it too late? Controversies and issues lead to a critical view of our current nutrition system and a serious, worrying future assessment. If nothing else, the term "sustainable farming" creates at least "themes of conversation", a sense of direction and an urgency that sparks a lot of exciting and innovative thinking."

The word "I support," from the Latin sustinere (sus-, below tenere, hold), I maintain existence, means long-term maintenance, permanence. Concerning agriculture, the word "sustainable" describes agricultural systems that "can sustain sustainably their productivity and utility for society". Such systems ... "must be economical, socially oriented, competitive on the market and environmentally friendly".

The term "sustainable agriculture" means an integrated system of farming and livestock practices with a site-specific application in the long term that:

• satisfies human needs of food and tissues;
• improves the quality of the environment and the basis of natural resources on which agriculture depends;
• uses the most effective non-renewable sources and available resources and integrates, where appropriate, natural biological cycles and controls;
• maintain the economic viability of agricultural operations; improves the quality of life of farmers and society as a whole.

How do we rethink food and fiber production in the light of sustainability? What are the environmental, economic, social and philosophical issues related to sustainable agriculture? The long-term viability of our current food system is questionable for many reasons. The mass media regularly presents us with paradoxical pictures of starvation in an abundance of food, such as hungry children, along with supermarket ads. Possible negative environmental effects on the part of agriculture and a growing number of food-borne illnesses also need our attention. "Farm crises" happen with recurring regularity.

The prevailing farming system, termed in various ways, such as "conventional agriculture", "modern agriculture" or

"industrial farming", gives high results in terms of productivity and efficiency. Global food production has grown over the last 50 years; The World Bank has estimated that between 70% and 90% of the recently grown food production is the result of conventional agriculture rather than larger arable land.

Karl N. Stauber and colleagues point out that conventional farming systems are different for different farms and countries. However, they have many common features:

• accelerated technological innovations;

• large capital investments for the application of production and management technologies;

• large-scale farms;

• Orientation to single crops / row crops grown without interruption for many seasons;

• uniform high yielding hybrid crops;

• Extensive use of pesticides, fertilizers and external inputs;

• high labor efficiency;

• dependency on agribusiness.

In livestock farming, most of the production comes from limited, concentrated systems. Significant negative consequences have emerged with the abundance associated with industrial farming. Issues related to modern agriculture are presented below. When considering these issues, the following should be considered:

• the relationship between agricultural systems and soil, water, the organic world and the atmosphere are complex - there is much to learn about their dynamics and long-term influences;

• Most environmental issues are tied to economic, social and political forces external to agriculture;

• some problems are on a global scale, while others are being tested only locally;

• Many of these problems are solved by conventional and alternative ways of farming;

• the list is not full;

• The list is not ranked by importance.

3. Environmental problems of agriculture

Agriculture affects a whole range of ecological systems. The negative impacts of current practices include the following:

• Decreasing soil productivity due to wind and water erosion of the surface layer; soil compaction; loss of organic soil, water-retaining capacity and biological activity; salinisation of soil and irrigation water in irrigated agricultural areas;

• Agriculture is the largest non-listed source of water pollutants, including sediments, salts, fertilizers / nitrates and phosphorus /, pesticides and manure. Pesticides of all chemical classes are often found in soil waters under agricultural areas; they are widespread in national surface waters. Eutrophication and "dead zones" due to food expenditure affect many rivers, lakes and oceans. Decreased water quality has an impact on agricultural production, drinking water supply and fish production;

• Water scarcity in many places is due to the excessive use of surface and ground water for irrigation without thinking about the natural cycle that maintains stable water availability;

• Other environmental damage includes over 400 insects and worms and more than 70 fungal pathogens that have become resistant to one or more pesticides; harmful effects on pollinators and other beneficial species through the use of pesticides; loss of wetlands and natural animal environment; and reduced genetic diversity due to genetic diversity in most animal cultures;

• It is only now that the link between agriculture and global climate change is being assessed. The destruction of tropical forests and other local vegetation due to agricultural production plays a role in increased levels of carbon dioxide and other greenhouse gases. Some recent studies have shown that soils can be sources or receivers of greenhouse gases.

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4. Economic and social issues

Economic and social issues related to agriculture can not be separated from external economic and social tensions. As obstacles to a sustainable and impartial food delivery system, however, problems can be described as follows:

• In economic terms, the history of Bulgarian agriculture includes relatively low government expenditure and corresponding participation of the state in investment decisions. Market competition is limited. Farmers have almost no control over agricultural production prices and do not receive any part of the buyer's money spent on agricultural products;

• The economic pressures have led to a huge loss of farms, especially small in size. This contributes to the disintegration of rural communities and localized market systems. Economically, it is very difficult for potential farmers to enter the business today;

• Impact on human health

Potential health risks are associated with the subtherapeutic use of antibiotics in livestock farming and water and pesticide contamination by pesticides and nitrates. Farmers are poisoned in the field, toxic residues are found in food, and some animal and human diseases have developed resistance to the antibiotics used.

