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ENERGY EFFICIENCY OF DIRECT INPUT IN THE CONVENTIONAL PRODUCTION OF CORN

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Abstract: Research of efficiency of conventional production of mercantile corn was held on production parcels in agroecological conditions of Posavina in a period of vegetation in 2017. In order to define costs of crop management from the point of view of energy and production aspects, in certain stages of production of corn grain, energy consumption and utilization of the horsepower of the tractor was monitored. During working operations the maximum amount of fuel was spent for ploughing (plough Leopard- L 30.3 VK aggregated with tractor Belarus 82.1) 26,4 l/ha, while the smallest amount was spent in chemical crop protection (sprayer RAU aggregated with tractor Universal UTB 450) 2,7L/ha. Accordingly, efficiency in various operations of production varied within 10-20% span. In our experiment efficiency varied from 6,91% during fertilization to 23,33% in the process of ploughing, which is in this case within optimum limits. In direct input almost one third or 27,13% went for the basic tillage system (81,77 kWh/ha) with a very high fuel usage of 23,33%. If we look at energy value of production of corn grains energy output will be 75243,20 MJ/ha with a ratio of 16,178 which is considered to be quite high, and productivity of 1,273 kg/MJ. In order to get the full picture of the above production of corn and energy outcome and not concentrating only on grain production, it is essential to include in energy analysis significant amounts of plant residues, that is maize biomass, which doubles the mentioned energy ratio to 31,846 and hence overall productivity of energy circulation in this production.

Keywords: MAIZE, FUEL AND ENERGY CONSUMPTION, COEFFICIENT OF UTILIZATION

1. Introduction

Modern agricultural production cannot be imagined without appropriate agricultural machinery and equipment, the use of which provides optimal and stable yields and significantly affect the increase in productivity and cost operation with a constant striving to achieve the minimum cost of the product. Machinery and investing in other technical resources are the key factors that determine the cost in the present-day conditions of modern agricultural production. The proper choice and functioning of the mechanization that participate in the process are affecting profitability.

Tillage is the largest consumer of energy in crop production. Pelizzi et al (1988) report that 55-65% of total energy consumption for work in the field is spent for tillage. Tillage consumes huge amounts of energy necessary for cutting, breaking, reversing layers of soil, crumbling clods and mixing structural aggregate of soil, planting and harvesting. Implements works on soil spending energy of the fuel (chemical energy), which is transformed into mechanical work by the tractor engine (Hernanz and Ortiz-Canvate, 1999). Conventional tillage system is based on very intensive functioning of mechanical force on land and reversing the layers of soil, and that is the main purpose of operation of the plow. Despite the fact that the ploughs on the market recorded a significant drop in overall demand and sales, plough still remains the main tool for primary tillage in Europe (Koller, 2004). Since on the surface remain relatively large clod and rough surface of arable land after the plow, the work is necessary to end with the additional tillage in order to form a shallow layer of soil ready for planting. Disc harrow is certainly the most well-known and most important tool for supplementary or pre-planting tillage. Shrestha and colleagues (2001) state that the creation of an energy-efficient tool intended for different working conditions requires both, understanding the interaction of the effects of different tools, as well as the knowledge of soil and operating parameters of the tools. Work performance in processing can be improved by increasing the performance or reducing fuel consumption. According to Smith (1993) potential savings can be achieved by the so-called gear-up throttle-down technique. Proper aggregation or alignment of tools and tractors is another method of increasing the performance. According to Filipovic (2005) the most advantageous use of tractor engine power in the plow is 18.14%, achieved at a depth of 35 cm and a velocity of 7.00 km/h. According to this author, the best use of the power of a tractor engine of 13.9% is achieved by a disc harrow with an operational reach of 550 cm at a speed of 10.50 km/h. For certain tools on a particular soil type total traction resistance is a function of the speed of movement, the depth of treatment and the width of the workload. Standards such as ASAE (the American Society of

Agricultural Engineers) show the required power and energy for the operation of certain tools in various processing operations and soil types, but of course the display includes a limited number of data (ASAE, 1999). According to the tillage analysis, maize is the most important crop cultivation in the Republic of Srpska and is grown on 46.7% of arable areas. Depending on the year, average yields range from 2.7-5.3 t/ha (Statistical yearbook of the Republic of Srpska 2018). The great significance of maize stems from its variety of use, fertility potential, the possibility of achieving high yields of grain and silage in the conditions without irrigation. The basic requirement for maize production is to obtain high and stable yields of grain of adequate quality. The modernization of agricultural production, and thus the production of corn achieved a positive trend in the average world yield of corn, which ranged from 4.81 t/ha in 2005 to 5.61 t/ha in 2014 year (Zratic et al. 2017).

