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Substantiation of the process of deep tillage with agricultural machines of digging type

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Abstract: The paper considers the issue of deep tillage, the use of the latest technical advances, in order to develop new tillage implements that provide better tillage and reduce erosion. The main attention is paid to the preservation of soil fertility and the use of funds in organic farming. The aim of the work is to improve the process of mechanical tillage by digging by developing a new working body and the process of interaction of digging working bodies with the soil, which change its physical properties and improve environmental safety. The most promising for deep tillage is the digger in terms of both energy and agronomic indicators (reduction of compaction, preservation and restoration of water and air balance, preservation of humus, preservation of biomass). Rotary diggers with rotational movement of working bodies are more effective in comparison with diggers having oscillating movement of working bodies. As a result of studying the dependence of the angle of the blades, providing the movement of the formation on the surface of the working body, from their position on the trajectory, it was found that the smallest value (5...7°) is the angle of inclination after turning the blade deepening. When lifting the formation from the bottom of the furrow to a certain height, the required angle of the blades increases, reaching a value of 28...30° when overturning the formation at a height of 0.20...0.25 m

KEY WORDS: DEEP TILLAGE, DIGGER, ENERGY CONSUMPTION, DEGREE OF GRINDING, DEPTH OF CULTIVATION

1. Introduction

In modern conditions, tillage remains the most important element of the agricultural system, which provides regulation of arable land productivity and energy consumption, preservation of the top layer of soil from erosion, increasing soil fertility.

When developing the optimal method of mechanical tillage, any landowner pursues one main goal - to create an optimal arable layer for growing crops. In this process, an important factor in quality tillage is to improve its structure, physico-chemical properties and provide the necessary water-air regime, which ultimately contributes to increasing soil fertility.

The main role in increasing soil fertility belongs to biological processes, the activity of which depends on its water-air regime and, accordingly, on the method of mechanical tillage. Therefore, the correct choice of treatment method is the most important means of regulating the vital activity of soil microflora, its number and species composition.

The main tillage is the most energy-intensive in modern agriculture, which involves preparing the soil for normal germination and development of cultivated plants. Paying attention to the invention of new, more advanced tillage bodies can have a great influence on the development of agriculture, improve the condition of soils, reduce the energy intensity of tillage, improve fertility.

The following scientists made a great contribution to the search for fundamentally new methods of tillage: Listopad D.N., Novikov Yu. F., Nadytko V.T., Oleksin V.O., Vasylenko P.M., Dalin A.D., Babiy P.T., Sokolov V.M., Dokin B.D., etc.

To provide plants with sufficient moisture, minerals and compliance with other agricultural requirements, there are four following main functions that must perform tillage tools:

First, the tool must loosen the soil to a certain density, as deviation leads to a decrease in plant yields.

Second - to turn the plow layer. However, agronomic requirements do not recommend such an operation for all cases and not for all climatic zones. However, the inversion of the arable layer in most cases is a useful operation that allows you to earn in the soil the upper layer of soil damaged by tractor running gear, crop residues, stubble and weed seeds.

Third, mix and level the soil layer, creating a looser structure in which fertilizers are evenly distributed.

Fourth - level the ground. Waves and ridges interfere with the operation of machines, create uneven water regime, increase evaporation, increase air erosion.

In connection with the above, more and more attention is paid to the means of tillage with active working bodies - rotors. If the traction efficiency of the tractor does not exceed 65...75% when working with the plow, then when working with traction-drive machines with energy transfer through PTO, the traction efficiency increases significantly [6].

In addition to the traditional principle of tillage by wedge cutting, which is used in plowing, scientists have identified seven different ways to grind the soil.

When designing tillage machines, you should try to create conditions for grinding with the lowest energy consumption, for which you should pay attention to the phenomena of friction between the surface of the working body and the soil.

Interesting in this regard is the application in tillage machines of the principle of grinding on the "cross sections of weak bonds", which is as follows. Instead of destroying the soil layer along the cross-sections caused by the tractors of the working bodies, which we call cutting, it is divided into parts of indefinite shape along the weakened cross-sections formed by cavities - cracks and porosity in the soil. This reduces the overall energy consumption of the process.

The following positive factors are a convincing factor in favor of diggers:

1. When digging, no plow sole is formed. As a result, precipitation penetrates more freely into the lower horizons, improves water permeability and soil aeration, the development of the root system of plants, the inflow of moisture and nutrients from the lower horizons.

2. After cultivation by diggers in the field there are no dumping ridges and collapsible furrows that excludes need of additional processing.

3. A large number of micro-depressions remain on the soil surface, which contribute to the retention of precipitation.

4. The diggers have a separate drive, which reduces the traction force required for operation and helps to reduce the traction class of the tractor for aggregation.

When tillage by rotary diggers, the translational movement of the unit is performed simultaneously with the rotational movement of the working body, which significantly increases the intensity of the impact of the working body on the soil. During this process, the length of the cutting path is of great importance, which varies in rotary machines from 0.03 to 0.3 m. In the first tillage machines with a mechanical drive, the working bodies performed a reciprocating motion and had the shape of shovels or forks. This is due to the fact that the scientists who invented such a machine followed the path of imitating manual techniques. [7].

2. Preconditions and means for resolving the problem

An important element of the farming system is the tillage system. The importance of mechanical tillage is due to the effect on all its properties and the presence of terrestrial factors of plant life, which determine fertility. Improper tillage causes significant damage to it, reducing potential and effective fertility. Observations
of scientists have established the levels of impact on the yield of cultivated crops of agronomic measures with their joint use: soil fertilization - 50%, tillage - 20%, varieties - 10%, protection against pests - 20% [1].

Intensive use of systematic plowing of soils in Ukraine in the 60's and 80's, even against the background of organic and mineral fertilizers, was not the last reason for a significant reduction in the amount of humus in them. Its average content in soils for these 20 years decreased from 3.5% to 3.2%, which is 1...2% less than the optimum [2].

In the country now 48% of arable land is negatively affected by water and wind erosion. The intensity of erosion processes now exceeds the natural soil formation by 2...10 times [2]. Soils are also negatively affected by physical erosion, which is manifested in their compaction under the influence of passages in the fields of tractors and agricultural machinery. With modern intensive technologies, the number of passes of units in the fields reaches 8...16, and soil compaction extends to a depth of 60...100 cm.

Today, intensive agriculture uses three main tillage systems: mini-till, no-till and clean ploughing.

Dumplage system is considered traditional [3]. This system provides as the main cultivation - autumn plowing with rotation of the soil layer and the use of plowshares and angles. Cultural plowing, therefore, is the main link of intensive agriculture.

The positive phenomena of plowing with traditional plows include: earning nutrient residues in the soil and creating conditions for their decay; deep earning of pathogens and weed seeds, which prevents their germination; good loosening of the top layer of soil, which accumulates in the root layer a large amount of moisture before the growing season of cultivated plants and creating conditions for active work of microbes involved in the process of humus mineralization, providing the culture with nutrients [4].

The disadvantages of this tillage system are the degradation of soil quality due to the accelerated mineralization of humus in the upper layer of the soil. High ridge increases the impact of water and air erosion. The weight of the tractor performing the operation has a great influence on the condition of the soil. The need to drive a wedge-shaped working body with horizontal cutting due to traction requires the use of heavy tractors that compact the soil to a depth greater than the stroke of the plow, which contributes to the formation of the plow sole - a compacted layer of soil below. The plow sole interferes with the normal gas and water exchange in the soil, prevents the development of the root system of cultivated plants and, as a consequence, leads to a decrease in crop yields. The soil compacted in this way loses a structure that is not restored by purely mechanical loosening.

One of the first known machines for mechanized main tillage was the Cooper steam engine (1875), which was called a digger because of its similarity to manual digging. The scheme of operation of this machine minimized cutting of the soil, and satisfactory quality of loosening was achieved by rupture of the formation by fork-shaped working bodies. It is noted that after the passage of the machine there was a well-leveled and loose surface, no compaction was created on the bottom of the furrow, but the rotation of the formation and wrapping of plant debris in comparison with the plow were unsatisfactory.

Other inventors were: William Mers, Francis Cohn, Lucius Gibbs, John Gilmore Jones, Jordan Hills and William Maches. Due to the unsatisfactory quality of work, these machines were not further developed and only in Italy, research continued.

Nowadays in Italy a number of companies such as Gramagna. FALC, Chelly, Sikma, Nardi produce diggers with oscillating movement of working bodies.

The disadvantages of these diggers include: incomplete rotation of the formation due to a slight deviation from the vertical trajectory of the cutting edge of the blade at the time of rejection of the cut layer.

Imants (Netherlands) produces tillage machines for tillage to a depth of 25 ... 90 cm. The shovel-like working bodies of this machine perform only rotational movement. Four working bodies are fixed on each rotor flange. The cut layers are discharged by a cleaner installed between two working bodies, in relation to which its position is regulated.

If it is necessary to prepare the soil for sowing in one pass, the blade rotary machine can be equipped with a second rotor of the original design.

In Croatia, since 1980, research and production of the rotary machine TL-8-LOPATOR at the plant Slovenija cesta tehnika under the license of the Italian company Vangatrici [8].

The principle of operation is similar to "FALC". Processing width is 1800 mm. The width of the digger's blade is 170 mm. Depth of processing to 30 cm. It is aggregated with tractors of a class of 0.6 ... 0.9 kN [9].

In our country such tillage machines as LT-1.4, KR-1.5 and MPT-1.2 have been developed. The most common machine MPT-1.2 is designed for milling and plowing [9, 10, 11].

A more advanced machine that was mass-produced is the MPT-1.2. It consists of a frame, a cardan shaft (1), a gearbox with a gearbox, a side drive (2), a drum shaft with L-shaped knives (4), two support skis (3), a casing and a cardan shaft with a safety clutch. At slow rotation of a drum (0.71 s⁻¹) digging of soil is carried out, at fast (2.71 s⁻¹) - milling [12].

1) the most promising for the main tillage is the digger in terms of both energy and agronomic indicators;
2) diggers with the active drive have three schemes of arrangement: with the working bodies rotating a layer; with working bodies, cultivating the soil without rotating the formation, but placed on one crankshaft; with working bodies without rotation of a layer with the working bodies located in pairs;
3) rotary diggers with rotational movement of working bodies are most effective in comparison with diggers having oscillating movement of working bodies.

The purpose of the work is to improve the process of mechanical tillage by digging by developing a new working body.

To achieve this goal, the following tasks are set in the work:
- to substantiate the relevance of machining by digging in modern conditions;
- to analyze the latest achievements in the use of rotary tillage machines;
- theoretically substantiate the parameters and design of tools for tillage by digging;
- to carry out ecological assessment and technical and economic calculations of tillage by digging.

The object of research is the process of interaction of mining type of working bodies with the soil, which changes its physical properties and improves environmental safety.

The subject of research - the pattern of influence of structural and technological modes of operation of working bodies of the mining type.

The nature of the influence of the design width of the shovel and the number of shovels on the power required to overcome soil resistance was calculated on a PC using Microsoft Excel.

3. Results and discussion

Based on the comparison of the obtained characteristics, the influence of design parameters and operating modes on the torque required to overcome the soil resistance force is evaluated.

The obtained data will help to determine which parameters of the design or operating mode should be increased or decreased to increase the performance of the unit without a significant increase in torque.

In order to substantiate the parameters and design of a rotary mechanized tillage unit, we compare the operation of such a unit with a similar process performed manually. It is known that mechanical tillage with the help of a macne and tractor unit (MTU) has a higher energy consumption than performing the same work.
The degree of grinding is the main indicator that takes into account the quality of soil loosening. For a commonly used plow type PNL, the degree of grinding is 2.6 ... 2.8 units, with the required degree of grinding - 46 units [15]. Therefore, in practice, several types of tools are used, performing sequential technological operations for tillage. One of the promising areas is the creation of such tool designs, which simultaneously combine several methods of soil destruction and which allow to ensure the required quality of processing. For this case, the degree of grinding of the soil will be:

\[
i = i_1 i_2 i_3 \cdots i_j,
\]

where \(i_1, i_2, i_3, \cdots, i_j\) - respectively the first, second, third and j-th methods of soil grinding.

As a result of the analysis of earlier researches of tools with rotary working bodies (Vasilenko P.M., Dalin A.D., Dokin B.D., and others) it is established that one of the main indicators of an operating mode is a relation between circular and translational speeds. [13,18, 19].

As a result of studying the dependence of the angle of the blades, providing the movement of the formation on the surface of the working body, from their position on the trajectory, it was found that the smallest value \((5...7^0)\) is the angle of inclination after turning the blade deepening. When lifting the formation from the bottom of the furrow to a certain height, the required angle of the blades increases, reaching a value of \(28...30^0\) when turning the formation at a height of \(0.20...0.25\) m.

To ensure the separation of the formation from the working body, the angle of overturning of the blades during design should take at least \(35...40^0\). And to ensure complete inversion of the arable layer - about \(180^0\).

Analysis of the influence of the moment of the beginning of overturning of the formation on the amount of displacement to the side, which is determined by the width of the open furrow, shows that the smallest displacement occurs when overturning it at a distance from the bottom of the furrow close to the depth of processing \((0.20...0.25)\) m, from the initial position equal to \(225...240^0\).

To find the parameter of the digging device that most affects the force acting on the shovel, we compare the value of the torque that occurs during digging. The results of the calculations are presented in Figure 2.4.

We will change the value of the rotor radius from \(0.4...0.6\) m with a step of \(0.05\) m, the digging step from \(0.15...0.25\) m with a step of \(0.025\) m, the working depth from \(0.2...0.3\) m with a step of \(0.025\) m and the rotational frequency from \(40...60\) min-1 with step \(5\) min.  