5. Philosophical problems

Historic agriculture has played an important role in our development and national identity. Due to the last economic crisis, 30% of Bulgarians produce food for the whole population. Can sustainable and impartial food production be established when most consumers are almost unrelated to the natural processes of food production? What innate Bulgarian values have changed and will change with the decline of rural life and landslide? "Sustainable agriculture is a philosophy based on human goals and the understanding of the long-term impact of our activities on the environment and other species." The use of this philosophy guides the application of our past experience and recent scientific achievements to create integrated, sparing and impartial agricultural systems, Charles Francis and Gart Yongberg (1990) note that "These systems reduce environmental degradation, support agricultural productivity, support economic viability in a short period of time long-term and long-term, and maintain stable rural communities and quality of life.

"Sustainable" agriculture does not mean return to low yields or poor farmers in the 19th century, but rather, sustainability is built on modern agricultural achievements by adopting a sophisticated approach that can maintain high yields and farm profits without to undermine the sources on which agriculture depends. "

"The systematic approach" is important for understanding sustainability.The system is considered in the broadest sense, from the individual farm to the local ecosystem and the communities affected by this agricultural system both locally and globally.The systemic approach gives us the tools to explore the interrelationship between agriculture and other environmental aspects ".

"Environmental sustainability" means:

• Meeting the basic needs of all peoples as a priority, to satisfy the appetites of a small number;

• keeping the population density, if possible, below the region's eligibility;

• setting consumption patterns and setting up management systems to enable renewables to be restored;

• preservation, recycling and setting of priorities for the use of non-renewable sources;

• Maintaining the environmental impact below the level required by the affected systems to recover and continue to develop.

"Ecologically sustainable agriculture is what is compatible and consistent with the above-mentioned criteria."

To help identify these real issues, one can distinguish between shallow (short, symbolic) and deep (long-term,

fundamental) sustainability. Shallow resilience focuses on resource efficiency and substitution strategies. It usually perceives the leading goals in society unreservedly and aims to solve the problems through healing solutions. Deep resilience, on the contrary, reassesses the goals of higher values and processes the systems to achieve these goals so that it can be done within ecological limits.

Sustainable agriculture is a "way of farming that seeks to optimize the skills and technology to achieve long-term stability of the farm, environmental protection and consumer security, through management strategies that help the manufacturer to select hybrids and varieties handling soil conservation practices and pest control programs The goal of sustainable agriculture is to reduce the harmful effects of the direct and bypass environment whilst ensuring sustainable level of production and profit. Robust resource conservation is an integral part of the means of achieving sustainable agriculture. "

Today, sustainable farming practices usually include:

Crop rotation, which reduces weeds, diseases, insects and pests; provides alternative sources of nitrogen in the soil; reduces soil erosion; and reduces the risk of polluting water with chemicals for agriculture.

- Pest control strategies that do not harm natural systems, farmers, their neighbors, or consumers. This includes integrated pest management techniques that reduce the need for pesticides through practices such as pre-research, the use of resistant cultivators, precise sowing time and biological pest control;
- increased mechanical / biological control of weeds; more practices for soil and water protection; and strategic use of livestock and green manure;
- use of natural or synthetic additives in a way that does not pose a serious threat to humans, animals or the environment.

This approach encompasses the whole farm by relying on farmers' knowledge, interdisciplinary teams of scientists and public and private sector specialists.

- Sustainable agriculture is a model of social and economic organization based on an impartial and committed vision of development, which recognizes ecological and natural resources as the basis of any economic activity. Agriculture is sustainable when it is environmentally sound, economically viable, socially just, culturally appropriate, and based on a holistic scientific approach;
- Sustainable agriculture supports biodiversity, soil fertility and water purity. It preserves and improves the chemical, physical and biological properties of the soil, recycles natural resources and preserves energy. Sustainable agriculture produces high quality food, tissues and medicines in a variety of forms;
- Sustainable agriculture uses local renewable resources, suitable and cost-effective technologies, and reduces the use of external and purchased supplements, thus increasing local self-sufficiency and self-sufficiency and providing a source of permanent income for peasants, their families, small farmers and rural communities. This allows more people to stay on the ground, strengthens rural communities and integrates people with their environment.