Mercantile corn is dominant with over 90% on arable land. Using conventional technology with the mandatory use of the plough in autumn basic tillage, fuel consumption ranges from 30 to 60 l/ha in tillage and sowing (Malinović et al., 2010) with the use of energy ranging from 90 to 120 kWh/ha. The concept of sustainable agriculture implies rational management of agricultural resources (Momirovic et al 1997), (Momirovic et al 1998) with a goal to meet the changing needs of the population in food and raw fibers and in order to preserve natural resources and protect and improve the environment. The basis of sustainability is the system's productivity expressed as the ratio of inputs and outputs, most often in the energy view. Since tillage in most of the farming systems is the most important item in the overall needs for supplementary energy, it has enormous economic significance. (Oljaca et al 2009), (Momirovic et al. 1998).

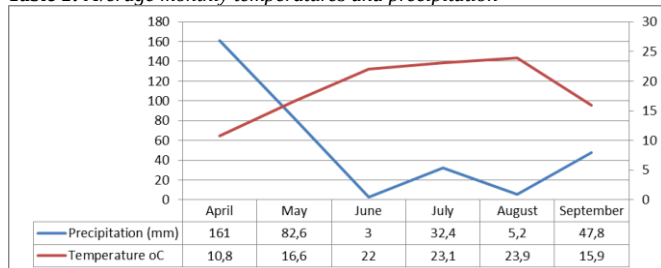
Today, fossil fuels are mainly used as sources of energy and in the last 300 years more than a third of the reserves have been exhausted. It should be mentioned that the most easily available and the finest part of these fuels has been used so far. The use of fossil fuels has an impact on the environment, primarily through the emission of gases with greenhouse effect, which is the cause of climate change, and through the emission of pollutants. Any reduction in fuel consumption - energy input, therefore contributes to the reduction of the negative impact on the environment as well as on productivity and profitability of the given production. Energy-efficient agriculture as a rule is financially more favorable, and certainly more favorable from the point of view of preserving the environment. From the point of view of the national economy and the preservation of resources, energy saving is very important for countries that are energy importers (<https://agroplus.rs/energy-efficiency-in-agriculture/>). On the other hand, for the realization of agricultural production it is necessary to invest in energy. The goal

is to make the ratio of the received and invested energy as favorable as possible. The energy efficiency of agricultural production is evaluated by comparing the obtained energy, which is contained in agricultural products, and those invested in production. The amount of energy received and invested is called energy efficiency, and the difference of obtained and invested energy is net received energy. The basis for defining the agricultural production system was given by Ortiz-Canavate and Hermanz (1999). The definitions and classification of energy inputs in plant production are given here, as well as the presentation of energy analysis based on them. It comes down to determining the energy productivity and energy ratio of the input and output of the reference plant production. The method under which the energy analysis of the agricultural production system can be carried out is reduced to determining the energy value of the input, based on the quantity and given energy equivalents, and the energy value of the output. Energy which is consumed in the process of plant production is divided into direct and indirect. Direct-consumed energy is the one consumed through fuel, while indirect-consumed energy is the one that includes the consumption of nutrients, chemical protective agents, the use of mechanization and irrigation systems, transport and human labor. (Dimitrijevic, 2007). Direct energy inputs are related to the use of energy from fossil fuels or renewable energy sources used as biofuels in the process. Currently most of the energy sources used in agriculture in developed countries are of fossil origin such as diesel, petrol, liquid petroleum gas, coal. Tractors and self-propelled agricultural machines are mainly powered by a diesel engine, as diesel engines have a higher efficiency and a period of exploitation. Diesel fuel is the most widespread of all direct inputs in agriculture (60-80% of the total). Liquid petroleum gas is mainly used for heating and drying, while electric power is used for irrigation of plants. To establish the energy values contained in these inputs it is necessary to consider their heating value (enthalpy), adding the energy needed to make the energy available directly to use. For example, a liter of diesel fuel contains 38.7 MJ. However, the processing, transport and availability of diesel fuel to the farmer should be added, and that is additional 9.1 MJ added to the total amount. Thus, the energy cost of using one liter of fuel is 47.8 MJ (Ortiz-Canavate and Hermanz, 1999). The aim of this paper was to look at the costs of agricultural engineering in the corn production for grain in certain phases of its production from the energy and production aspect.