As can be seen from the graphs in fig. 3, the rotational frequency has almost no effect on the torque when digging by a rotary digger (Fig. 3c), and other parameters change the torque linearly, with almost the same speed (Fig. 3 a, b, d).
In fig. 3 we see that with increasing depth of processing the value of torque increases linearly, but observing the digging process we can see that the value of torque with increasing depth of processing will first increase, and then at a depth of 25... 30 cm will decrease, reaching values close to oscillation frequency when rotating the rotor at idle. This phenomenon is explained by the increase in the time of interaction of the working bodies with the soil, at which the soil begins to act as a damper [20].

The power consumed for digging increases with the depth of processing, and the specific power consumed per unit volume of soil, at which the soil begins to act as a damper [20].

When increasing the feed rate by 4.7 times leads to an increase in power consumption by 4.2 times.

In the study of the influence of the magnitude and speed of feed on the change in power expended on digging, it was found that when increasing feed torque and power will increase. Moreover, with increasing feed rate by 4.7 times it leads to an increase in power consumption by 4.2 times.

Analysis of the change in specific power shows that at a feed rate greater than 0.4 m · s⁻¹ it practically does not decrease. This allows to justify the optimal feed rate equal to 0.3... 0.4 m · s⁻¹, which is provided when feeding to one working body 0.15… 0.20 m.

Studies of the digger's work process show that there is a significant uneven load in the process of work. The reason for this is the constructive and technological scheme of digging machines. To reduce the load peaks, when designing digging machines, their sections should be installed so that in the process of work they provide overlapping of the load phases. Using the methods of physical modeling it is established that the work of shovels with overlapping is provided when installing them at an angle of 35... 50°, while the minimum number of shovels on one digging machine is 9. With more shovels on one machine increases the coefficient of simultaneous shovel work. Increasing this coefficient leads to a decrease in the value of the fundamental oscillation frequency.

4. Conclusions

1. The main tillage is an energy-intensive process. Therefore, attention should be paid to combined tools, or the development of machines that reduce the number of technological operations.

2. To perform the main technological processes use general-purpose tools: plowing, flat-cutting, chiselling, cultivation, grinding, harrowing, milling, mechanical digging. The most promising for deep tillage is the digger in terms of both energy and agronomic indicators (reduction of compaction, preservation and restoration of water and air balance, preservation of humus, preservation of biomass).

3. Rotary diggers with rotational movement of working bodies are more effective in comparison with diggers having oscillating movement of working bodies.

5. References


Assessment of agrotechnical indicators of the seeder for sowing grass seeds

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Abstract: Field laboratory tests of the seeder under development with the intellectual control unit for the technological process of sowing non-loose grass seeds, consisting of a frame, seed box with sowing devices, attachment, sowing section, running gear and sowing device drive, were carried out on the territory of the University’s research and production campus, which was divided into plots 37 * 3.6 m in size.

The following parameters were adopted for the breadboard model of the seeder: speed of movement 7 km / h; seed placement depths of 2 and 4 cm. Aisle spacing of 30 cm was taken. The maximum and minimum seeding rate for the selected crop was defined.

An analysis of laboratory tests of the seeder showed that the sowing ability of the seeder is 8-30 kg / ha, while the unevenness of the sowing was 4.60% when sowing grain and 4.80% when sowing the awnless bun. The instability of the total sowing is 2.90% when sowing wheat grass and 2.7% when sowing the awnless bun.

The field germination of “Burabay” wheatgrass seeds in experimental plots amounted to 90%, and on the plot sown with awnless bun “Akmolinsky Emerald”, the germination rate was 89%; the uniformity of the seeding depth of the seeds of the prototype seeder is 6.28% in the sowing of wheatgrass, and the sowing of the awnless bun is 5.78%; the number of seeds embedded in the layer of average actual depth and two adjacent layers on the sowing of wheatgrass was 91% and on the sowing of awnless bun is 90%, which corresponds to agro technical requirements; when testing a prototype planter of the seeder, the distribution of seeds over the feeding area was 62% for the sowing of grain and 64% for sowing of the awnless bun.

An analysis of the results of laboratory field tests of the seeder showed that, according to the quality indicators of the technological process, the developed seeder meets the agro technical requirements for grass sowing and is not inferior to foreign seeders and it is necessary to conduct its extended field tests.

KEY WORDS: SEEDER FOR NON-LOOSE GRASS SEEDS, SOWING, GRASS SEEDS, UNIFORM DISTRIBUTION OF SEEDS, SOWING APPARATUS, WORKING BODY.

The current state of the feed base in the farms of Northern Kazakhstan does not satisfy the needs of domestic animals, both quantitatively and qualitatively. Therefore, the production of feed requires no less attention than the production of grain.

Fodder production is important and versatile, as it provides cheap and diverse feeds: green mass, hay, silage, grass meal, briquettes, pellets, etc. Fodder crops are used as green manure crops (siderates) to improve soil structure, restore soil humus, enrich water and air modes. One of the main ways to obtain high yields is the method of sowing and technology for its implementation. The production and breeding of new varieties of high-quality seed material is associated with the sowing of a wide range of crops having various physical and mechanical properties of seeds [1, 2, 3]. In existing sowing machines, sowing devices are capable of sowing loose and medium-flowing seeds of wheat, barley, rye and other crops. For hard-flowing small-seeded crops in sowing devices, auxiliary devices are used that ensure a constant supply of material to the sowing device and its further transportation to the working bodies for introduction into the soil. A characteristic disadvantage when making hard-flowing (non-flowing) seeds is the presence of a zone of arch formation, which should be destroyed.

In Northern Kazakhstan, sowing of grain crops was carried out and is carried out today by seeders of neighboring countries S7ZS-2,1; T7ZS-6; S7ZS-12, and foreign companies Flexi-Coil, John-Deer, Concord, Amazonia, Horsh, Lemken and others [4, 5].

At the same time, the park of domestic seeders does not resume, and the country turned out to be completely dependent on foreign suppliers of agricultural machinery, while the purchase of expensive machinery is only possible for large companies, and this technique is not available for small and medium farmers. In this connection, the transition to new technologies is impossible without appropriate technical support, and today the creation of new machines taking into account domestic and foreign experience is necessary [6]. In order to improve the quality indicators of sowing non-loose seeds, we created a seeder. Figure 1. Design parameters and optimal modes of the working bodies of the seeder were theoretically justified earlier by us [6, 7]. The seeder has an intellectual process control unit, a frame, a seed box with sowing devices, an attachment, a sowing section, a running gear and a drive of the sowing devices.

The seeder has a working width of 3.6 m, a row spacing of 0.3 m, a sowing rate range of 10 to 30 kg / ha, and a seed placement depth of 2-8 cm. A planter research program with an intellectual process control unit for sowing non-flowing grass seeds has been developed, which includes the following:

- bench tests of a prototype seeder;
- laboratory and field tests of a prototype seeder.

Bench tests were carried out in order to verify the quality of the technological process by the sowing machines of the sowing machine for sowing those crops that are zoned in the area of application of the sowing machine. During bench tests, the characteristics of the seed material and the quality indicators of the technological process were determined. The latter include irregularities in the sowing between the sowing apparatus and instability of the total sowing of seeds, damage to the seeds and the sowing ability of the sowing machine [8, 9, 10, 11].

For laboratory and field tests of a seeder with an intellectual control unit for the technological process of sowing non-loose grass seeds, an experimental plot of 150 m long and 14.4 m wide was allocated on the territory of the scientific and production campus of S. Seifullin Kazakh Agro-Technical University, which was divided into plots of size 37 * 3.6 m.

The following parameters were adopted for the breadboard model of the seeder: speed of movement 7 km / h; seed placement depths of 2 and 4 cm. Row spacing makes up 30 cm. The maximum and minimum seeding rate for the selected crop was defined.

When determining the conditions for laboratory and field research tests, the following were taken into account: soil type; mechanical composition; relief; soil moisture and hardness; weediness; the presence and characterization of plant residues; surface roughness.

After the drill went through, the following indicators were determined: the coulter stroke depth h, the seed placement depth h, the number of Q, seeds planted in the horizon corresponding to the average depth and two adjacent 1 cm layers.

The results of laboratory tests of a seeder with an intellectual control unit for the technological process of sowing non-flowing grass seeds are shown in tables 2 and 3.
Figure 1 - General view of the seeder for sowing grass loose seeds

Table 1 - the Plan of experiments of laboratory field research tests

<table>
<thead>
<tr>
<th>Crop</th>
<th>Seeding rate Kg/ha</th>
<th>Opener Depth h₁, cm</th>
<th>Movement speed V, km/h</th>
<th>Criterion of assessments</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Awnless bun, variety “Akmolinsky Emerald”</td>
<td>For both crops: 13,4; 17; 8,4; 12</td>
<td>2, 4</td>
<td>7</td>
<td>Seeding depth, the number of seeds embedded in the layer corresponding to the average depth and two adjacent 1 cm layer, stubble conservation, furrow depth</td>
</tr>
<tr>
<td>- Wheatgrass variety “Burabay”</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2 - Agrotechnical indicators in laboratory tests of the seeder with an intellectual control unit for the technological process of sowing non-flowing grass seeds when sowing grain

<table>
<thead>
<tr>
<th>№ n/h</th>
<th>The name of indicators</th>
<th>The value of indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Movement speed, km / h</td>
<td>7,0</td>
</tr>
<tr>
<td>2</td>
<td>The sowing ability of the system, kg / ha:</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>minimum</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>maximum</td>
<td>30</td>
</tr>
<tr>
<td>5</td>
<td>Seeding quality at an economic rate:</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>setting rate of sowing, kg / ha</td>
<td>8,4</td>
</tr>
<tr>
<td>7</td>
<td>actually obtained, kg / ha</td>
<td>8,61</td>
</tr>
<tr>
<td>8</td>
<td>uneven seeding on coulters - standard deviation, ± r</td>
<td>0,58</td>
</tr>
<tr>
<td>9</td>
<td>the coefficient of variation, %</td>
<td>4,60</td>
</tr>
<tr>
<td>10</td>
<td>Instability of General Seeding:</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>standard deviation, ± r</td>
<td>4,38</td>
</tr>
<tr>
<td>12</td>
<td>the coefficient of variation, %</td>
<td>2,9</td>
</tr>
</tbody>
</table>

Table 3 - Agrotechnical indicators in laboratory tests of the seeder with an intellectual control unit for the technological process of sowing non-flowing grass seeds when sowing of the awnless bun

<table>
<thead>
<tr>
<th>№ n/h</th>
<th>The name of indicators</th>
<th>The value of indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Movement speed, km / h</td>
<td>7,0</td>
</tr>
<tr>
<td>2</td>
<td>The sowing ability of the system, kg / ha:</td>
<td>8</td>
</tr>
<tr>
<td>3</td>
<td>minimum</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>maximum</td>
<td>30</td>
</tr>
<tr>
<td>5</td>
<td>Seeding quality at an economic rate:</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>setting rate of sowing, kg / ha</td>
<td>13,4</td>
</tr>
<tr>
<td>7</td>
<td>actually obtained, kg / ha</td>
<td>13,72</td>
</tr>
</tbody>
</table>
The analysis of tables 3 and 4 shows that the sowing ability of the seeder is 8-30 kg / ha, while the unevenness of the sowing was 4,60% when sowing grain and 4,80% when sowing of the awnless bun. The instability of the total sowing is 2,90% when sowing wheatgrass and 2,7% when sowing of the awnless bun. Thus, the quality indicators of the technological process of the developed seeder meet the agrotechnical requirements for grass sowing.

Laboratory and field research tests were carried out on the territory of the scientific and experimental campus of S.Seifullin Kazakh Agro Technical University, Figure 2.

![Seeder with an intellectual control unit for the technological process of sowing non-flowing grass seeds in laboratory field tests](image)

The sowing process of the crops varieties “Burabay” and the awnless bun “Akmolinsky Emerald” was done. The seeding rate and seed placement depth, the size of the experimental plots of 3,6 * 37 m, were established. The collected material for phenological observations of the experimental plots was recorded in the observation log book. Table 4 presents data on the completeness of seedlings and on field germination of seeds of wheatgrasses and the awnless bun.

<table>
<thead>
<tr>
<th>Crops</th>
<th>Number of plants, pcs / m²</th>
<th>Field germination, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wheatgrass, variety “Burabay”</td>
<td>295</td>
<td>90</td>
</tr>
<tr>
<td>Awnless bun, variety ”Akmolinsky Emerald”</td>
<td>331</td>
<td>89</td>
</tr>
</tbody>
</table>

The field germination of Burabay wheatgrass seeds on experimental plots was 90%, on the Akmolinsky Emerald awnless bun camp site, the field germination was 89%, which corresponds to the passport data provided by the seed laboratory. This shows the high quality of the experimental sowing apparatus and the embedding part of the prototype seeder.

<table>
<thead>
<tr>
<th>№</th>
<th>The name of indicators</th>
<th>Wheatgrass “Burabay”</th>
<th>Awnless bun ”Akmolinsky Emerald”</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Date</td>
<td>28.05.2019</td>
<td>28.05.2019</td>
</tr>
<tr>
<td>2</td>
<td>Movement speed, km/h</td>
<td>7,0</td>
<td>7,0</td>
</tr>
<tr>
<td>3</td>
<td>Seeding rate, kg/ha:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>a) adjusted</td>
<td>8,4</td>
<td>13,4</td>
</tr>
<tr>
<td></td>
<td>b) factual</td>
<td>8,61</td>
<td>13,72</td>
</tr>
<tr>
<td>4</td>
<td>Installation depth of seeding embedment, cm</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>Maximum seed embedment depth, cm</td>
<td>4,4</td>
<td>4,3</td>
</tr>
<tr>
<td>6</td>
<td>Minimum seed embedment depth, cm</td>
<td>3,8</td>
<td>3,7</td>
</tr>
<tr>
<td>7</td>
<td>Uniformity of embedment depth, total:</td>
<td>4,12</td>
<td>4,02</td>
</tr>
<tr>
<td></td>
<td>a) average, cm</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>b) standard deviation, ± cm</td>
<td>0,26</td>
<td>0,232</td>
</tr>
<tr>
<td></td>
<td>c) the coefficient of variation, %</td>
<td>6,28</td>
<td>5,78</td>
</tr>
<tr>
<td></td>
<td>d) seeds embedded in a layer of average actual depth and two adjacent layers, %</td>
<td>91</td>
<td>90</td>
</tr>
<tr>
<td>8</td>
<td>The number of seeds not embedded in the soil, pieces per m²</td>
<td>no</td>
<td>no</td>
</tr>
</tbody>
</table>
An analysis of Table 3.4 shows that the uniformity of the depth of seed placement with wheatgrass model of the seeder is 6.28% for sowing wheat, and the sowing of awnless bun is 5.78%, which meets agricultural requirements and is at the level of performance indicators of foreign seeders.