Sustainable agriculture respects the ecological principles of diversity and interdependence and uses the insights of modern science to refine and not to replace the traditional wisdom accumulated over the centuries by an endless number of farmers around the world.
Sustainable agriculture does not use prescribed practices. Instead, it induces manufacturers to think about long-term implementation of practices and the broad synergies and dynamics of farming systems. It invites consumers to take an active part in farming by learning more and becoming active participants in their food systems. The main objective is to understand agriculture from an ecological point of view - from the point of view of nutrients and energy dynamics, as well as the interaction between plants, animals, insects and other organisms in the agroecosystem. All this has to be balanced with profits, public and consumer needs.

Sustainable agriculture is a holistic-systemic attitude towards food, nutrition and other tissue industries that balances ecological stability, social equity and economic viability across all sectors of society, including international and age groups. Inherent in this definition is the notion that sustainability needs to be expanded not only globally but also for an unlimited period of time, and to reach all living organisms, including humans. “Sustainable agro-ecosystems” maintain their natural resource base, rely on minimal extra-farm benefits, fight pests and diseases through internal regulatory mechanisms, and recover from harvesting and harvesting disturbances.

6. The Future of the Sustainable Agriculture Concept

Many representatives of the farming community have realized the urgency and direction outlined by the concept of sustainable agriculture. The lack of a precise definition has not diminished its authenticity.

Sustainability has become a major component of many government, commercial, and non-economic efforts for agricultural research. It is becoming an integral part of agricultural policy. An increasing number of farmers take on their own paths towards sustainability, including related and innovative approaches in their own businesses.

Critical discussions on the concept of sustainable agriculture will and should continue. Understanding will deepen; will continue to give answers. Continuous dialogue is also important for another reason: with more participants, each with their own agenda entering the "tent", only continual concentration on real issues and goals will prevent sustainable agriculture from turning it into such a comprehensive idea that it will become meaningless. Yongberg and Haru's 1989 assertion still sounds true: "We are still far from knowing what methods and systems at different locations will bring sustainability ... In many areas of the country, however, as well as many cultures, the specific combination of methods that will allow to limit the use of harmful chemicals or to create a variety of crops, thus ensuring economic success, is still unclear, and challenges have been prepared not only for practitioners but also for researchers, lecturers agricultural industry. " Sustainability is both extremely important and practically unnecessary. It consists of a set of ideas that are fundamentally different in nature. Therefore, until now, there has been no success in giving a single definition of sustainability. There can not be a satisfactory definition that is not varied. This poses serious difficulties for the practical application of sustainability as an objective in the actual decision-making process.

To conclude: A number of researchers (David Panell and Steven Shilliy (1999)) suggest that these difficulties should be addressed by focusing on the specific aspects of sustainability that the decision-maker considers important and providing information on the replacement of these aspects within the decision-making formula with multiple criteria.

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TECHNOLOGICAL PROCESSES AND STAGES OF PLANT GROWTH AND DEVELOPMENT

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Abstract: *The importance of agriculture lies in the fact that its organic substances are an irrevocable source of energy without which the existence and everyday life of man and a substantial part of the animal world are impossible. Man, as a higher biosystem, defines the nature and importance of agriculture as a production sector.*
KEY WORDS: *PLANT GROWTH, NATURE, DEVELOPMENT*

1. *Introduction*

The importance of agriculture lies in the fact that its organic substances are an irrevocable source of energy without which the existence and everyday life of man and a substantial part of the animal world are impossible. Man, as a higher biosystem, defines the nature and importance of agriculture as a production sector.

2. Materials and method

The main technological processes to be carried out in field production with the necessary quality and volume in the cultivation of crop production are mainly fertilization, mainly soil reversal, pre-sowing soil treatment, sowing, care during vegetation and harvesting. Their success, as well as the technique used, depends on the success of the entire production in agriculture. The logical framework of the technological sequence is presented 1.