2. Materials and methods

In order to determine the energy and economic efficiency of primary and secondary tillage, sowing, cultivation and harvesting of mercantile maize, tests were carried out in the production parcels in agroecological conditions of Posavina in the period of vegetation in 2017. On the territory of the municipality of Šamac, where the research was carried out, pseudogley soils were represented. The climate is continental and data on average monthly air temperatures and precipitation for the investigated area (Šamac) during the 2017 are shown in Table 1. The data was taken from the nearest meteorological station.

Table 1: Average monthly temperatures and precipitation



The aggregate consumption was determined by the volume method, fueling up to a full tank and subtracting from the initial value of the full tank. Fuel consumption per unit area is calculated using a calculation method. The chronometer method recorded all the operations individually and determined the performance of the aggregate. The table data and calculation method of the realized

power for aggregate operation were used according to ASAE Standards D497.4 and ASAE Standards EP496.2. The tests were carried out within the existing possibilities, considering the available equipment. In order to calculate the energy output of mercantile maize we obtained the harvest yield of 5.920 kg/ha. with 15.4% moisture.

These tests included either the individual phases mentioned before or the entire technological process. In the energy analysis process the methodology by Ortiz-Cañavate and Hermanz (1999) was used. It provides a procedure for determining the energy input and output, based on the measured values of the consumed material and the yield achieved, and given energy equivalents, i.e. conversion factors. Specific energy input, energy relationship and energy productivity are determined on the basis of the obtained values.

The energy parameters that define the reference plant production are:

$$\text{Specific energy input (EI)} = \frac{\text{Energy input in the production cycle (MJ/ha)}}{\text{Output (kg/ha)}} \quad (\text{MJ/kg})$$

$$\text{Energy ratio (ER)} = \frac{\text{Energy production value (MJ/ha)}}{\text{Energy input in the production cycle (MJ/ha)}} \quad \frac{\text{Output (kg/ha)}}{\text{Output (kg/ha)}}$$

$$\text{Energy productivity (EP)} = \frac{\text{Energy production value (MJ/ha)}}{\text{Energy input in the production cycle (MJ/ha)}} \quad (\text{kg/MJ})$$

Energy inputs can be quantified according to their energy value or intensity.

3. Results and discussion

Polish research was carried out in agroecological conditions and in the production parcels of Posavina (municipality of Šamac) in the period of vegetation in 2017. It was carried out on the soil type pseudogley and on the plot area of 1 hectare in the basic operations of conventional tillage. For operations in the primary and supplementary cultivation of the land the tractor Belarus 82.1 was used, while for other operations up to the moment of harvest the tractor Universal UTB 450 was used. During working operations the maximum amount of fuel was spent for ploughing (plough Leopard- L 30.3 VK aggregated with tractor Belarus 82.1) 26.4 l/ha, while the smallest amount was spent in chemical crop protection (sprayer RAU aggregated with tractor Universal UTB 450) 2.7l/ha. Table 2 gives average data on capacity performance of machine and fuel consumption in individual operations.

The following table presents the energy parameters of primary and secondary tillage, fertilizing, sowing, protection, cultivation and corn harvest. All parameters are expressed in terms of fuel consumption per unit area of Qha (l/ha) and a value of 47.8MJ/kg was adopted for thermal power of the fuel (Ortiz-Canavate and Hermanz, 1999).