The number of seeds embedded in the layer of average actual depth and two adjacent layers on the sowing of wheatgrass was 91% and on the sowing of awnless bun was 90%, which corresponds to agro technical requirements. In the wheatgrass model of the seeder, the distribution of seeds over the feeding area is 62% for the sowing of grain and 64% for sowing the awnless bun which corresponds to the indicators of grass sowing by foreign seeders.

Laboratory and laboratory field tests of a seeder with an intellectual control unit for the technological process of sowing non-flowing grass seeds were carried out, as a result of which it was established:

- the sowing ability of the system is 8-30 kg / ha, while the non-uniformity of sowing was 4.60% when sowing grain and 4.80% when sowing awnless bun. The instability of the total sowing is 2.90% when sowing wheatgrass and 2.7% when sowing awnless bun;

- field germination of Burabay wheatgrass seeds in experimental plots amounted to 90%, and on the site of Akmola Emerald seedlings sown with awnless bun seedlings, field germination was 89%;

- the depth uniformity of the seeds of the prototype seeder is 6.28% in the sowing of wheat grain, and in the sowing of the awnless bun makes up 5.78%;

- the number of seeds embedded in the layer of average actual depth and two adjacent layers on the sowing of wheatgrass was 91% and on the sowing of awnless bun was 90%, which corresponds to agro technical requirements;

- when testing a prototype planter of the seeder, the distribution of seeds over the feeding area was 62% in the sowing of grain and 64% in the sowing of the awnless bun.

In conclusion, according to the results of laboratory-field experiments of the seeder, it should be noted that, according to the quality indicators of the technological process, the developed seeder meets the agro technical requirements for grass sowing and is not inferior to foreign seeders and it is necessary to conduct its extended field tests.

References

Technologies for soil surface maintenance in perennials

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Summary: Perennials are an important strategic sector for agriculture in Bulgaria. In order to obtain good results from their cultivation, a scientifically based system for the maintenance of the soil surface is needed. Existing technologies have been analyzed to support the selection of an appropriate soil maintenance system. The size of the agricultural holdings in Bulgaria for the most widespread perennial plantations, which are the vineyards and are substantiated by economically expedient technologies and machines for soil cultivation suitable for the majority of the agricultural producers, is analyzed. The advantages and disadvantages of the technologies and the machines for their realization are presented.

KEY WORDS: PERENNIALS, TILLAGE MACHINES.

Introduction

A significant part of agricultural production is obtained from perennial crops. In order to obtain quality products, it is necessary to create conditions for the development of cultivated crops [2,3,4]. One of the most important measures to create favorable conditions for perennials is the maintenance of the soil surface. Perennials occupy a certain area for a long period of time and the maintenance of the soil surface is difficult compared to annual crops. The repeated passages of the machine-tractor units compact the soil and destroy its structure [5,6,7,8], which requires an analytical study of the technologies and machines for supporting the soil surface in the inter-rows of the permanent crops.

Modern trend of Bulgarian agriculture and importance of perennials

In recent years, there has been a tendency to reduce the number of agricultural producers and at the same time increase the area of agricultural enterprises. This concentrates agricultural production in a small number of producers who work with highly productive equipment, mainly grain production and industrial crops. The share of intensive crops is low, most of which are perennials. Stimulating these sectors could partially solve the employment problem, rural depopulation and other social problems. Self-produced and semi-market farms account for almost 90% of those employed in agriculture. The main number of farms are small, up to 10 decares, but they cultivate a very small part of the land. Much of the land is cultivated by a small number of farmers. The number of large farms in the typical mountainous and semi-mountainous areas is small, where the arable land is smaller and on sloping terrains, which are more difficult to unite, consolidate and apply modern management technologies and they are suitable for intensive permanent plantings.

Areas with fruit, nuts and berry plantations in agricultural holdings

in 2018 they occupy 68.3 thousand hectares. 39.8 thousand hectares were harvested. The produced production of fruits is 228.5 thousand tons. In 2018, 88% of the fruit-bearing areas occupied by fruit, nutl and berry plantations were harvested. Due to climatic and other reasons, about 12% of the fruit-bearing areas with fruit species are not harvested. The total harvested areas in 2018 are 7.8% more than in 2017. The largest share is occupied by cherries - 25.2%, followed by plums and junipers - 18.5%.

According to the structure of agriculture in Bulgaria in 2016. from 201014 agricultural holdings 23966 specialize in the cultivation of perennials.

The preferred tillage is plowing or hoeing, applied to 71% of the area under orchards. Chemical decontamination is applied to 3% of the areas, mainly cherries, apples, plums and peaches.

Mixed perennials - the item unites mixed plantations of fruit species. The minimum area is 500 m² (0.05 hectares), if the area is smaller refer to isolated trees or family garden according to the environment. Their area decreased by 6.0%.

The vineyards are the other main group of perennials, according to Agrostatistics [1] in our country 59 991ha vineyards from 45 179 farms are cultivated. The characteristics of the vineyards are shown in Fig. 1A depending on the number of farms and Fig. 1B depending on the size of the cultivated areas. It can be seen that 2/3 of the vineyards have an area of over 10 hectares on average 3 hectares and in the other groups they are 5-10%.

![Distribution of vineyard farms in Bulgaria](image1)

A) According to the number of farms

B) According to the size of the cultivated areas

FIG. 1. Distribution of vineyard farms in Bulgaria

The distribution of the areas depending on the age is shown in fig. 2. Most farms 89% grow old vineyards over 30 years. FIG. 2A. Regarding the areas, 69% of the post office is occupied with vineyards of 30 and more years fig.2B.
All this shows the need for cost-effective technologies and high-productivity tillage machines suitable for most farmers.

**Importance of soil treatment in perennials**

Soil treatment improves the physical, water and air properties of the surface soil layer, thus creating favorable conditions for the development of trees and helping to increase their resistance to pests [3]. Through the main tillage the plant remains and weeds are buried and thus the process of leaf mass mineralization is activated and limits the infectious background from scabs on apple and pear, gray and brown spots on pear, white rust on stone species, gnomoniosis on apricot, mushroom ball and others. The process of mineralization begins in the fall, but along with lowering the temperature and freezing of the soil, it gradually subsides. When the main treatment is carried out with deepeners, the arable layer is deepened, creating conditions for the development of the root system of the trees. The increase of temperatures during the early spring period, together with the spring vegetation treatments, activate the mineralization process and lead to a reduction of the primary inoculum for the new vegetation period.

Proper treatment protects the soil from water and wind erosion, preserves soil moisture as it destroys soil capillaries and reduces evaporation from them. The row spacing of perennials is cultivated to a depth of 18-20 cm. Where possible, around the trunk of the trees is dug to a depth of 8-10 cm. In this way mechanically destroy some of the wintering forms of a number of economically important enemies, such as fruit octopuses, mining moths, fruit wasps, cherry fly and others. Another part of them is exported to the soil surface, where they die from adverse weather conditions in winter. The autumn tillage of the soil not only improves the aeration and destroys the wintering period of the pests, but also increases the cold resistance of the fruit species. When weeds remain under the trees, even if they are dry, the danger of frost is greater because the radiation of low temperatures from the soil to the crown of the trees increases. Autumn cultivation is best done by plowing with inversion of the layer and deepening of the subsoil layer, and other plant residues, weed seeds are plowed deep if fertilizers are applied, they are also deep to be used intensively. The main tillage is carried out after the completion of all other agro-technical measures.

**Technologies for maintaining the soil surface in perennials**

Each soil maintenance technology aims to provide all the conditions described in the previous point, as well as to facilitate their cultivation practices. [4] In general, the systems are: black fallow, herbicide fallow, perennial turf and inter-row cultivation.

**Black fallow** Traditional for fruit growing system, which consists of continuous tillage to control weeds and maintain soil moisture. The soil is cultivated to a depth of 15 cm four or five times during the growing season. It is suitable for all terrains and ways of irrigation. Its main disadvantages are related to the preservation of soil fertility. With long-term irrigation and tillage, the soil structure is destroyed, the porosity and water available to plants are reduced, the soil is depleted of organic matter and highly dusty. The compacted soil cannot return to its original structural condition even after 30 years, and the cultivation of the tracks up to 0.40-0.45 m has no effect. The reduced water permeability caused by the degradation processes due to the long-term maintenance of the soil in black fallow is often found in orchards. The roots of the trees do not have access to the compacted soil volume under the tracks, as well as to the most nutrient-rich surface soil layer. Maintenance in black fallow requires special preparation of the soil surface before harvesting, especially if the production is harvested mechanically.

**Herbicide fallow** This technology is only applicable to fruit species with a crown located above the ground in the case of shrubby plantations. Weed control in plantations is carried out entirely through herbicide treatments. It greatly reduces the risk of soil compaction in depth. The roots have the opportunity to develop in the fertile surface soil layer; the effect of fertilization also increases. Harvesting is facilitated. Due to the loss of tillage, surface irrigation is possible only by flooding. For this purpose, however, the soil surface must be leveled before planting the trees. The use of herbicides is expensive. It is believed that after several years of application the weeds will be suppressed and the consumption of herbicides will decrease. However, some weed species may be replaced by others resistant to certain herbicides. Herbicides can adversely affect the biological activity of the soil. There is a risk of soil and water contamination. Absorption of water can be difficult due to compaction and crusting of the soil surface. When it rains, the water drops further destroy the soil structure. The solar energy reflected from the bare soil surface increases the risk of burns.

**Perennial turf.** Sprinkler and micro-sprinkler systems can be used to maintain a durable turf of perennial grasses in between rows, which is an effective means of preserving soil fertility. The role of perennial grassing against wind and water erosion is undeniable. As they grow, grass roots convert hard-to-reach forms of phosphates and potassium into easily digestible ones. Decomposed cut grass and dead roots enrich the soil with organic matter. The physical, chemical and water properties of the soil, as well as their microbiological regime are improved. The root system of the trees covers evenly the active soil layer, including the most humus-rich surface layer 0-20 cm. In cultural grassing the roots in the row spacing are twice as many as in black fallow. The mulching layer dissipates solar energy and protects the soil surface from overheating. Under irrigation conditions, grassing is an effective means of protecting the soil from gradual degradation and compaction. The volume of additional turf water consumption varies from 6% to 50% of the irrigation rate, with higher values associated with sprinkling and lower values with micro-sprinkling.
In addition to additional water, the grass needs additional fertilization during grazing, at least in the first years after the creation of turf. When placing the sprinklers, the micro-sprinklers and the irrigation wings in the rows of the plantation, the control of the weeds in the row is carried out through the periodic treatments with herbicides. Mulching with foil on an artificial or textile basis is sometimes used, which, in addition to suppressing weeds, allows water from rainfall and irrigation, but prevents evaporation from the soil surface. The row strip can also be kept free of weeds and cultivation to avoid competition with the plantation. For this purpose, its width must be in accordance with the type and age of the plantations. Perennial turf should not include grasses that are hosts for pests, diseases and nematodes on cultivated species. The turf facilitates the mechanized collection of the production, especially in the rainy days inherent in the autumn. It is necessary to provide nitrogen fertilization for the grass, especially in the first years after sowing. Maintaining perennial turf reduces the yield and quality of the fruit, if it is not combined with an irrigation and fertilization system.

**Interrow crops.** They are grown in between rows of young plantations, where the crowns of the trees still cover a small part of the soil surface, and it must be kept free of weeds anyway. For this purpose, some annual forage grasses such as peas, soybeans, turnips, green rye and cereal-legume mixtures are recommended, which release the soil in the plantations early. It is allowed to grow beans, early potatoes, peanuts, watermelons, melons, pumpkins, mint, carrots, turnips, onions, garlic. According to some authors, it is absolutely unacceptable to grow wheat, rye, oats, corn, sunflower, poppy, sesame, rape, tobacco, cotton, hemp, flax and other crops that would compete with trees for water and nutrients. However, the practice in the countries and regions of modern agriculture shows that the cultivation of corn and cereals, and probably all the others, can be successful if the needs of both crops are met, which is not a problem with an irrigation system. Perennials can also be used to compact other perennials, such as walnuts, which bear fruit after several years. In the region of Grenoble, France, raspberries are used for this purpose, and in the Institute of Fruit Growing - Plovdiv, an experiment with peach is being conducted and the results so far are positive. The limitations in the choice of inter-row or compaction culture come rather from the possibilities for combining cultural practices. For example, the preparations used for plant protection treatments of the main plantation may be contraindicated for the intermediate crop or the time of spraying may coincide with its harvesting period. In any case, leaving a clean line would restrict interspecific competition.

**Combined system for maintaining the soil surface**

There are options for maintaining the soil surface through several systems, for example the row to be ground and the rows to be treated, while the row can be covered or covered with black polyethylene foil or other materials, plant residues, waste from the woodworking industry and others. Inter-rows can be maintained with intermediate crops or with green manure crops, with black or herbicide fallow. There are many variants of systems for maintaining the soil surface in perennials. This issue is complicated and complex and cannot be solved unequivocally, so many factors must be taken into account when deciding on the technique and technologies for maintaining the soil surface in perennials.