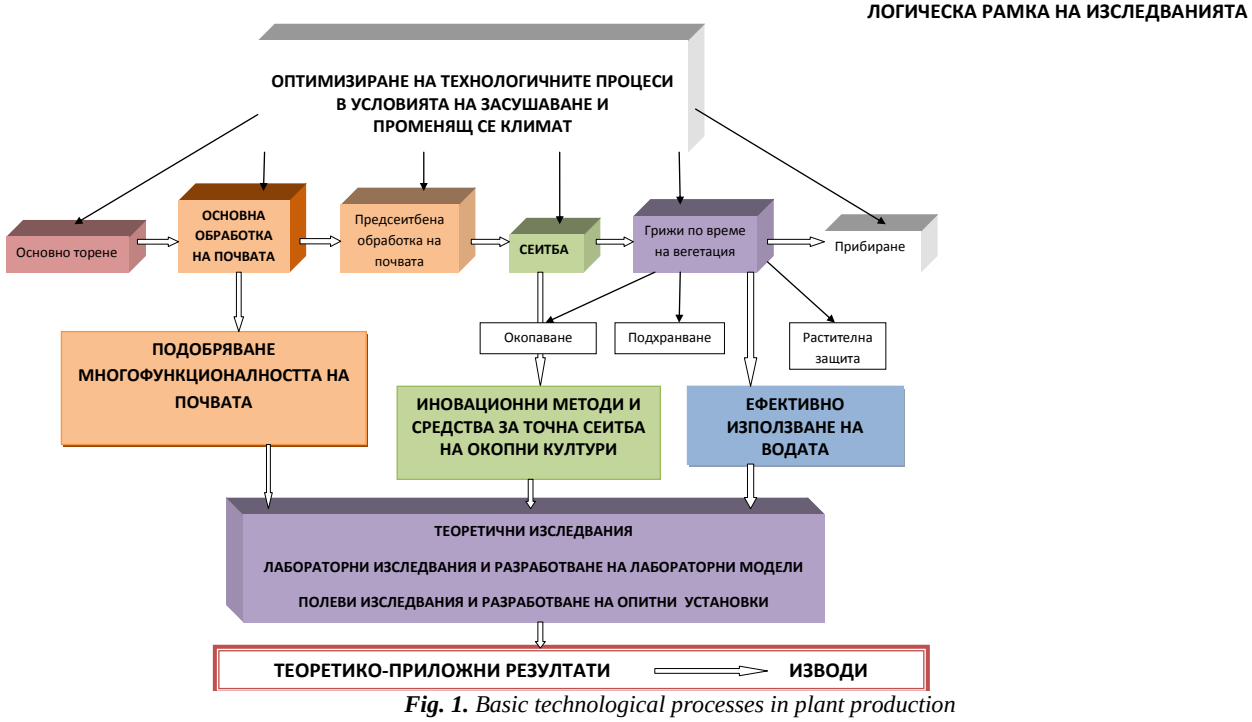


Fig. 1. *Basic technological processes in plant production*

Coordination of technological processes with the biological features of plants
Successful activity in the field of agricultural production would be a real magnitude if we take into account and determine the correlation between the growth and the development of the plants applied technological processes.

In crop plants, the following more important phases are known: sprouting, germination, third leaf, braking, spraying, decapitation, flowering, grain formation and pouring, and maturation, fig.2.

For their proper development correspond technological processes, which should be carried out in optimal agrotechnical terms and with the necessary quality.

The main fertilization, the basic and the pre-sowing treatment of the soil ensure the execution of quality sowing. After the sowing, the first germinating phase is activated, ($\bar{}$AB of Figure 2). It begins with the swelling of the nipple and ends with the appearance of the germ root and swears. Optimum moisture, temperature and oxygen are needed for seed germination and their values vary by crop type. For the sap, the seeds should absorb about 50% of their mass.

The second most important factor is the temperature. It has been proven that wheat and barley can germinate at 1-2 oC. The lower the temperature, the slower the germination occurs and vice versa.

The presence of oxygen has a significant effect on germination. Its absence stops the conversion of insoluble substances into soluble and the seed does not germinate. The air is insufficient in the over-moistened heavy, fractured and formed crust soils.

In the conditions of Bulgarian agriculture, the biggest problem is the humidity, especially in winter cereal crops. On dry soil the seed may remain for a long time without damaging it. Seed sowing is very dangerous in so-called. "Colorful moisture" where part of the seeds germinate and die, resulting in a rare and uneven crop.

The second phase, depending on the above factors, is germination, (before point B). Under favorable conditions, grain cereals germinate for 1-2 weeks. Example: Corn root system evolves rapidly. When the plants are 0.02 m high above the soil surface, the roots have already penetrated to a depth of 0.15 - 0.20 m. Up to 0.07 m - they are already at a depth of 0.30 m. Once they appear, the primary roots are routed horizontally, penetrate 0.25-0.30 m to the side and then curve and point downwards. An important feature is that the primary roots should be protected from

injury, causing disturbance to growth. The distribution of the root system in depth and sideways depends both on climatic conditions and on those created in the soil, depending on the applied soil cultivation technology. The choice of variety or hybrid also affects.