Table 2 Capacity performance of machine and fuel consumption

Aggregate	Efficiency (ha/h)	Total utilization of fuel (l/ha)	Coefficient of utilization of time*
Belarus 82.1 + plough Leopard-L 30.3 VK	0,43	26,4	0,85
Universal UTB 450 + spreader INO	2,50	2,6	0,80
Belarus 82.1 + disc harrow Comet 2.5	1,08	14,8	0,80
Belarus 82.1 + rotary harrow Pegoraro 2.5	1,42	16,2	0,85
Universal UTB 450 + OLT PSK-4	1,23	5,1	0,70
Universal UTB 450 + roller Cambridge	2,03	3,6	0,85
Universal UTB 450 + sprayer RAU (I treatment)	2,05	2,7	0,65
Universal UTB 450 + sprayer RAU (II treatment)	2,05	2,7	0,65
Universal UTB 450 + inter-row cultivator IMT	1,25	4,2	0,80
Combine harvester ZMAJ 142	0,92	19,0	0,65

*ASAE Standards D497.4

Table 3 Energy consumption per operation

Aggregate	Efficiency (ha/h)	Total power utilization *(kW)	Total utilization of fuel (l/ha)	Total energy of fuel (MJ/ha)	Utilization of energy (kW/h/ha)	Technological processing energy (MJ/ha)	Coefficient of utilization of fuel (%)
Belarus 82.1 + plough Leopard-L 30.3 VK	0,43	34,98	26,4	1261,92	81,77	294,36	23,33
Universal UTB 450 + spreader INO	2,50	5,96	2,6	124,28	2,38	8,58	6,91
Belarus 82.1 + disc harrow Comet 2.5	1,08	27,44	14,8	707,44	25,46	91,67	12,96
Belarus 82.1 + rotary harrow Pegoraro 2.5	1,42	21,45	16,2	774,36	15,13	54,48	7,04
Universal UTB 450 + OLT PSK-4	1,23	13,96	5,1	243,78	11,34	40,81	16,74
Universal UTB 450 + roller Cambridge	2,03	12,41	3,6	172,08	6,12	22,03	12,80
Universal UTB 450 + sprayer RAU (I treatment)	2,05	5,96	2,7	129,06	2,91	10,46	8,10
Universal UTB 450 + sprayer RAU (II treatment)	2,05	5,96	2,7	129,06	2,91	10,46	8,10
Universal UTB 450 + inter-row cultivator IMT	1,25	10,43	4,2	200,76	8,34	30,04	14,96
Combine harvester ZMAJ 142	0,92	35	19	908,2	37,99	136,77	15,06

*ASAE Standards D497.4, ASAE Standards EP496.2

Bowers (1985) states that the total energy efficiency within the range of the normal working regime for the tractor and tools is within the limits of 10-20%. Combination of tractor and tools with a performance below 10% shows inadequate adjustment to load and poor tractive performance, while values above 20% show optimal adjustment to load and very high performance. As part of our research, according to various operations in production, the efficiency varied within the range of 10-20%. In our experiment the value ranged from 6.91% during the discharge of mineral fertilizers to 23.33% in the process of plowing, which in this case is within the optimal limits.

Direct energy inputs (Table 4) in the production of mercantile corn were monitored through the energy spent on fuel for the propulsion of technical systems, that is, a combination of tractor - machine aggregates in the performance of various operations. Therefore, the percentage share of direct inputs is the highest in primary and secondary tillage, while it is the lowest in the chemical protection of crops.

Table 4 Total direct inputs and the participation in the production of maize

Operation	Direct inputs (MJ/ha)	Participation %
Ploughing	1261,92	27,13
Fertilization	124,28	2,67
Disc harrowing	707,44	15,21
Harrowing	774,36	16,65
Sowing	243,78	5,24
Rolling	172,08	3,7
Protection 1	129,06	2,77
Protection 2	129,06	2,77
Cultivation	200,76	4,32
Combine harvesting	908,2	19,53
TOTAL	4650,94	100