**Conclusions**

1. A significant part of agricultural production is obtained from perennial crops, they are a strategically and economically important branch of agriculture in Bulgaria.
2. In order to obtain quality production from perennials, it is necessary to maintain favorable conditions for the development of crops and this is achieved by maintaining the soil surface.
3. The maintenance of the soil surface in perennials is a complex problem for which there are many solutions, it is the subject of many studies and can not be solved unambiguously, it is necessary to take into account all the features of crops, cultivation technologies, natural and social factors and to choose a suitable system for maintaining the soil surface according to the specific conditions.
4. The size of agricultural holdings in Bulgaria shows the need for economically viable technologies and machines for tillage with high productivity suitable for most farmers.
Experimental research of agricultural bridge unit in the state of harrow aggregate

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Abstract. From the standpoint of energy saving, the issue of research of agro-bridge units in the composition of new agricultural lands adapted to them is important and relevant tools that operate on the principles of track and bridge farming. One of the latter is a heavy tooth harrow with flat segments. Experimental determination of the characteristics of the agronomic bridge harrowing unit in its composition, in order to establish compliance of its parameters with the basic principles of the effective implementation of track and bridge farming, was adopted as a research objective. Experimental research was carried out both according to generally accepted and developed methods, and provided for the use of modern strain gauge and control equipment with analog-digital conversion of signals from information sensors. The processing of experimental data was carried out on a PC using probability theory, regression, and correlation-spectral analysis. Physical objects of researches were wide-track agricultural bridge construction vehicle TDATU with its track width of 3.5 m and harrowing machine (BZSS-1.0 type). According to the results of experimental tests of agricultural bridge harrowing unit as part of the dental harrow proved its good adaptability to work in the units of track and bridge farming and high quality of the technological process. The latter is also a consequence of the fact that the movement of the agricultural bridge is carried out on the compacted traces of a constant trample, whose roughness profile is low-frequency in comparison with the longitudinal profile of the harrower. The constructive version of the tooth harrow is well reflected in the nature of its unevenness in traction resistance. It is established that the fluctuations of the harrow’s traction resistance express a random function in which there are no harmonic components. The coefficient of variation of resistance fluctuations on the hook of the agricultural bridge during harrowing is no more than 10%. The latter indicates a high stability (low variability) of the process of harrowing the soil, has a positive impact on the stable movement of the agricultural bridge unit.

KEY WORDS: AGRICULTURAL BRIDGE MEANS, TOOTHED HARROW, EXPERIMENTAL TESTS, PROFILE OF AGROPHONE IRREGULARITIES.

1. Introduction

Further highly efficient development of agricultural production in any country is possible with the widespread implementation of scientific and technological progress. These include the organization of field mechanized work on the principles of track and bridge systems of agriculture [1-5]. At the same time, the issues of finding new tillage implements, machines and implements for their effective use in track and bridge systems of agriculture are becoming important. Some of the representatives of the latter include a toothed harrow, made on the type of harrow “Nadykty-Ayubov” [6]. The functionality of the latter can provide loosening of the surface layer of the soil to a fine state without the removal of the wet layer on the surface, the stability of the harrow at depth, loosening and high quality tillage.

2. Preconditions and means for resolving the problem

Analysis of recent research. Such scientists as Nadykto VT, Uleksin VO, Kyurchev VM made a significant contribution to the development and popularization of track and bridge agriculture, and other. However, the analysis of the research results published by them showed [7,8] that it is not enough to work out the issue of experimental studies of wide-track agricultural bridge tillage units.

Regarding the use of the latter with adapted working bodies, the harrow with teeth with flat-cutting segments is of interest [9]. Segments of all rows on it are installed in the horizontal plane and at the same angle. But the use of this harrow construction does not allow effective destruction of weeds (weeds are wound on the working bodies). Also, the deepening of the working bodies of this tool into the soil is insufficient for its quality cultivation.

Known construction of the harrow “Nadykty-Ayubov” [6]. In it in the longitudinal-vertical plane the flat-cutting segments of the first row, and the second - at a bigger angle of inclination to horizon, than segments of the last rows are established. Such constructive execution provides, according to the authors of the development, high quality of tillage and is attractive for use in the composition of wide-track agricultural bridge units, which move in the footsteps of a constant technological track.

The purpose of the article. Experimental determination of the characteristics of the agricultural bridge harrowing unit in order to establish compliance of its parameters with the basic principles of effective implementation of track and bridge agriculture.

Research methodology. Experimental studies were conducted according to both conventional and developed methods and involved the use of modern strain gauge and control measuring equipment with analog-to-digital conversion of signals from information sensors. The experimental data were processed on a PC using probability theory, regression, and correlation-spectral analyzes.

In the process of performing the experiments it was assumed: to determine the longitudinal profile of the irregularities of the traces of the constant technological track and the irregularities of the agro background before and after harrowing, soil moisture and density, depth of cultivation.

The physical objects of research were a wide-track agricultural bridge tool with a track width of 3.5 m and harrowing tools (type BZSS-1.0) (Fig. 1). The specified agro-bridge means used tires of wheels of the size 9.5R32. A specially equipped laboratory for its testing, which is located on the territory of TSATU, was used for research.

Fig. 1. The studied agricultural bridge harrowing unit (a); dynamometer (b); automated profilograph (c); analog-to-digital converter (ADC) and PC (d).

To register some of the measured parameters, such as unevenness of the profile of the agricultural background, the traction resistance of harrowing tools, we used a measuring and
Obtained in the process of experimental research implementation in the form of digitized data was transferred to the software environment Microsoft Excel. It calculated such statistical characteristics as: average value; standard deviation (standard); dispersion; coefficient of variation; sampling average error; normalized correlation function; normalized spectral density. These statistical parameters were determined by methods [10-12]. The error of direct measurement of parameters did not exceed 1%.

Soil moisture was determined by a standardized thermostat-density-weight method. The depth of cultivation in the research process was measured with a specially designed depth gauge in 10 places on the diagonal of the treated area.

Experimental tests of the agro-bridge harrowing unit were carried out on the control and test section with a length of 50 m of the mentioned laboratory. The speed of operation of the agro-bridge unit was 3.6-4.5 km·h⁻¹.

3. Results and discussion

During the research, the average value of soil moisture in the layer of 0...10 cm was 26.8%, and the density was 1.23 g·cm⁻³.

Analysis of the obtained experimental data showed that the profile of the constant technological track is significantly smoothed in comparison with the profile of the treated agricultural background. Thus, if the standard deviation of the profile of the harrowed agricultural background is ± 1.36 cm, then for the track profile this figure is ± 0.84 cm, i.e. 1.6 times less (Fig. 2).

According to their internal structure, the inequalities of the profile of traces of a constant technological track are characterized by a function that contains, along with random components - harmonic, which are expressed by attenuating periodic oscillations of the normalized correlation function, which is presented in Fig. 2a. The length of the correlation of the ordinates of the irregularities of the profile of the traces of the constant technological track is about 0.18 m, which corresponds to the pitch of the ground on the tires of the agro-bridge means, the value of which is equal to 0.175 m.

The spectrum of frequencies that make up the random function of the inequalities of the profile of the traces of the constant technological track determines the normalized spectral density of the ordinates of the mentioned inequalities of the profile (Fig. 2b). From the analysis of the normalized spectral density (see Fig. 2b) it was found that the cutoff frequency for this process is approximately 0.3 cm⁻¹. The main share of variances of oscillations irregularities of the profile of the technological track traces is concentrated in the frequency range 0...0.3 cm⁻¹. The standard deviation of the ordinates of these irregularities is consistent with the height of the ground hooks of the tires of the agricultural bridge means, the value of which was equal to 0.03 m.

The above analysis of the characteristics of the irregularities of the profile of the constant technological track on which repeatedly moves the agricultural bridge means shows that the generator of the formation of these irregularities are the parameters of the ground engagement of the tires of its wheels.

The internal structure of the oscillations of the longitudinal profile of the cultivated area of the agricultural background is slightly different from the structure of the irregularities of the profile of the traces of the constant technological track (see Fig. 2). The length of the correlation relationship of the ordinates of the irregularities of the harrowed agricultural background is about 2 times larger and is about 34 cm. This profile of the agricultural background is typical for a field prepared for sowing cultures.

In contrast to the unevenness of the profile of the traces of the constant technological track formed by the tires of the wheels of the agricultural bridge means, the profile of the harrowed section of the agricultural background has a lower frequency character (see Fig. 2b). From the analysis of the normalized spectral density it was found that the cutoff frequency for this process is 0.18 cm⁻¹. The main share of variances of oscillations inequalities of the processed agricultural background is concentrated in the range of frequencies 0...0.18 cm⁻¹.

Fluctuations in the traction resistance of the harrowing tool express a random function in which there are no harmonic components (Fig. 3a). The main spectrum of dispersions of traction resistance oscillations is concentrated in the frequency range 0...3.5 s⁻¹ (see Fig. 3a). According to its energy (Fig. 3b), the dispersion of the oscillations of the traction resistance of the studied harrow was 0.027 kN², and the standard deviation is 0.166 kN. With an average value of traction resistance of 1.71 kN of three harrows in the
bridge unit, the coefficient of variation of its (ie resistance) oscillations during harrowing is 9.76%. The latter is a desirable feature that indicates the high stability (low variability) of the process of harrowing the agricultural background agricultural bridge means in the harrow "Nadikty-Ayubov".

Indicators of soil harrowing quality corresponded to agricultural requirements related to this technological operation [13]. In particular, the deviation of the actual depth of cultivation from the set did not exceed ±1 cm, and the height of the ridges on the agricultural background was not more than 2 cm.

4. Conclusions

According to the results of experimental tests of the agricultural bridge harrowing unit, it is good adaptability to work in the units of track and bridge agriculture and high quality of the technological process have been proved. The latter is also a consequence of the fact that the movement of the bridge agricultural tool is carried out on the compacted traces of a constant technological track, the profile of the irregularities of which is low-frequency in comparison with the longitudinal profile of the harrowed agricultural background.

The structural design of the "Nadikto-Ayubov" dental harrow is well reflected in the nature of its uneven traction resistance. It is established that the fluctuations of the harrow's traction resistance express a random function, in which there are no harmonic components. The coefficient of variation of the resistance fluctuations on the hook of the agricultural bridge at harrowing is no more than 10%. The latter indicates high stability (low variability) of the process of harrowing the soil. And this reduces the unevenness of the moment of resistance on the engines of the agricultural bridge, which positively affects the stable movement of the agricultural bridge unit.

5. References


Computerized ecotechnology for managing crop water status making agricultural activities more efficient and protecting the environment

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Abstract: The paper deals with the perspectives for developing ecologically based biological agriculture in Bulgaria, the European Union and the other countries. Innovative technology (for computerized monitoring the soil water deficit and scheduling the irrigation) replaces the periodical local (point) measurements of soil moisture. Its application helps to be taken into account the physiological features of crop, creating appropriate energy level of soil moisture through ecologically accepted watering technique in each agricultural crop field. It ensures to be obtained the scientifically planned amount and quality of crop yield, saving on average 30 % of irrigation water and one third of nutrients added for plants. New universal estimation of crop water status, current computerized monitoring of the water deficit in root zone of soil, and exact management of productivity are possible to be accomplished. Data were obtained under field conditions over 30-year research period. Fundamental physical laws and recent Bulgarian and foreign world-top scientific achievements were aggregated and applied to be created the new scientific basis of the technology. The obtained results showed the successful applications of: (a) the new hydro-physical index and the method for its determination under both non-irrigation and irrigation conditions and (b) the Technology for Monitoring, Estimating and Managing (TMEM) of the water status of this layer in irrigation rural activities, taking into account the European ecological requirements. The technology is easily applied as Decision Support System (DSS) in irrigation agriculture.

KEY WORDS: SOIL WATER STATUS, ENERGY LEVEL OF MOISTURE, NEW SCIENTIFIC BASIS, PHYSIOLOGICAL IRREVERSIBLE PROCESS.

1. Introduction
For the first time in the world agricultural science and practice, we can practically control the physiological processes in cultural plants. These processes concern the water and nutrients uptake by plants. New biophysical index (L) of soil moisture energy levels, method for its determination and new scientific basis and ecological technology are recently developed [1, 2, 3]. Applying the offered Decision Support Ecotechnology (in research version) during a period of 8 years, the precise schedules include 3.125 times of watering on average less with total irrigation norm equal to on average 2780 m$^3$/ha (or 29.5 % less amount of water) than tradition [4, 5, 6, 7]. We obtained 12 ± 0.5 t/ha of grain under appropriate N, P and K nutrition for each year (Table 1). We recommend L = 15 (J/kg) to be realized in agricultural practices [8].

2. Problem discussion
Enormous losses of energy, fuels, water, fertilizers and human labour are due to the lack of current representative monitoring and integrated scientific management of farmer activities in each agricultural field under irrigation. We offer a new scientific tool to solve these cardinal problems in the world agricultural practices. Moreover, this tool will help the modern research for creating and examining new sorts and hybrids. It will significantly reduce or completely remove the pollution caused by the agricultural activities in each field under irrigation around the world.

The recent achievements in biophysics of plant populations and the application of biophysical approach contributed to be created the Computerized Decision Support Ecotechnology (CDSE). It is possible to be created a version of this universal Computerized Decision Support Ecotechnology (CDSE) for Monitoring, New Estimating and Managing Agroecosystem Water Status as a market product friendly for farmers and agrarian associations. Its application will ensure economically-efficient crop production and environmental protection.

3. Objective and research methodologies
The aim is to overcome the risk coming from the influence of the most important water factor during growing season on agroecosystem productivity. This risk can be completely removed applying the ecotechnology under conditions of ecologically-acceptable irrigation technical facilities and available water resources. The minimum total needed amount of water and its precise distribution during each growing season to obtain a planned crop yield can be reached using the offered Computerized Decision Support Ecotechnology (CDSE). This ecotechnology is recommended for farmers, who can organize good technical implementation of the agricultural activities in their crop fields.

The offered ecotechnology ensures the amount of planned crop yield to be obtained and helps the exact determination of nutrient rates necessary for the formation of planned crop yield. It ensures significant increase of yield and great reducing of irrigation water, human labour, and other costs [8]. The ecotechnology is based on new complete scientific biophysical basis, which includes: 7 current daily meteorological indices twice a week; physical characteristics of the soil profile; biological function for each crop; fundamental (physical and biological) laws and established regularities of the soil-crop-atmosphere processes [1, 8]. We established the maize susceptibility of each stage of ontogenesis and we included it in the scientific basis of the ecotechnology (Fig. 1).