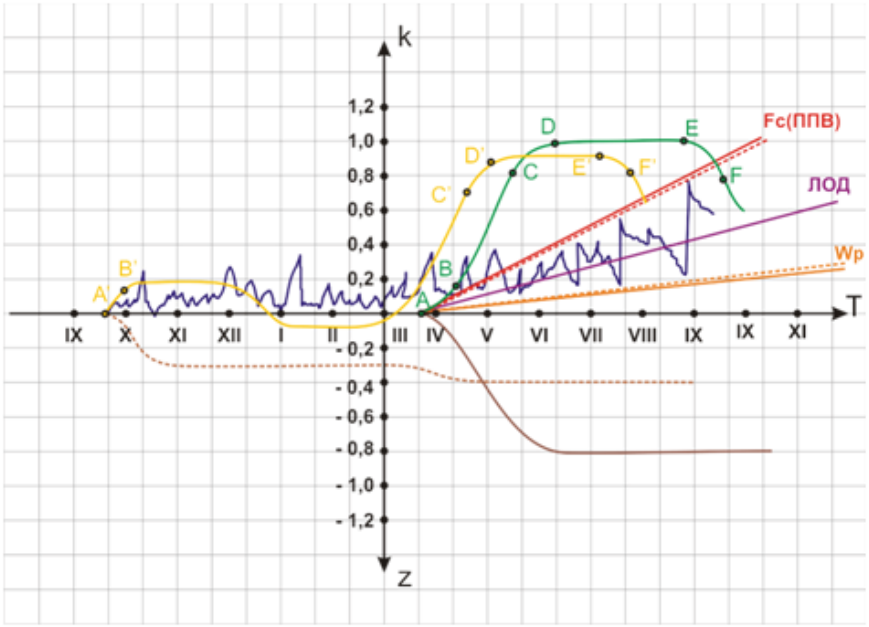


Fig. 2. *Coordination of technological processes with the stages of growth and development of plants green color - annuals; yellow color - wintering. point A - sowing; ¯AB - period of germination and germination; - beginning of a third-phase phase; ¯B a period of rapid growth; tC - beginning of braking, (spindle, flowering); ¯D - yield betting period; ieD - shaping of the teats, (class, cat); ¯DE - accumulation of yields; ie - reaching technological (waxy) maturity; ¯EF - optimal agro-technical time for harvest; F - completion of the cultivation and harvesting technology of a given crop and preparation of the next crop*

Consequently, depending on the biological pests of crops grown, a specific technology for plant nutrition, soil cultivation and sowing should be applied.

Typically, about 30-35% of the keno system is located in the 0-0.05 m layer, 50-60% at a depth of 0.35-0.55 m and about 10% in the deeper layers. This feature should be taken into account when determining the type and depth of soil treatment.

From the point C (beginning of flowering, twisting, grinding) there is another critical period related to the presence of sufficient nutrients and water, although the availability of sufficient water is an important condition. In the climatic conditions of the Republic of Bulgaria, the optimum soil moisture must be maintained in the bush 70-75% of the MFA. During blooming (spraying, grinding), soil moisture should be 80-85% of PFF in the soil layer to a depth of 0.50 m. The amount of water required depends on calculating the water balance in the soil, reaching values of 600 - 670 mm.

After shaping the clams, the soil and the nutritional status of the soil should be maintained around the optimum yield line (Figure 2 - LOD).

Stages of plant development and their water needs

Interest in modeling of processes is the development of annual plants, which are the main representatives of plant growing.

Three phases of development can be distinguished during their vegetation period - an exponential phase, a phase of full development, and a phase of maturation and dying growth. (Figure 3)

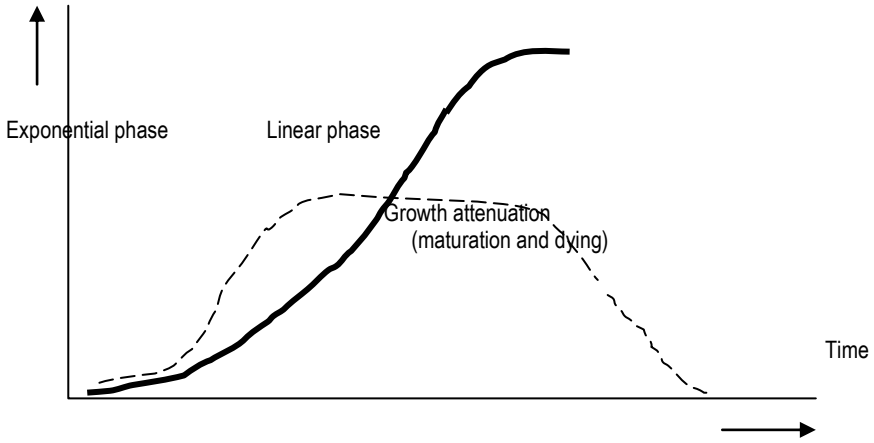


Fig. 3. *Schematic representation of the growth of annual plants as a function of time (dashed line and accumulation of biomass over the three periods - continuous line*

In mild climate conditions, the three phases of development usually coincide with the spring, summer and autumn seasons. They also limit the length of periods.