Energy output

The calculation of energy output depends on the type of production. In the case of mercantile maize production, the energy output is defined by the yield and heat value of the product. Corn has a high energy value of 12.71 MJ/kg of gross energy (Radovanovic T. , Rajic I. 1990). In the 2017 experiment in the conditions without irrigation the average grain yield of mercantile corn was 5920 kg/ha with 15.4% moisture. After performing the

calculation of the given yield we get the following results: Energy production value (MJ/ha) = 12.71 MJ/kg * 5920 kg/ha = 75243.20 MJ/ha for energy value of corn grain. After the harvest of corn, besides corn on the surface remains a large quantity of crop residues, that is, maize stalks. Practical knowledge of the use of that biomass indicates a low level of maize utilization. Since the average ratio of grain and mass (the so-called harvest ratio) is 53% to 47%, it comes out that there is about as much agricultural waste as grain. While it is indisputable that part of the waste must first be returned to the ground, experienced estimates show that about 50% of the residue can be used to produce energy. Biomass (maize) is of a small energy value per unit of mass, due to its natural origin and the influence of moisture content and ash. However, it is nothing less significant in the overall balance of our energy analysis. According to Sisic et al (2013) the heat power of corn is 13.88 MJ/ha, which in our calculation is: Energy production value (MJ/ha) = 13.88 MJ/kg * 5250 kg/ha = 72870.00 MJ/ha for energy value of maize.

Energy analysis of direct input

Based on the established direct energy inputs and energy output, the energy analysis of direct inputs for grain production of mercantile corn was accomplished.

Table 5 Energy balance of direct inputs for grain production of mercantile corn

Direct energy inputs (MJ/ha)	4650,94
Yield of corn grain (kg/ha)	5920 kg/ha
Energy output (MJ/ha)	75243,20 MJ/ha
Energy parameters	
Specific energy input (EL)	0,785 MJ/kg
Energy value (ER)	16,178
Energy productivity (EP)	1,273 kg/MJ

According to the obtained data, in the total direct inputs of the production of grain of mercantile corn, the biggest share of the fuel consumption inputs in the process of harvesting is 27.13%, and the harvest process itself is 19.53%. The lowest inputs are in the fertilization process 2.67% and chemical protection 2.77%. Considering the given data, the dependence on the production of

maize from direct inputs (fuel consumption) can be seen. As the corn grain has a high energy value, it is understandable that it has a quite high degree of energy utilization, i.e. ratio of the output and total direct energy inputs in the production cycle. In the production of maize analysis, besides grain we took into account data on energy balance and plant residues (maize stalks). Table 6 presents a summary analysis of the given production.

Table 6 Energy balance of direct energy inputs for corn production (grain + maize stalks)

Direct energy inputs (MJ/ha)	4650,94
Yield of corn (kg/ha)	11170
Energy output (MJ/ha)	148113,20
Energy parameters	
Specific energy input (EL)	0,416 MJ/kg
Energy value (ER)	31,846
Energy productivity (EP)	2,402 kg/MJ

From the given data it can be concluded that there is a high degree of energy utilization in the production of corn - 31,846. Besides the energy contained in the grain as the main product, a lot of the energy remains in the plant residues, which makes this analysis more complete. This certainly affects the energy efficiency of production.

4. Conclusion

The process of maize production is mainly mechanized, starting from the primary and secondary tillage through care measures and the harvesting itself. A lot of energy is consumed in the conventional corn production (194.35 kWh/ha) and yet it is still the most important tillage system in the municipality of Šamac. Of this amount in direct inputs, almost third, i.e. 27.13% is spent on basic tillage (81.77 kWh/ha), with very high fuel consumption utilization of 23.33%. If the energy value of production of maize grain is looked into, the energy output is 75243,20 MJ/ha with a ratio of 16,178, which is considered to be quite high, and productivity of 1,273 kg/MJ. In order to get the complete picture of the given production and energy balance we cannot not to mention the significant amount of plant residues, i.e. biomass of corn, which changes given energy ratio for twice as much (31,846) and therefore the overall productivity in the energy circulation in this production.