A stage
Germination, formation of first and second roots and five leaves 20 %
Extremely-critical
(ec)

B stage
Extending cone of growth and formation of new leaves 20 %
Important
(i)

C stage
Flowering, insemination and maize-cob formation 50 %
Extremely-critical
(ec)

D stage
Active phases of filling the grain 30 %
Critical
(c)

Fig. 1. Scheme of ontogenesis stages based on the maize susceptibility to decrease the amount of grain yield when reducing the soil moisture. The percentages show the decrease of yield amount at lowering $\Delta W = 30 \ J/\text{kg}^{1/2}$ of the energy level of soil moisture only at the corresponding stage and keeping the genetically optimal level at all other stages. The yield losses at the separate stages are irreversible damage that accumulates till the end of growing season. The experimental data are obtained and verified during a period of 30 years.
4. Results and Discussion

In some agricultural practices for example, the farmers plan 10 t/ha maize-grain amount of yield. They calculate the fertilizer (N, P, K, microelements) rates and bring these nutrients in soil. In fact, they obtain 6.5-7.0 t/ha. That means 30-35% losses of fertilizers, which are not used for plant nutrition. Those losses pollute the environment (water in rivers, lakes, dams, etc. and underground water). Applying the new offered ecological technology, the farmers significantly reduce or completely remove these losses and protect the environment.

The ecotechnology currently takes into account the following physical and biological characteristics:

Based on precise field experiments over a period of 30 years, we established the dependence of maize grain yield (Y, t/ha) on the energy level L (J/kg)\(^{1/2}\) (Figs. 2 and 3). The equation for yield mass (obtained without irrigation and under irrigation schedule currently determined by us using the ecotechnology) is:

\[
Y = 19.45 - 0.55 L.
\]

The general form of this equation is: \[ Y = A - B L, \]
where A and B are the coefficients characterizing the crop physiological features. The correlation coefficient is equal to \( R = -0.980. \)

Fig. 2. Dependence of maize grain yield (Y, t/ha) obtained at appropriate N, P and K rates on the energy level L (J/kg)\(^{1/2}\). Correlation coefficient is equal to \( R = -0.98 \).

Fig. 3. Dependence of the maize-grain yield reduction \( \Delta Y_{ec}, \% \) on the lowering \( \Delta L_{ec} (J^{1/2}/kg^{1/2}) \) of soil-moisture energy level only at the extreme-critical C stage of plant.
The crop physiological features are as follows.

- Gradual reduction of the water supply in the soil root layer from the field capacity (FC) to the wilting point (WP) causes irreversible physiological processes with increasing intensity in the plant organism. The cardinal problem related to these processes can be solved, applying the ecotechnology.

- The degree of plant irreversible damage is different at the various mentioned stages under conditions of one and the same moisture reduction of the same soil (Fig. 1).

- The plant irreversible damages caused at all stages are accumulated during the growing season. These damages irreversibly limit the amount and quality of crop yield, irrespective of the increase in soil moisture caused by subsequent irrigation or rainfall.

- The irreversible physiological defeat depends on the energetic status of moisture in soil. This energetic status corresponds to different moisture contents in soils of diverse mechanical composition.

### Table 1. Average amounts of maize (H-708) grain yield (t/ha) obtained under different rates of fertilizing, depending on the energy level $L$ (J/kg)$^{1/2}$ of soil water status (Lom, Bulgaria)

<table>
<thead>
<tr>
<th>Rate of fertilizing</th>
<th>Levels L of soil water status</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$L = 5$</td>
</tr>
<tr>
<td>$N_{34}$ P$<em>{45}$ (3) K$</em>{16}$</td>
<td>Genetically put in hybrid</td>
</tr>
<tr>
<td>$N_{28}$ P$<em>{32}$ (3) K$</em>{12}$</td>
<td></td>
</tr>
<tr>
<td>$N_{22}$ P$<em>{23}$ (3) K$</em>{8}$</td>
<td></td>
</tr>
<tr>
<td>$N_{0}$ P$<em>{0}$ (3) K$</em>{0}$</td>
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5. Conclusions

Applying the Decision Support Ecotechnology, we are precisely establishing the needed irrigation schedule currently during growing season each year to create the necessary universal energy level $L = 15$ (J/kg)$^{1/2}$ of soil moisture through its implementing. This level is recommended by us for all soils and crops in the agricultural practices.

The level $L = 5$ (J/kg)$^{1/2}$ of soil moisture belongs to the Biological Optimum of Plant Soil Water Comfort. We recommend it to be created in field using the offered ecotechnology in order to obtain the crop yield, which is genetically possible for new sorts and hybrids. This study provides information for the practice of competency-based management.

Dependence of the maize yield on the introduced universal estimate is established for the first time in agricultural sciences and practices. The application of DSS (research version) showed higher efficiency compared to the traditional irrigation regime. The maize grain yield increased on average more than 70% implementing the DSS schedules to maintain the energy level $L = 15$ (J/kg)$^{1/2}$ of water status, which took into account the meteorological features of each year and saved on average (over eight years) 29.5% of irrigation water in comparison with the traditional irrigation regime for considered crop and region.

The research version of ecotechnology was tested in field experiments over 30 years. The complex scientific base and many results are accepted by scientists working at the University of California (USA); University of Moscow (Russia); Land Reclamation Institute of Sindos (Thessaloniki, Greece); University of Beijing (China); Aegean University of Izmir (Turkey); Institute of Water Problems and National Institute of Meteorology & Hydrology, both at Bulgarian Academy of Sciences, Sofia (Bulgaria); and Poushkarov Institute for Soil Science, Agrotechnology and Plant Protection, Sofia (Bulgaria).

6. References


A decision support system for field vegetable fertilization

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Abstract: Decision Support System (DSS) is a computer-supported interactive system, i.e., a software product to assist decision-making at any level of management, with an emphasis on making a directly applicable decision. The purpose of this software for the application in the process of fertilization is to organize and classify data, transform information, and choose how to make decisions and embody them. In its sophisticated form, it is an interactive computer program that uses and integrates a simulation model, a database and a decision model for optimal crop fertilization with different fertilizers. Fertilization recommendations in most countries around the world are based on years of fertilization experiments. When using DSS, the user must enter 3 data groups: 1) the type of vegetable and the planned yield; 2) results of agrochemical soil analysis (soil pH, soil organic matter content, available phosphorus and potassium, mineral nitrogen); 3) plans for organic fertilization and available fertilizer data. The flowchart of DSS main part consists of 12 steps: 1) determination of target yield; 2) calculating the required amount of nutrient for the target yield; 3) calculating the optimal need of N in fertilization; 4) calculating the optimal need of P and K in fertilization; 5) determination of optimal organic fertilization; 6) calculation of the liming needed; 7) optimal distribution of N(8) optimal distribution of P and K with respect to fertilization dynamics; 9) the need and plan for application of micronutrients; 10) choosing the optimal form of nutrient and calculating the amount of optimum fertilizers (single and complex); 11) calculation of the nutrient balance; 12) calculating the economic effect of vegetable fertilization and growing. DSS groups results into several sets of data: 1) interpretation of the results of agrochemical properties and soil fertility; 2) recommendation of the quantity of N, P, K and types of fertilizers (required quantities of primary nutrients in mineral fertilization of vegetables, types and quantities of mineral fertilizers required for the mentioned fertilization); 3) balance of primary nutrients, tips and warnings (optimal formulation of fertilizers, the balance of planned mineral fertilization, needs of fertilization with microelements). After receiving the results and guidance, the user simply obtains new output values according to the changes made by simply changing the input data (e.g., to plan a lower yield, other formulation fertilizer, cheaper fertilizer). This mode of operation enables rapid multiple comparisons of the required fertilization with different available fertilizers, on different production sites, and for different target yields and economic effects of vegetable cultivation.

Keywords: NITROGEN UPTAKE, PHOSPHORUS UPTAKE, POTASSIUM UPTAKE, NUTRIENT NEEDS, FERTILIZER FORMULATION, NUTRIENT BALANCE, ECONOMIC RESULT

1. Introduction

Fertilization is an agrotechnical measure of fertilizer application with the aim of achieving high yields, but the impact and the importance of fertilization are significantly more complex in terms of yield quality, soil fertility and sustainable production [1]. Fertilization significantly affects the soil fertility, and thus the yield stability because higher fertility implies a greater ability of the soil to neutralize stress conditions and the adverse effects of insufficient or excessive fertilization. Insufficient nutrient availability is a limiting factor of production and the appropriate fertilization will result in increased nutrient availability and yield. However, if availability is sufficient and is not a limiting factor of production, fertilization will not increase the yield, but may positively affect yield quality. The impact of the added nutrients on the yield of vegetable depends not only on the quantity and dynamics of the available nutrients, but also on the type and cultivar of vegetables as well as the availability of all nutrients [2]. Furthermore, if nutrient availability has already been optimal, the increased availability through fertilization will negatively affect the quality and may result in reduced yields due to the lower harvest index, leaching, more intense pathogen attack, necrosis, and possible toxic effect of excessive nutrient availability. Fertilization optimization is a complex task due to the simultaneous biological, technological, ecological and economic optimum conditioned by climatic, pedological, physical, chemical and biological factors/agents. Since optimization should be made based on high number of agroecosystems’ indicators and simultaneously for different production units, decision support systems (DSS) are most probably among the best solutions [3].

Decision Support System (DSS) is a computer-supported interactive system, i.e., a software product developed to assist decision-making at any level of management, with an emphasis on making a directly applicable decision. The purpose of this software for the application in the process of fertilization is to organize and classify data, transform information, and choose how to make decisions and embody them. In its sophisticated form, it is an interactive computer program that uses and integrates a simulation model, a database and a decision model for optimal crop fertilization with different fertilizers. Fertilization recommendations in most countries around the world are based on years of fertilization experiments.

The aim of this paper is to describe the decision support system based on the results of soil analyses and field experiments in vegetable growing and fertilization.

2. Materials and Methods

The created DSS is based on the results of fertilization experiments which investigated the influence of soil fertility and fertilization on vegetable yield. These include interpretations of soil chemical analysis [1, 5], comparison of different soil nutrient availability analyzes [5, 6], impact of mineral and organic fertilization on nutrient removal and yield in vegetable growing [2, 7], impact of fertilization on soil fertility and nutrient availability [2, 7, 8], impact of liming on nutrient availability and yield [9], and previously created DSS for optimizing vegetable fertilization [3, 10, 11].

First part of DSS is calculation of physiological needs for basic nutrients (N, P, K) required to achieve the targeted yield [2]. Subsequently, physiological needs were adjusted based on soil fertility with the basic principle of increasing fertilization on poor soils and reducing fertilization on fertile soils well supplied with nutrients [1]. This fertilization correction considers not only the level of nutrient availability in the soil, but also the elasticity of the soil, i.e. the ability of the soil to neutralize stress conditions and current changes in soil properties due to fertilization with larger amounts of mineral fertilizers. Also, the correction of the necessary nutrients is carried out with the aim of maintaining soil fertility and preserving the environment [12].

The second part of the DSS refers to the recommendation of the optimal fertilizer and the forms of N, P and K in fertilizers considering dynamics of the required amounts of nutrients and the estimated soil fertility [1, 2].

The last part of the program is a simplified economic analysis of field vegetable growing. The cost structure in the program is done...
according to the analyses of the field vegetable production on family farms in eastern Croatia [13, 14, 15]. The economic part of the program consists of yields, prices, variable costs, fixed costs, income and break-even point for every vegetable species. The group of fixed costs consists of accommodation costs, insurance, interest payments and overhead costs related to the machinery management. For machinery amortization costs, insurance and interest payments also are calculated. The total price of aggregate work hour consists of tractor’s costs, related machinery and worker’s wage. It is multiplied by the number of hours (7-8) and what turns out is the financial value of the total cost of aggregate in one shift. This value is divided by the machine effect or norm. This is the final price of machinery in €/ha [16].

3. DSS structure and description

The described DSS uses data on providing information about major nutrients (N, P and K) through a certain vegetable yield, the results of fertilization experiments in vegetable growing [2, 7, 8], the interpretation of the results of agrochemical soil analysis, fertilization recommendations to maintain soil fertility and achieve the target yield as well as elements of the evaluation of the economic effects of vegetable cultivation.

Using the software is very simple. The user enters three groups of data in the left part of the interface (Fig. 1):

1. choosing the type of vegetable, the planned yield, pre-crop, pre-crop fertilization and the achieved pre-crop yield
2. results of agrochemical and physical soil analysis (soil pH, soil organic matter content, phosphorus and potassium available to the plant, residual mineral N in the soil, soil textural class)
3. conducted and planned fertilization with organic fertilizer and available mineral fertilizers.

![Fig. 1 Data input for the planned vegetable production](image)

On the right side of the interface there are windows with several groups of new data (Fig. 2):

1. Interpretation of the results of agrochemical properties and soil fertility
2. Recommendation of the amount of basic nutrients (NPK) in the vegetable fertilization with and without the use of organic fertilizers
3. Recommendation of fertilization with organic fertilizer:
   a. the amount of planned organic fertilizer
   b. optimal organic fertilizer according to P / K ratio required in fertilization
4. Recommendation of optimal quantities of available mineral fertilizers for cultivation without the use of organic fertilizers:
   a. optimal formulation of NPK fertilizer
   b. the amount of available NPK fertilizer (in the example shown NPK 7-20-30)
   c. the amount of simple fertilizers (in the example urea and CAN)
   d. main nutrient balance (NPK) as the difference between the need and fertilization possible with available fertilizers
5. Recommendation of optimal amounts of available mineral fertilizers for cultivation with the use of organic fertilizers (optimal formulation of NPK fertilizers, amount of available fertilizers and balance of main nutrients)

![Fig. 2 Output data: required nutrients and the fertilization recommendation](image)

After getting the results and guidance, by simply changing the data in the left part of the interface (e.g., planning lower yields, planning production on more fertile plots, choosing fertilizer of optimal formulation), after re-pressing the <Calculate> button in the left part of the interface, the user gets new results as output compatible with the changes made. This mode of operation enables a quick multiple comparison of the required fertilization with
Different available fertilizers, on different plots and for different target vegetable yields.