Figure 3 presents some quantitative features over the three development seasons. The links that are used refer to the overall development of plants and describe the model in its entirety. They

are the basis for a deeper analysis that can be done when physiological processes are dealt with in detail.

The main methods for classical analysis of plant growth and development can be applied after relatively more schematic models are developed.

3. Phases of growth and development

When plants are in their exponential phase of development, most of the space around them is still not filled with other plants. The appearance of each new sheet helps to absorb more light and thus increases the growth rate of the plant. There is still no overshadowing and the contribution of the newly formed leaves is assumed to be equal to that of the existing ones. Therefore, the growth rate remains unchanged. Plants are still green in this exponential part. Later, when the leaves begin to gradually self-glance and the leaf index (LAI) reaches 3 m^2/m^2 or more, the newly formed leaf surface contributes to a large extent to the absorption of the light rays. From now on, this first (exponential phase) goes into the phase of linear development. This does not mean that the index will no longer increase. When optimal amounts of water and nutrients (especially nitrogen) are present, LAI may reach values of 6 m^2 or more, but these values do not contribute to the accumulation of additional biomass, growth remains linear. During this period dry matter build up.

The final phase of plant growth begins when it begins to reduce the absorption of light from the leaves and the leaf index value falls below 3 m^2/m^2. The LAI reduction, for example, of 6 m^2/m^2 means that the process of transferring nutrients from the foliage to the storage organs (grain, roots, tubers, etc.) has begun. Holding LAI at values slightly higher than m2 / m2 has a relatively small effect on plant growth. Values below 3 m^2/m^2 show a strong reduction in plant growth and degeneration of the photosynthetic system. There are also slight differences in the accumulation of dry matter when the yellowing leaves remain on the plant. This can be observed in cereals.

Figure 4 shows the relationship between dry matter accumulation and leaf index of plants. The dry mass w accumulates as a value s that can be calculated during the exponential phase by data for itself or by the value of the relative increase rm. During the linear phase s depends on the maximum linear increment cm. Therefore, c can be determined by the amount of absorbed light I, which in turn is dependent on LAI.

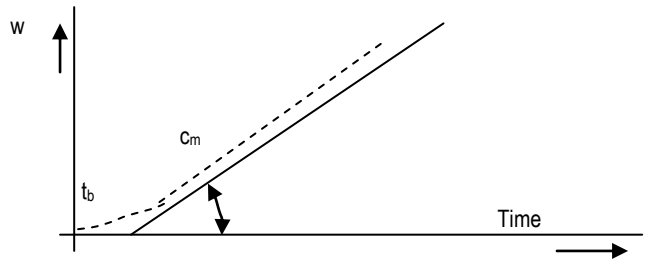


Fig.4.*Exponential growth curve (w - accumulation of biomass, [gm-2], cm - the maximum increase value, [g m-2 d-1], tb - the moment when the linear development phase begins [d]*

LAI can be defined in two quite different ways:

• One is by using the relationship between the leaf area and the accumulated dry matter, so *dL/dt* depends on *c*;

• The second is to use the temperature instead of *dL/dt* to determine dry accumulation values. These two ways are extremes that can be used, but there are a number of others. Who to implement is a matter of experiment and analysis of results.

For the first (exponential) development phase the equation describing the exponential development of plants is:

$$\frac{dw}{dt} = wr_m \qquad [g\ m^{-2}\ d^{-1}]; \qquad (1)$$

$$w = w_o e^{(r_m t)} \qquad [g\ m^{-2}] \qquad (2)$$

where:
w is the accumulated biomass, [dry matter, gm^{-2}];
w_o – the start of the biomass accumulation, [gm^{-2}];
r_m - the value of relative biomass accumulation during plant growth, [$gg^{-1}d^{-1}$];
t – the time, [d].

Exponential development is only possible when the plant cover is relatively small or approximately when about 100 gm^{-2} biomass is accumulated. The value of relative biomass accumulation during plant growth, r_m, is completely dependent on temperature, solar radiation and the type of crop. The numerical value is r_m = 0.1 $gg^{-1}d^{-1}$ at the beginning of the period. Doubling of the value can be expected after one week (ln (2) /0.1d) and tenfold increases in 23 days (ln (10) /0.1d).

Linear phase of plant growth

The equation for the linear phase is

$$\frac{dw}{dt} = c_m \qquad [g\ m^{-2}\ d^{-1}]; \qquad (3)$$

$$w = c_m (t - t_b) \qquad [g\ m^{-2}] \qquad (4)$$

where:
w is the accumulated biomass, [gm^{-2}];
c_m - maximum growth value, [$gm^{-2}\ d^{-1}$];
t – the time [d];
f_b - the time of the plants entering the linear phase, [d].