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THE ENERGY EFFICIENCY OF INTELLECTUAL MANAGEMENT OF LIQUID FEED DISTRIBUTION SYSTEM AT PIGSTY FARMS

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Abstract: In the paper is discussed an energy saving effect of implementation at pig-breeding farms the automatic system of distribution the liquid feeds multi-times per day. There is given a mathematical description of the intellectual functions of the operator transferred to the PLC program of the control system. There is quantitatively estimated an energy saving effect of distribution the liquid feeds multi-times per day compared to twice per day.

Keywords: ENERGY SAVING, MATHEMATICAL MODELLING, INTELLECTUAL CONTROL, FEED DOSING, PLC

1. Introduction

Automation and mechanization of industrial technological processes usually leads to increase of the power of technological equipment. This is due to the increase in labor productivity of the staff person who manages the mechanized equipment. At that time the increase in power of technological equipment usually leads to an increase in its metal construction and energy intensity. Using mathematical modeling methods and modern program logic controllers allows changing the approach to the choice of parameters of agricultural process equipment. For example, the distribution of liquid feed many times a day will significantly reduce energy consumption by reducing the performance of equipment due to its round-the-clock operation in discrete-continuous mode.

In the Republic of Belarus are more than 100 industrial pigsty farms. Feeding of pigs by liquid concentrated feeds is a widespread feeding technology providing high efficient use of expensive resources. Usually it is used a double distribution of feed in accordance with zoo technical standards. Feed distribution is an energy and labor intensive process. Reducing the amount of consumed electrical energy can be achieved through the use of modern automated methods of process control. Moreover it allows shifting the operator's intellectual control functions to the computer device. Eliminating the need for the presence of the operator in the process control allows you to increase the operating time of the equipment and significantly reduce its performance and power.

Liquid feeding is a fully mechanized process and ensures high efficiency in feeding pigs [1, 2]. Therefore, the energy estimation of the effectiveness multi-times per day feed distribution compared to traditional technology of feeding pigs twice per day is actually important.

2. Mathematical model of energy consumption for feed distribution

The main functions of feeding process management are the following ones [3]:

- 1 determining of feeding time;
- 2 calculation of feeding doses in accordance with the animals number and age;
- 3 preparation of the required amount of feed;
- 4 distribution of feed for feeders in accordance with the planned doses;
- 5 control of food consumption.

In the past, functions (1, 2 and 4) have been completed by staff [3]. The need for staff in determining doses of feeding and control of feed consumption caused double feeding of pigs during the working day. Accordingly, the process equipment had to ensure the preparation and distribution of a daily dose of feed in 2-4 hours. The development of modern programmable logic controllers (PLC) and the use of mathematical models for pig growth process [1, 4]

allow to implement the function (1) by PLC without the presence of personnel.

The algorithm for feeding dose calculation is based on the mathematical model of the weight gain for fattening pigs [1, 4]:

$$P(m) = \mu \cdot m^\alpha \cdot \frac{(D - D_{\text{maint}})}{(D + D_{\text{maint}})}, \quad (1)$$

where m [kg] is the animal body weight; P [kg per day] is a weight gain per day; μ , α are empirical constant values determined by pig breed and environmental and feeding conditions at the farm; D [feed unit] is a day feeding dose; D_{maint} [feed unit] is the maintenance daily dose of feeding.

The maintenance daily dose of feeding provides 420 kJ/kg^{3/4}. It is determined by the formulae:

$$D_{\text{maint}} = k \cdot m^{3/4} \quad (2)$$

where k [feed unit/kg^{3/4}] is a constant value depending on the energy content in 1 kg of the feed.

Model (1) is valid for various zoo technical experiments when being adjusted by selecting coefficients: the values of μ and α depend by the animal breed and the farming conditions and the value of k depends on the quality of feeds used. By analyzing a large amount of experimental data there was made an estimation of the adequacy of the proposed mathematical model (1). As an example, some experimental data and the results of calculations according to formula (1) are presented at Table 1.

Table 1: Experimental data and analysis of the adequacy of the formula (1).

m [kg]	D [feed unit]	D_{maint} [feed unit]	P [kg]		Error [%]
			experiment	calculated by eq. (1)	
36,3	2,1	0,444	0,75	0,78	-3,8
45,4	2,542	0,525	0,82	0,83	-1,4
54,5	2,838	0,602	0,86	0,86	0,0
72,6	3,185	0,746	0,91	0,88	3,1
90,8	3,895	0,882	0,95	0,95	0,2
100	4,312	0,949	0,98	0,99	-0,5

Obviously, formula (1) adequately describes the required dependence, since the error does not exceed the possible for these data (2-3%).