### 3.1. The procedure of calculating the required vegetable fertilization

The procedure of calculating the optimal vegetable fertilization is carried out in 10–12 steps, depending on the soil acidity and the reaction of vegetables to organic fertilization [2]:

1. determining the target yield
2. calculating the required amount of nutrient for the target yield
3. calculating the optimal need for N in fertilization
4. calculating the optimal need for P (P₂O₅) and K (K₂O) in fertilization
5. determining optimal organic fertilization
6. calculating the required liming
7. optimal distribution of N with respect to fertilization dynamics
8. optimal distribution of P and K with respect to fertilization dynamics
9. determining the need and application plan of micronutrients
10. choosing the optimal form of nutrient and calculating the amount of fertilizers (single and complex) in the basic fertilization and top dressings
11. calculation of the nutrient balance (the difference between the determined need for fertilization and the fertilization that is possible with available fertilizers)
12. calculating the economic effect of vegetable fertilization and growing.

#### 1 Determining the target yield

Determining the target yield depends on the genetic potential of the selected cultivar and the vegetable growing system. It is necessary to realistically determine the target yield based on soil fertility and the experience in certain production conditions. After calculating the optimal amounts of nutrients and required amounts of fertilizers, it is possible to correct the set target yield if the soil fertility is not at the necessary level to achieve the target yield (e.g., a large amount of phosphorus or potassium fertilizers should be applied and the soil is too acidic or too light textured so that the application of these fertilizers could be of low efficiency).

#### 2 Calculation of the required amount of nutrients

The calculation of the required amount of nutrients refers to the total amount of NPK that needs to be ensured in order to achieve the target yield and maintain soil fertility, which includes the total amount of nutrients that will be removed from the soil by a given yield and associated residual biological mass. It is also very important that after harvesting or vegetable picking a significant amount of aboveground mass of the plant remains on the production plots. It is important to know what the remaining amounts of N, P and K in the residues of pre-crop are for the calculation of nutrient balance, but also whether they are going to be available for the next crop. The amount of residual nitrogen in the soil after removing the pre-crop is extremely significant because it can make up more than 50% of the total needs. Mineral nitrogen (Nmin) that is left behind in the soil should definitely be considered an available nitrogen, either as a result of mineralization or as a consequence of previous mineral fertilization that the pre-crop did not use (e.g. due to lower yields or excessive or to late fertilization with nitrogen). Additionally, N which can be found in the rest of the aboveground mass that will be decomposed during the vegetation of the next crop is also considered available.

#### 3 Calculation of the optimal N need in fertilization

Optimal nitrogen fertilization is calculated on the basis of the total need (physiological needs or removals) for the planned yield, determined amount of Nmin in the soil, the assessment of mineralization and the available N from organic fertilizer.

\[
\text{Fertilization N} = \text{Physiological need} - \text{Nmin} - \text{N mineralization} - \text{Inorganic fertilizer} + \text{Correction}
\]

#### 4 Calculation of the optimal need for P and K in fertilization

Optimal fertilization with phosphorus and potassium is calculated on the basis of the soil phosphorus and potassium availability classes [1]. The basic principle is to enrich poor soils (classes A and B), preserve the availability of nutrients in well-supplied soils (classes C and D) and omit phosphorus and/or potassium fertilization in very well supplied soils (class E) while gradually reducing the availability of nutrients in such soils.

The required amount of phosphorus and potassium in fertilization can be calculated in two very similar ways, using factors [1, 2] or continuous correction functions.

The correction factor depends on the soil supply class and is 0-1.5 for P₂O₅ and 0-1.75 for K₂O [1]. Very well supplied soils (class E) have the lowest value (0) and indicate that fertilization with phosphorus and/or potassium in this vegetation is not necessary at all. The highest values (1.5 or 1.75) are for very poor soils (supply class A) and indicate that the soil will be enriched by 50 % more phosphorus or 75 % more potassium than the amount removed by the planned yield. Such an approach allows for the continuous enrichment of poor soils because more nutrients will be introduced into the soil than removed by yield. On the other hand, in soils with the level of available nutrients above a good supply, the amount of available nutrients will gradually, slowly and in a controlled manner decrease.

The estimated annual amount of P₂O₅ and K₂O through mineralization of organic fertilizer is calculated in the same way as the amount of N. Thus, 10 t/ha of organic fertilizer with 0.2 % P₂O₅ (e.g. beef cattle manure) will result in 10 kg/ha of P₂O₅ in the first, and only 4 kg/ha in the third year. It is clear that the calculation of optimal fertilization depends not only on the planned yield, the specifics of cultivars, agrotechnics of pre-crop, but, above all, on soil fertility.

#### 5 Organic fertilizer calculation

The recommendation of organic fertilization is calculated based on the reaction of the selected type of vegetable to organic fertilizers, soil fertility, quality and availability of organic fertilizer. The calculation equation of organic fertilization is a conditional which is not carried out if direct organic fertilization is not suitable for the selected type of vegetables. However, organic fertilization in vegetable production is always useful and almost necessary, either directly for the planned vegetables or for the pre-crop for which an organic fertilizer has previously been applied. The type of organic fertilizer will be chosen based on soil fertility. For example, if phosphorus deficiency is pronounced, the most suitable organic fertilizers will be poultry fertilizers (hen, turkey, chicken, broiler manure) and separated pig manure due to the increased content of phosphorus compared to potassium. The use of cattle manure and horse manure is more suitable on soils with a pronounced potassium deficiency.

#### 6 Calculation of required liming

The need for liming is also a conditional step because it is calculated only for soils whose pH value is too low, and the limit of excessive acidity in vegetable growing can be considered soil acidity below 5.0-5.5. The required liming is calculated in order to achieve the optimal soil pH value, the upper limit is considered to be pH 6.8-7.0. The lower limit depends on the tolerance of the vegetable species to soil acidity. On the so-called organic soils with a higher content of organic matter all types of vegetables tolerate slightly lower pH values due to Al³⁺ cations being less toxic than in mineral soils with a low content of organic matter [17, 18].

#### 7 Optimal distribution of N with respect to fertilization dynamics
The optimal distribution of N depends on the type of vegetables (growth intensity, required amount of N, length of vegetation), required amounts of N in fertilization, vegetable growing system, and soil fertility (leaching, denitrification, volatilization of the part of the added N). The distribution of N fertilization in all types of vegetables is very important, often crucial for the height and quality of yield. Nitrogen is added for most vegetables, partly by pre-sowing fertilization, and partly by fertigation. Care should be taken as unnecessary excessive fertilization or late fertilization. Fertilization amounts above the optimum do not have to have a negative effect on the yield, but the same yield with less fertilization would be achieved, which means that in order to achieve the same yield, the cost of fertilization could be lower.

8 Optimal distributions of P and K with respect to fertilization dynamics

Mineral fertilizers for most types of vegetables are applied to the soil in the spring, before sowing/transplanting or even together with sowing. For certain types of vegetables, a part of the total required amount of phosphorus and potassium is introduced into the soil by autumn basic tillage, and the rest by pre-sowing fertilization. In the case of vegetables with long vegetation and prolonged fruiting, part of the phosphorus and part of the potassium are applied to the fertilizers along with fertigation systems.

9 Establishing the requirements of microelements and microfertilizers application planning

In soils with unfavorable pH value, micronutrient deficiencies are common. In acidic soils a lack of available Mo and in alkaline Fe, Mn, Zn, Cu and B is expected. It should also be borne in mind that vegetable types differ significantly in sensitivity to or needs for trace elements.

10 Selection of the optimal form of nutrients and calculation of fertilizer quantities

After calculating the quantities and selecting the optimal method of distribution of nutrients, the choice of optimal forms of nutrients and fertilizer formulations remains. The choice of the optimal nutrient form means the choice between the amide, ammonium or nitrate form of N; water-soluble, citro-soluble or less soluble form of phosphate; chloride or sulfate form of the potassium; ammonium or nitrate form of N; water-soluble, citro-soluble or less soluble form of phosphate component.

11 Calculation of the predicted nutrient balance

The predicted nutrient balance (the amount of nutrients added to the soil by planned fertilization - the amount of nutrients removed from the soil by planned yield) must be calculated for the reason of advanced (several years ahead) fertilization planning. After calculating the required fertilization for the upcoming vegetation, the planned nutrient balance must be incorporated into the fertilization balance plan for several years ahead in order to maintain soil fertility, but also within the framework of economically viable fertilization. In case of necessary and possible cost reductions, fertilization can be rationalized by reducing the amount of fertilizer or reducing the rates of the application of fertilizer on fertile lands. Namely, in case of one vegetation type fertilization with phosphorus and/or potassium on fertile plots where there is a small need for fertilization with P and/or K can be missed. The obligation to compensate for these nutrients in the next vegetation remains due to the planned fertilization balance.

12 Calculating the economic effect of vegetable fertilization and growing

Calculation of the economic effect of vegetable growing and fertilization is done in the part of model deals with economic issues presenting simplified economic analysis of the field vegetable organic farming. The offered costs are integrated in the program as a help for the user who doesn’t have adequate costs data (mostly for the production profitability predicting). Also, all the amounts, prices or even costs structure or type variable (seed, fertilizers, pesticides, machinery costs, wages etc.) changes are allowed as a new input. Thus, it’s very simple to compare specific production conditions [11] with default model concepts, and to analyze economic importance of site-specific soil fertility, production investments, prices or any other factor. The structure of the most important part of the program, the economic analysis, includes the calculation of total income (TI), variable costs (VC), fixed costs (FC), break even points (BEP) and profit (P). Total income is a sum of income (yield sale amount) and subsidies. Variable costs (VC) are costs which change in accordance with the production volume change. They include: seed or seedlings costs, pesticides, fertilizers, machinery services, fuel, oil and lubricant costs, soil analysis, wages and other (species specific costs). Machinery cost is the sum of every related operation cost (listed in model) that is pronounced in prices per hectare (costs of ploughing, fertilizing, pesticides spraying, harrowing, sowing...). Fuel and oil consumption of one’s own machinery is calculated according to the using level, usage effectiveness, specific density, unit price, specific fuel consumption and machinery ages. Lubricant costs are calculated on the basis of annual consumption (2.5 kg/tractor/year, averagely). Wages are product of labor (hours/ha) and average price. Breakeven point of variable costs (BEVC) as the lowest production efficiency level (where the economic efficiency is zero) is the difference between the total income (TI) and variable costs (VC).

Incomes and variable costs of field vegetables according to the achieved yield and costs are calculated using a model default value. The most significant difference between incomes and variable costs is achieved for tomato, then carrot, pepper and the lowest for white cabbage and Savoy cabbage [4]. Nutrient status changes are described as low, medium and high fertility soil with differences in soil pH (pH = 4, 5, 6, respectively), humus content (1 %, 2 % and 3 %), phosphorus content (10, 20 and 30 mg/100 g P2O5), potassium content (10, 20 and 30 mg/100 g K2O) and Nmin content (0, 25 and 50 kg/ha Nmin). The yield levels are Croatian state average. The most convenient variant is the one with the highest yield on the highest potential fertility soil (the lowest fertilizer variable costs) as expected. Fixed costs (FC) include costs independent of production volume. They are distributed on vegetable species according to sown structure. These costs are the sum of: machinery amortization costs, machinery insurance costs, machinery upkeep costs, obturning amortization costs, obturning upkeep costs, general farm costs, salaries of permanently employed, credit interests, costs of hired agriculture land and insurance premium. Linear amortization method is a part of the model and it includes all farm machinery. Amortization is related only to machinery within proper term use. Profit or loss (P/L) is a final calculation result derived from a difference between total income and total costs: P/L = TI - (VC + FC).

Future improvement of economic fertilization model should include possibility to exchange mineral fertilizers with organic fertilizers. Some of these calculations were conducted implying that the shares of direct fertilizer costs are much more present on less fertile soils due to high nutrient requirements than on fertile soils. Furthermore, the costs of fertilizers participate more in mineral fertilization than the costs of application due to high prices of fertilizers and high performance of their application. The costs of application are the highest in organo-mineral fertilization, because in that case the costs of fertilizer are lower. Economic analysis of different fertilization models has proven the economic efficiency of mineral fertilizer substitution with manure that strongly depends on soil fertility and application costs [2].

4. References

1. Z. Lončarčić, K. Kralić, Mineralna gnojiva i gnojidba ratarskih usjeva (Faculty of Agriculture in Osijek University of Josip Juraj Strossmayer in Osijek, 2015)
2. Z. Lončarić, N. Paradikoivć, B. Popović, R. Lončarić, J. Kanisek, Gnojidba povrća, organska gnojiva i kompostiranje (Faculty of Agriculture in Osijek University of Josip Juraj Strossmayer in Osijek, 2015)
8. Z. Lončarić, A. Gross Bošković, N. Paradiković, V. Rozman, Z. Krailik, R. Baričević, V. Bursić, S. Miloš Utjecaj poljoprivrede na kakvoću hrane u pogranicnim područjima (Faculty of Agriculture in Osijek, Osijek, 2015)
9. Z. Lončarić, D. Rastija, K. Karalić, B. Popović, V. Ivezić, R. Lončarić, Kalcizacija tala u pogranicnim područjima (in Croatian) (Faculty of Agriculture in Osijek University of Josip Juraj Strossmayer in Osijek, 2015)
12. Z. Lončarić, A. Gross Bošković, N. Paradiković, V. Rozman, Z. Krailik, R. Baričević, V. Bursić, S. Miloš Utjecaj poljoprivrede na kakvoću hrane u pogranicnim područjima (Faculty of Agriculture in Osijek, Osijek, 2015)
17. B.J. Alloway, Heavy Metals in Soils (Blackie Academic and Professional, Glasgow, 1995)
Sunflower irrigation in conditions of water deficit

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Summary: An analysis has been made of the research work to determine the impact of water deficit on the quantity and quality of sunflower production. Studies have also taken into account the more frequent drought in the last decade - soil and atmospheric. Research shows that its good drought resilience allows it to be grown under irrigation conditions, but it is sensitive to severe droughts, especially in the critical stages of development which leads to poor quality and drastic decrease in yield, and in some years to the lack of yields. The results show that sunflower irrigation has a large reserve for obtaining additional yield, which has been established through experiments in different parts of the country. The increase in irrigation is about 30-40%, and critical for water stress is the period of 20 days before and 20 days after flowering.