The determination of the time of plant passage in its linear phase of development is based on observations. The beginning of this transition is the day when the plant cover completely covered the soil.

The easiest way to determine the amount of biomass accumulated at this time is by comparing the values obtained at the exponential and initial stages. For practical purposes, it can be assumed that the moment of transition has occurred when the maximum growth value (cm) reaches values of 20 [$gm^{-2}d^{-1}$]. If we take into account the relative growth value, which is 0.1 [$gg^{-1}d^{-1}$], 200 $gm^{-2}d^{-1}$ accumulated biomass will be obtained at the time of the linear phase transition.

Transition from exponential to linear growth

If it is assumed from a purely theoretical point of view that plant growth can be divided into a purely exponential and purely linear phase, the moment of transition from one phase to the next could be described by equality:

$$r_m w = c_m \quad [g\ m^{-2}\ d^{-1}] \qquad (5)$$

The ratio values $\frac{c_m}{r_m}$ determine when the transition from one phase to the other occurs. The amount of biomass that accumulates to reach this ratio is assumed with the same productivity as the one already accumulated, whereas after the critical point has passed, the accumulated biomass no longer influences the increase in the growth rates. This kind of growth process is not very common. An example of this is the plants that have leaf rosettes and horizontally arranged leaves and vertical standing. In this case, each new sheet absorbs the same amount of light as when the whole soil surface covers a plant cover.

In practice, when sorting the leaves, distribution is seen to

absorb more light, but mutual shading will arise from planting upward. This gradual transition can be described by an exponential growth equation.

$$w = \left(\frac{c_m}{r_m} \right) \ln\left(1 + e^{r_m (t - t_b)}\right) \qquad [\text{g m}^{-2}] \qquad (6)$$

Equation 6 gives an accurate description of the moment of transition from the exponential to the linear phase.

It is known that the process of plant photosynthesis and transport of asymylates to plant organs and tissues depends entirely on the intensity of light. This part of the light rays that reach the surface of the soil is a loss for photosynthetic activity usually reduced in exponential dependence on the foliar index of plants (LAI).

$$I_b = I_o e^{(-K*LAI)} \qquad [\text{J m}^{-2}\,\text{s}^{-1}] \qquad (7)$$

where:
I_b is that part of the photosynthetic active radiation that reaches the surface of the soil and is a loss for the plants, [PAR, $Jm^{-2}s^{-1}$];
I_o – the photosynthetic active radiation,, [PAR, $Jm^{-2}s^{-1}$];
K –the radiation attenuation factor, [m2 soil surface, m^{-2} leaf surface];
LAI – the index [LAI, m^2 leaf area, m^{-2} soil area].

The degree of light absorption increases with increasing LAI, thus increasing the value of the assimilates. But if it is expressed through LAI, growth will gradually decrease. The value of K depends on the light, the positioning of the leaves and their characteristics. For PAR values, K = 0.7 is taken as the mean value.

The Monteith (1981) trials show that daily growth rates correlate with the daily amount of light absorbed by plants. Since PAR is about 50% of the total solar radiation, the calculation can be used for the convenience of calculations.

Monteith determines the relationship between PAR and total radiation.

$$\alpha = \frac{PAR}{GR} \qquad (8)$$

Expressed in this way, it takes values between 0.8 for leguminous crops and 1.5 [$\mu g J^{-1}$] for mixed crops (wheat).

Maximum growth rates, c_m, can be established if they are proportional to $I_o (c_m = \alpha I_o)$ and then dependence can be obtained:

$$\frac{dw}{dt} = f c_m \qquad [\text{g m}^{-2}\,\text{d}^{-1}] \qquad (9)$$

where:
f is the fraction of the total radiation absorbed by the plants expressed by the exponent of LAI and the radiation attenuation factor:

$$f = 1 - e^{(-K*LAI)} \qquad (10)$$

The method for assessing plant growth values works well if:

- a known LAI. LAI can be determined by measurements during vegetation by direct measurements or destructive (plants are destroyed after measurements);
- the intensity of light above and below the plant cover is known;
- using modern remote measurement technique (satellite connection).

The cost of obtaining this data is considerable.

Another approach that could be used if there is no instrument for direct measurement of the leaf area without destroying the plant is the introduction of a supplementary unit weight - leaf weight index (LWR). It is a ratio of the total leaf biomass relative to the total dry matter mass of the whole plant. This quantitative approach can be realized by periodic harvesting of plants (destructive method).