KEYWORDS: SUNFLOWER, IRRIGATION, YIELDS, IRRIGATION RATES, RAINFALL, SUNFLOWER, SOIL AND CLIMATIC CONDITIONS, SUNFLOWER YIELDS, WATER DEFICIT, WATER STRESS

The agro-climatic features of Bulgaria determine the need for irrigation of a number of agricultural crops mainly in the period June-September to compensate for the emerging water deficit in order to create suitable conditions for their development.

The role of irrigation in ensuring sustainable yields of high production quality while drastically reducing the adverse effects of climatic factors in different years in this respect is undeniable and proven by its practical use and long-term research conducted in different regions of the country, [10].

Sunflower seed as a strategic oilseed crop is also the subject of this type of research, most of which are related to the search for economically justified irrigation regime by optimizing the size of the irrigation rate or by studying the sensitivity of the crop to water stress during the different periods of vegetation. The ultimate goal is to save irrigation water without significant loss of production.

The good sun-tolerance of the sunflower allows it to be grown under irrigation conditions in our country. Growing it under non-irrigation conditions is a prerequisite for allowing water stress for most of the years, resulting in a decrease in yield [2,4] found that irrigation can increase yields by nearly 3 times. According to the author, irrigation must maintain soil moisture above 80% of the PPV during flowering and over 70% of the WHC during the rest of the growing season. As an optimal one, this irrigation scheme was proposed by our scientists more than 30 years ago. [3,6] find that the highest yields of sunflower are obtained when irrigation is carried out according to the scheme 70-80-70% of WHC for the period before budding, flowering and seeding respectively. Plaut and Grava [1]) propose that sunflower irrigation be managed by evaporation data from a free water surface (reported by a "Class A" evaporator), offsetting 80% of it.

Sunflower irrigation has a large reserve for obtaining additional yield, which has been established through experiments in different parts of the country. The increase in irrigation is about 30-40% [6]. Critical to water stress is the period of 20 days before and 20 days after flowering [9].

The specialized scientific literature indicates the different depths at which the root system of sunflower plants penetrates and exhibits considerable activity. Plaut, Grava [1] found that after depletion of easily accessible moisture in shallow soil layers, sunflower absorbs all available moisture to a depth of up to 1.2 m, and according to [11], this depth is up to 3.1 m. [12] also consider that the root system of the sunflower reaches 2.5 m, but specify that the root mass, located in the 20-30 cm layer, has the highest absorption capacity for nutrients and water. In addition, the authors note that, after significant rainfall or after irrigation, many active roots are formed in the upper moist soil layer, through which the plants significantly improve their water and nutrition regime. This fact largely explains the good results obtained with sunflower irrigation.

Table 1 presents summary data on the magnitude of sunflower production losses as a percentage of the yields obtained while maintaining optimal irrigation regimes. The data show that, in the critical phases, losses are not only the largest, but also the most variable. The reasons for this are - the time of irrigation cancellation during the critical period, the duration of the water deficit, the random nature of the rainfall.

Studies on the significance of irrigation (one or two), carried out only in certain phases, have shown that it is determined by all the factors considered so far to produce yield under conditions of unstable moisture. For sunflowers, irrigation in the critical phase alone provides on average 79.0% of optimal yield, but ranges from 47.0 to 98.0%.

Data from experiments with canceled irrigation show that in the critical phase the value of losses is very large for the main irrigated crops up to one quarter of the production.

Cancellation or holding off of the same irrigation does not lead to an equal decrease or increase in yield. Most often, irrigation in the critical phases alone is able to ensure the formation of 60-70% of the maximum yield obtained by optimally providing plants with water.

The reduction of individual irrigation rates leads to a decrease in yields, which is not proportional to the reduced irrigation rate. The water deficit resulting from this has a different effect on the amount of yield depending on the type of crop, the phases in which the irrigation took place, the magnitude of the reduction of norms, and especially the amount and distribution of rainfall.

It has been found that, with the irrigation technique used now, it is more economical to cancel irrigation than to reduce all irrigation rates, despite the fact that the latter leads in all cases to a lesser reduction in yield.

Research to determine the impact of water scarcity on the quantity and quality of agricultural production in field crops continues with new varieties, lines and hybrids, with newly created dry forms. Studies have also taken into account the more frequent drought in the last decade - soil and atmospheric.

To determine the right time for sunflower irrigation, experiments were conducted mainly in two directions - by performing the irrigation phases of growth and development and by maintaining a different pre-irrigation humidity.

Sunflower is considered to be resistant to drought and high temperature due to its biology - the root system is characterized by high power and plasticity, penetrates to a depth of 200 cm and a width of up to 150 cm and has a high suction capacity. This allows it to better extract the moisture that is difficult to absorb, and its large branching in the plow layer is a prerequisite for better use of...
nutrients and moisture in this horizon. The xerophytic structure of the leaves and the stem makes it easier for the crop to overcome soil and atmospheric drought. This good drought resistance makes it possible to grow it under irrigation conditions. Sunflower is susceptible to severe droughts, especially in the critical stages of development which leads to deterioration of quality and drastic decrease in yield, and in some years to non-formation of yields.

In our country, a number of attempts to irrigate sunflower have shown its high responsiveness to a rich water and nutrition regime. As a result of irrigation, sunflower yields are 56 to 200 kg / dka higher than the yield of irrigated sunflower. Individual years range from 150 to 330 kg / dka and depend on the amount and distribution of rainfall during the growing season of the crop. On the irrigation carried out and the level of applied agricultural technology, which is a large reserve for receiving additional quantities of grain and oil.

Figures 1 and 2 show the sunflower yields in areas where soil and climatic conditions are best suited for cultivation. The data show that the highest yields (maximum) under optimal irrigation were obtained in the Dobrich region - 400 kg / dka [5], for the Republic of Bulgaria and 300 kg / dka (Burgas) for the South Bulgaria. The increase in yield relative to non-irrigated sunflower is from 30 to 40%. When implementing irrigation regime without a single watering, there is no drastic decrease in yield compared to yield under optimal irrigation, which can be applied under water deficit conditions.

Experiments conducted with sunflower in Stara Zagora have shown that irrigation increases the yield in the years from 64.0 to 150.0 kg / dka. As a result of irrigation, the yield has increased from 143.0 to 162.0 kg / dka for grain and from 74.0 to 82.0 kg / dka for oil, while in sunflower growing under irrigation and fertilization conditions high yields are ensured - 432.0 kg / dka grain and 205.0 kg / dka oil (Karnobat), achieved by the implementation of 2-3 waterings made during the curing of the sunflower pies, the mass flowering and the beginning of the grain filling.

Under rainfall conditions sunflower [5], according to the field of Sofia, 450 - 500 kg / dka of grain was obtained with maintaining 80% humidity. High yields from sunflower irrigation - from 367 to 425 kg / dka are also established for the conditions of Dobrudza.

Table 1: Criticality of phases, deadlines for submission of irrigation and loss of yields in percentages with cancellation of irrigation by phases of sunflower development on average in the country

<table>
<thead>
<tr>
<th>Main stages of development of culture</th>
<th>Grading of the criticality of the water phases</th>
<th>Possible timing of the watering at ten days a month</th>
<th>Yields under optimal irrigation regime kg / dka</th>
<th>Grain losses as a% of optimal yield at unsupplied irrigations at separate stages of development</th>
<th>Provided yield in% of the optimal when watering only in certain stages of development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergence - inflorescence formation</td>
<td>3</td>
<td>II - III June</td>
<td>250 - 350</td>
<td>3.5 – 34.3 av. 16.5</td>
<td>47.0 – 98.0 av. 79.0</td>
</tr>
<tr>
<td>inflorescence formation - flowering</td>
<td>1</td>
<td>III June - I July</td>
<td></td>
<td>5.2 – 20.2 av. 12.6</td>
<td>57.0 – 92.0 av. 77.0</td>
</tr>
<tr>
<td>– flowering - seedgrowing</td>
<td>2</td>
<td>II – III July</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>maturing</td>
<td>4</td>
<td></td>
<td></td>
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</tr>
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</table>

Figure 1. Sunflower yields (kg / dka) in areas with suitable soil and climatic growing conditions - Northern Bulgaria
The results of the studies conducted to determine the most appropriate time for sunflower irrigation show that the critical stages of irrigation are the onset of budding, growing of pies, mass flowering and grain filling. Depending on the amount and distribution of rainfall, it is usually necessary to make from 1 to 3 watering’s. For a number of objective and subjective reasons, and mainly due to the lack of a single working methodology, the issue of optimal sunflower humidity is not sufficiently well understood from both a biological and economic point of view. This requires that the research work in this area should be continued mainly by bringing a system of ecological field experiments in a uniform methodology and under a single guidance in order to cover the most complete soil and climatic diversity of our country, [7,8].

In the future, based on multifactorial field trials and under a uniform methodology, studies to determine the optimal parameters for the influence of the water regime on the quantity and quality of yield of new sunflower hybrids should continue.

Conclusions:
The results of the studies conducted to determine the most appropriate time for sunflower irrigation show that the critical stages of irrigation are the onset of budding, growing of pies, mass flowering and grain filling.

It has been found that, with the irrigation technique used now, it is more economical to cancel irrigation than to reduce all irrigation rates, despite the fact that the latter leads in all cases to a lesser reduction in yield.

References
Microbial indicators and their relations with hydrophobicity in Spolic Technosols under different vegetation

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Abstract: Hydrophobicity (water repellency) have negative impact on soil structure, plant growth and production. The knowledge on soil hydrophobic properties is important for proper amelioration of water repellent soils. A monitoring study on hydrophobicity level, microbiological indicators and the relationships between them in a coal ash reclaimed Technosol under different vegetation cover (pine trees, acacia trees and stubble) was performed. It was found that the surface layers possessed extreme or severe hydrophobicity and below 30 cm depth the soil was slightly hydrophobic. The structure of microbial population changed depending on vegetation. Oligotrophic microorganisms dominated in soils under trees and fungi prevailed in the soil under stubble. The soil under pine trees had the highest microbial parameters. Soil hydrophobicity level was very highly positively correlated with the amount of fungi in both areas under tree vegetation. Under stubble, negative correlation of WDPT with fungi and cellulolytic microorganisms was found. Relations with basal respiration and microbial biomass carbon were weak.

Key words: SPOLIC TECHNOSOL, HYDROPHOBICITY, MICROBIAL AMOUNT, BASAL RESPIRATION, MICROBIAL BIOMASS

1. Introduction

Technosols are technically created with soil-forming materials obtained as a result of human activity. The most extensive territories of Technosols in Bulgaria are located in the region of Maritza-Iztok coal mines. In recent years, studies on hydrophobic (water repellent) soil properties of Technosols are being developed in our country [1, 2, 3]. The knowledge on soil hydrophobic properties is important for proper amelioration of water repellent soils.

Hydrophobicity (water repellency) is reduced water retention of soils. It is associated with hydrophobic organic substances of plant or microbial origin that coat soil particles [4, 5]. Higher levels of hydrophobicity increase the soil erosion risk and decline soil fertility [6, 7, 8].

The relation between hydrophobicity and soil microbial indicators received much attention in the scientific literature. The possible role of microorganisms in the appearance of hydrophobic soil properties has been examined for many years but it is still not clear. In the first studies soil hydrophobicity was mostly associated with soil fungi [9]. Later, evidences for contribution of actinomycetes [7] and bacteria [10] to soil repellency were also shown. It was found that fungal hyphae and hydrophobic metabolites of microorganisms that coat soil particles [5, 10] reduce soil porosity thus decreasing water retention ability of the soil. Results obtained for different soils are diverse suggesting that the causes of soil hydrophobic properties are more complex [8, 11]. Soil organic matter, particle size distribution, water content, pH, fire incidence may contribute to hydrophobic properties, as well [8, 12, 13].

Little information is available about hydrophobicity and possible relations with microbiological properties in Technosols. The aim of this work was to determine microbiological indicators of Technosols from Maritza-Iztok coal mines and to assess their relations with soil hydrophobicity in areas under different vegetation cover.

2. Material and Methods

The experimental site was located in Maritza-Iztok coal mine region at the Obrouchiste-3 spoil. The plot consisted of loam Pliocence overburden sediments (yellowish-green and greyish-green clays), meliorated with fly ash. The soil was classified as Spolic Technosol [14] (IUSS Working Group WRB, 2015). The samples were taken in the autumn of 2019 from several points of a grid Δm of ~40m² using a core sampler (3 cm wide and 25 cm long). Areas with different vegetation cover – pine trees, acacia trees and stubble were sampled from 0-5 and 5-15 cm depth. Also, samples from a soil profile set in the area of stubble were collected from six layers up to 85 cm depth.

The following microbiological indicators were determined:
- numbers of main microbial groups (heterotrophic bacteria, actinomycetes, microscopic fungi, cellulolytic microorganisms and oligotrophic microorganisms) on selective agar media using the plate count method [15]. The amount was converted in relative share (%) of different microbial groups.
- basal respiration (CO₂ evolution) – titrimetrically [16];
- microbial biomass carbon content - by the method of Anderson and Domsch [17].