The same approach can be applied to the so-called a specific leaf area (SLA) that grows in the ratio of the leaf area and the accumulated biomass in the leaves of the plants.

The same characteristics can also be obtained by using static and dynamic coefficients describing the state of the dry matter and the specific leaf area. The static coefficients refer to the total amount of dry matter accumulated and the dynamic ones to that accumulated in the last formed leaves.

Models describing the growth and development of plants
The main task of the developed models describing plant growth is to enable the description of a possible larger number of crops. At the same time, each culture has unique values of the parameters included in the models.
The actual growth of plants from sowing / planting to harvesting depends on the accumulated temperature.
A Mitchel equation was used to describe the temperature model (Mitchel G. et al., 1997).
The growth of plants from a given crop is based on the accumulated daily temperature.

$$HU_k = \sum_{\kappa=1}^{n} \left(\frac{T_{\max,k} + T_{\min,k}}{2} \right) - Tb_{,j} \qquad \text{HU}_k \geq 0 \qquad (11)$$

where:
- HU_k is the amount of heat accumulated during the growing season;
- $T_{max,\,k}$ - maximum temperature on day k, [^{o}C];
- $T_{min,\,k}$ - the minimum temperature on day k, [^{o}C];
- $T_{b,\,j}$ - the specific temperature above which is observed for culture development j, [^{o}C]; (no development below or equal to that temperature T_b);

n - the number of days in the growing season.

Perennials maintain their root system throughout the year, although they may be forced to rest if severe colds occur. They resume development when the average daily temperature exceeds the temperature minimum.

$$HUI_i = \frac{\sum_{k=1}^{i} HU_k}{PHUj} \qquad (12)$$

where:
- HUI_i is the heat index for day i;
- PHU_j - the potential thermal minimum required to maintain a culture j.

The heat index changes from 0 at sowing to 1 at harvesting 1.0. The PHU values can be calculated using the model for the normal sowing and harvesting dates. The harvest date, leaf growth and ripening, optimal nutrient concentration, and distribution of accumulated dry matter between the roots, stem, leaves, and yield are influenced by HUI. In a number of cases, information can be found in the reference literature.

This approach is used to segment crops according to their specific heat and climate requirements in a given region or country.

Potential development of plants

The arrival of solar radiation is determined by the law of Beer, expressed by the following.

$$PAR_j = 0.5(RA)_j\left[1-\exp\left(-0.65LAI_j\right)\right] \quad (13)$$

where:
• PAR_j is the total solar radiation reaching the surface of the leaves for day j, [MJ m^{-2}]; (Rn)
• RA_j - the denticulated radiation for day j, [MJ m^{-2}]; (R5)
• LAI_j – the leaf area index for the day j.

The constant 0.5 is used to convert solar radiation into photosynthetic active radiation (Monteith, 1973). Attempts show that the declining coefficient changes and depends on plant cover, sunlight, line spacing, line orientation, and latitude. (Thornley, 1976). Values around *f* (0.65) are typical for crops with small line spacing (Uchijima et al., 1968). Smaller values (0.4 - 0.6) refer to tropical areas where the average sun angle is high and the line spacing is greater. (Begg et al., 1964; Bonhomme et al., 1982; Muchow et al., 1982).
Using the (Monteith, 1977) approach, the potential daily growth of biomass can be determined by the equation:

$$\Delta B_{p,j} = 0.01(BE)_j(PAR)_i \quad (14)$$

where:
• Δp is the daily potential growth of biomass, [t/ha];
• BE – the plant parameter to convert energy into biomass, [kg/ha MJ/m^2]
• The conversion of energy into biomass depends on the vapor pressure deficit (VPD) and the level of CO^2 in the atmosphere.

The plant parameter for converting energy into biomass BE is determined by the Stockle equation (1992)

$$BE^* = \frac{100CO_2}{CO_2 + \exp\left(bc_1 - bc_2(CO_2)\right)} \quad (15)$$

where:
• CO_2 is the level of CO_2 in the atmosphere, [ppm]
• bc_1 and bc_2 are the parameters of the culture.

The correction of the VPD vapor pressure can be done with the equation:

$$BE = BE^* - bc_3(VPD-1) \qquad \text{VPD} > 0.5 \quad (16)$$

where:
• VPD is the vapor pressure deficiency, [kPa];
• bc_3 - the parameters of the growth plants.

4. *Conclusions*:

All plant growing processes are important, but the planting is among the first. Ensuring favorable conditions for joint emerging lead to normal development of all plants and based on that the technologist can implement other processes on time and to reduce the yield losses.

The space and soil volume that each plant need for its normal development can be ensured y the correct adjustment of the planting machine. So, the LAI and other parameters will depends on this action and the plant growing models can be build accordingly.

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