Soil hydrophobicity (water repellency – WR) was determined by measuring the water-drop-penetration-time (WDPT) in seconds [6]. Hydrophobicity level was classified as: wettable or hydrophilic (< 5s), slight (5-60s), severe (600-3600s) and extreme (>3600s) [18].

Relationships between microbial indicators and soil hydrophobicity levels were statistically analyzed by Pearson correlation coefficients using SPSS 22 for MS Windows.

3. Results

Most of the samples under pine trees were characterized with severe or extreme hydrophobicity (1130-14610 s). Higher values in the 0-5 cm layer were measured (fig. 1).

![Fig. 1. Hydrophobicity level at 0-5 cm and 5-15 cm soil depth in different monitoring points of the Technosol under pine and acacia trees.](image-url)
and actinomycetes had the biggest share followed by fungi and bacteria. The amount of cellulolytic microorganisms was negligible (fig. 2).

Basal respiration had similar values in both layers and varied between 2.14-5.46 mg CO$_2$/g/24 h. Microbial biomass carbon content (Cmic) was between 9.78-15.18 mg C/h.

Very high positive correlation between WDPT (hydrophobicity) and the amount of fungi ($r=0.942^{**}$) for all soil layers was found. Actinomycetes ($r=0.615$) and cellulolytic microorganisms ($r=0.450$) showed also a positive trend with the hydrophobicity level.

![Fig. 2. Relative share of microbial groups in the Technosol under pine trees at 0-15 cm depth. Legend: bact - heterotrophic bacteria, act - actinomycetes, fungi, cellulolytic microorganisms and oligotrophic microorganisms](image)

Soil hydrophobicity values under acacia trees varied between 3-1500 s with the highest levels (severe and extreme) being determined in the 0-5 cm layer (fig. 1). Oligotrophic microorganisms and bacteria had the biggest share among microbial groups studied. Lesser parts of actinomycetes and fungi, and a fewest part of cellulolytic microorganisms were determined (fig. 3).

Basal respiration rate was lower under acacia trees comparing to the soil under pine trees. Values varied between 1.45-2.77 mg CO$_2$/g/24 h and they were similar in both layers. Microbial biomass (Cmic) was between 5.78-18.18 mg C/h.

Microbial group of fungi was in high positive correlation ($r=0.835^*$) with WDPT under acacia trees. Actinomycetes ($r=0.657$) and cellulolytic microorganisms ($r=0.685$) tended to positively correlate with the hydrophobicity.

![Fig. 3. Relative share of microbial groups in the Technosol under acacia trees at 0-15 cm depth. Legend: bact - heterotrophic bacteria, act - actinomycetes, fungi, cellulolytic microorganisms and oligotrophic microorganisms](image)

Summarizing for both soils under tree vegetation and both layers, a correlation between WDPT ($r=0.831^*$) and fungi amount was found. Stronger correlations in the 5-15 cm layer for fungi ($r=0.978^{**}$) and cellulolytic microorganisms ($r=0.981^{**}$) were noticed. There was no relation of WDPT and basal respiration (CO$_2$ production) in those soils. Cmic indicator showed positive relation ($r=0.639$) with hydrophobicity in the 0-5 cm layer only.

Under the stubble, WDPT varied between 16-17120 s. The half of samples possessed extreme hydrophobicity (11780-17120 s) in both layers. The rest of them had slight or strong hydrophobicity (16-1470 s) (fig. 4).

![Fig. 4. Hydrophobicity level at 0-5 cm and 5-15 cm soil depth in different monitoring points of the Technosol under stubble.](image)

In the soil under stubble, correlation coefficients for both soil layers of soil hydrophobicity with all microbial groups studied were negative: -0.257 for bacteria, -0.293 for actinomycetes, -0.597* for fungi, -0.526* for cellulolytic microorganisms and -0.494 for oligotrophic microorganisms. The correlations were stronger for the 5-15 cm layer for cellulolytic microorganisms (-0.787*) and bacteria (-0.734*). Cmic was also in negative correlation ($r= -0.845^{**}$) with hydrophobicity in the 5-15 cm layer. The relation with basal respiration was weak.

Extreme hydrophobicity was determined in the surface (15270 s) and sub-surface (6850 s) layers of the soil profile (fig. 6). Below 30 cm depth the soil showed slight hydrophobicity (17-26 s).
The amount of microbial groups was the highest at 0-40 cm depth. Among all groups, oligotrophic microorganisms had the biggest share, followed by fungi and cellulolytic microorganisms (fig. 7). Bacteria and actinomycetes had little parts.

In the profile under the stubble, negative correlation coefficients for microbial groups and WDPT were determined. In the 0-20 cm layer of the profile the coefficient for fungi and WDPT was $r = -0.569$. In the 20-30 cm layer, WDPT was in negative correlation with bacteria ($r = -0.734^*$), cellulolytic microorganisms ($r = -0.787^*$), oligotrophic microorganisms ($r = -0.672$) and fungi ($r = -0.639$).

![Fig. 6. Hydrophobicity level at different layers of the Technosol profile under stubble.](image)

![Fig. 7. Relative share of microbial groups in the Technosol profile under stubble at 0-20 cm depth.](image)

Legend: bact - heterotrophic bacteria, act - actinomycetes, fungi, cellulolytic microorganisms and oligotrophic microorganisms

4. Discussion

Soil hydrophobicity level (as measured by WDPT) widely varied with different monitoring points and soil depths in the Spolic Technosol. Most of the samples at 0-15 cm depth possessed severe or extreme hydrophobicity. The soil profile was extremely hydrophobic up to 30 cm depth, and slightly hydrophobic in lower layers. Data are in confirmation with the well known spatial variability of the hydrophobicity in coal mine soils [1, 19, 20]. It is commonly related to the heterogenic composition of the Technosol and to randomly distributed coal particles and ashes in different layers [2].

Technogenic soils often have low microbial activity due to low pH, low organic matter content, poor soil structure, poor nutrient and water contents [21, 22]. The Technosols studied were characterized with relatively low microbial population numbers ($10^6-10^7$ CFU/g). The soil under stubble had less microbial numbers than the soils under tree vegetation. The structure of microbial population also changed depending on vegetation cover. Under tree vegetation oligotrophic microorganisms and actinomycetes prevailed among microbial groups, and cellulolytic microorganisms had very low part. Under acacia trees, oligotrophic microorganisms and bacteria were the dominant microbial groups, while cellulolytic microorganisms had minor share. Fungi and oligotrophic microorganisms prevailed in the soil under stubble, and actinomycetes were the smallest microbial group.

Results obtained showed high positive linear relationships of hydrophobicity with the amount of soil fungi in Technosols under tree vegetation. The relation was higher under pine trees than under acacia trees. Other authors reported about a connection between fungal hydrophobins and soil water repellency [23] or between fungal biomass and water repellency under Pinus trees [12].

Soil hydrophobicity in the soil under stubble was negatively correlated with fungi and cellulolytic microorganisms. This could be related to different agricultural use of the soil, vegetation and heterogenic soil properties.

In general, no or weak relations of WDPT and basal respiration were found in all soils studied. Cmic indicator was positively correlated with hydrophobicity in the 0-5 cm layer under tree vegetation and negatively correlated in the 5-15 cm layer of the stubble.

5. Conclusion

The Technosol reclaimed with fly ash was hydrophobic in most of the monitoring points. At 0-15 cm depth extreme or severe hydrophobicity was determined in the areas under pine trees, acacia trees and stubble. The soil profile was extremely hydrophobic up to 30 cm depth, and slightly hydrophobic in lower layers.

Relatively low microbial numbers were registered in the Technosol. The soil under stubble had smaller microbial amount than the soil under trees.

The structure of microbial population changed depending on vegetation cover. Oligotrophic microorganisms prevailed at 0-15 cm depth in both soils under tree vegetation, followed by actinomycetes - under pine trees, and by bacteria - under acacia trees. Under the stubble fungi were the dominant microbial group, followed by oligotrophic microorganisms.

Soil hydrophobicity level (WDPT) was very highly positively correlated with the amount of fungi in soils under trees. In the soil under stubble, negative correlation of WDPT with fungi and cellulolytic microorganisms was found. Relations with basal respiration and microbial biomass carbon were weak.

Acknowledgments

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6. References:


Evapotranspiration and biophysical coefficients of large-fruited tomatoes grown in unheated greenhouses under drip irrigation

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Summary To determine the overall and average evapotranspiration of tomatoes grown in unheated greenhouses, studies were conducted under soil and meteorological conditions in the area of the village of Chelopechene - Sofia with drip irrigation.

The total evapotranspiration, which reaches 537 mm during the vegetation period of the crop, is experimentally determined, and the established daily evapotranspiration values range from 1.50 to 5.5 mm with two minima - at the beginning and end of the growing season and one maximum in August. For the purposes of practice and design, the daily values of the biophysical coefficients Z, R and Kp are also calculated, which depends on the biological characteristics of the crop and the meteorological factors.

Introduction

Determination of evapotranspiration is important for the design of the irrigation design and the efficient operation of the irrigation area. It is a major cost factor in the water balance of the soil, on which the number of irrigation, inter-irrigation period and the amount of watering and irrigation rates depend. Additionally, the values of evapotranspiration are influenced by the biological characteristics of the plants and the environmental conditions. Finding the connection between evapotranspiration and the factors that determine it allows predicting the time for irrigation, an important moment in realizing an optimal irrigation regime.

Predicting evapotranspiration values with the precision required to determine the parameters of the irrigation regime to meet the needs of plants with water is a matter of great practical value. The problem with the cultivation of crops in cultivation facilities that are drip irrigated, where the plants have to recover water consumed almost daily, has a high degree of relevance.

Studies have been conducted to establish evapotranspiration of vegetables grown under greenhouse conditions are scarce and insufficient given the changed conditions. It has been found that when growing pepper in drip irrigation in unheated greenhouses in Sofia region, evapotranspiration reaches 668 mm [6] and with greenhouse small-fruited tomatoes - 373 mm [1].

The results obtained from studies [5,7] in our country prove that the values of evapotranspiration are influenced by the biological characteristics of the plants and the environmental conditions. They are the ratio between the evapotranspiration of the culture and the meteorological factors - air temperature, water vapor saturation deficits, and daily hours for every ten days in% during the year.

Water balance calculations were performed [1] using the formula:

\[ ET = W_{w} - W_{kp} + m, \]

where: \( ET \) is evapotranspiration in mm; \( W_{w} \) - the water supply in the layer 0-50 cm at the beginning of the period for which the ET is calculated, in mm; \( W_{kp} \) - water stock in the layer 0-50 cm at the end of the period in mm; \( m \) - Water application rate in mm.

Based on the obtained values of culture evapotranspiration, the daily values of the biophysical coefficients \( Z, R \) and \( K_p \) were calculated using the following formulas, [4]:

\[ Z=ET / \sum t, \]

where: \( ET \) is evapotranspiration in mm; \( \sum t \) - - the daily amount of daily average air temperatures in °C; \( Z \) is the biophysical coefficient to be determined for each crop individually depending on the final temperature sum of the period.

The biophysical coefficient (R) according to [3] is determined by the formula:

\[ K_p = 100 . ET \cdot [p \cdot (45.7 \cdot t + 813)]^{-1}, \]

where: \( ET \) is evapotranspiration in mm; \( p \) - the duration of the daylight hours for each ten-day period in% during the year; \( t \) - average daily air temperature in °C over the period considered;

\( K_p \) - the biophysical coefficient.

The biophysical coefficient (R) according to [2] is determined according to the final sum of the average daily water vapor saturation deficits for the period.

\[ R = \frac{ET}{\sum D}, \]

Where: \( \sum D \) are the daily sums of daily average water vapor saturation deficits in mb; \( ET \) is evapotranspiration in mm; \( R \) is the biophysical coefficient.
Results
The intensity of ET directly affects the duration of the inter-irrigation period and, consequently, the number of irrigations and the size of the irrigation rate.

During the irrigation period, 33 irrigation units were realized in the variant with a irrigation rate of 16.5 mm (100% irrigation rate), with the irrigation rate for the vegetation of the crop being 544 mm.

On the basis of data on the dynamics of soil moisture during the growing season and the submitted waterings, the course and the change of the evapotranspiration of tomatoes was determined. For the period from the second week of May to the end of September the total water consumption was 536 mm (Table 1, Figure 1). The highest daily average ET values were in the second week of July and the first in August. Measured ET daily values are in the range of 1.5 to 5.5 mm and the average value for the growing season is 3.7 mm. At the beginning and end of the growing season, the values are lowest, which is due to the lower stress of the weather factors and the lower crop needs for water. In general, changes in ET during the growing season follow the evolution of the culture and changes in meteorological factors.

To meet the needs of water use planning, methodologies and models have been developed to determine evapotranspiration in a computational way. For their application, it is necessary to determine the biophysical coefficients experimentally. They reflect the specificity of water consumption, depending on the biological requirements of the culture, the phase of development, the manifestations of meteorological factors.

Calculated daily values of biophysical coefficients based on experimental determination of evapotranspiration and daily sums of mean daily air temperature (for coefficient Z), duration of daily hours for each ten day in% during the year. (for the coefficient Kp), the weekly sum of the average daily water vapor saturation deficits in mb (for the coefficient R); are presented in (Table 1, Figure 1). Changes in the values of these coefficients follow changes in evapotranspiration during the growing season of the crop. The determined values of the biophysical coefficients represent an objective basis for determining the design irrigation regime and forecasting the irrigation time of the crop.

The values of the biophysical coefficient Z of culture varied from 0.14 to 0.27, of the coefficient Kp from 0.38 to 0.98, and of R from 0.27 to 0.64 on average over the study period.

Conclusions
The total amount of evapotranspiration was determined for the growing season of tomatoes and daily average values ranging from 1.5 to 5.5 mm with two minima - at the beginning and end of the growing season and one maximum - in July and August.
Figure 1  Daily evapotranspiration (ET, mm) and biophysical coefficients (Z, R, Kb) of tomato by drip irrigation for the vegetation period in Chelopechene, Sofia, average for the period 1988-1990.

References