To calculate the feed dose, it is necessary to justify the optimum criteria. For example, when using as an optimum criteria minimum cost of the feed unit, the required feed dose is determined by the ratio:

$$D_{1\text{opt}} = (1 + \sqrt{2}) \cdot D_{\text{maint}} \approx 2.4 \cdot D_{\text{maint}} \quad (3)$$

That is, knowing the initial weight of the pig on the first day we can determine the maintenance dose by the formulae (2) and then calculate the optimal feeding dose by the formulae (3). And then a daily weight gain is calculated by the formula (1). On the next day one should repeat the calculations.

Then the animal live mass at the day number n since the starting of feeding will be calculated as follows:

$$m(n) = m(1) + \sum_{i=1}^n P(i). \quad (4)$$

where n is the number of day elapsed since the start of feeding; $m(1)$ [kg] is the animal's live mass at the start of feeding; $P(i)$ [kg per day] is the daily weight gain at the day n .

Fattening pigs are contained in group boxes, so a group feed dose for the box number l is the following:

$$D[l] = N[l] \cdot 2.4 \cdot D_{\text{maint}}. \quad (5)$$

And the total amount of feed required for all group boxes is:

$$V = \sum D[l]. \quad (6)$$

The performance of the liquid feed distribution line Q should ensure the distribution of feed for the whole number of animals in the farm according to technological requirements [3]:

$$Q = V / (n \cdot t). \quad (7)$$

where V [L] is a required day amount of the feed of the desired moisture value; n is the number of feedings per day; t [sec.] is the duration time of the feed distribution process.

Earlier in [5] the correlation between the power of the liquid feed pump and its performance was empirically determined

$$P = l \cdot K_0 \cdot Q^\gamma. \quad (8)$$

where Q [m³/sec] is the current flow rate of the liquid feed; l [m] is the feed line length; K_0 and γ are approximation coefficients depending on the feed moisture W [%] and geometrical characteristics of the feed distributing line. According to experimental data there in Table 2 are shown the following results.

Table 2: Experimental correlation data between the power of the food pump P and its performance Q and feed moisture W .

Feed moisture W , %							
85.9	Q , [L/sec]	1.28	1.52	2.25	2.98	3.63	3.79
	P , [kW]	0.8	1.2	1.6	2.3	3.4	4.2
84	Q , [L/sec]	1.32	1.69	2.33	2.96	3.41	3.82
	P , [kW]	0.6	1	1.6	2.3	3.3	4.3
82.5	Q , [L/sec]	1.11	1.74	2.28	2.63	3.28	3.56
	P , [kW]	0.6	1.1	1.6	2.4	3.4	4.3
80	Q , [L/sec]	0.93	1.32	1.51	1.94	2.82	3.37
	P , [kW]	0.68	1.1	1.6	2.4	3.3	4.3
78.6	Q , [L/sec]	0.44	0.71	0.92	1.11	1.47	2.03
	P , [kW]	0.7	1.1	1.7	2.4	3.3	4.3
77	Q , [L/sec]	0.28	0.53	0.85	1.1	1.2	1.33
	P , [kW]	0.7	1.2	1.8	2.6	3.5	4.4

Daily energy consumption for distribution of feed will be determined by the formulae:

$$E = P \cdot t \cdot n. \quad (9)$$

Substituting (7) and (8) in (9) we get:

$$E = (l \cdot K_0 \cdot V^\gamma \cdot t^{1-\gamma}) \cdot n^{1-\gamma}. \quad (10)$$

Using typical equipment at pigsty farms requires staff presence. Therefore a technology of feeding pigs twice a day is accepted. The implementation of automatic intelligent control will eliminate the presence of the staff and apply multiple feeding in smaller doses. As a result, this will reduce energy consumption for the distribution of liquid feed in 2 or more times compared with 2-time feeding (see Fig. 1).

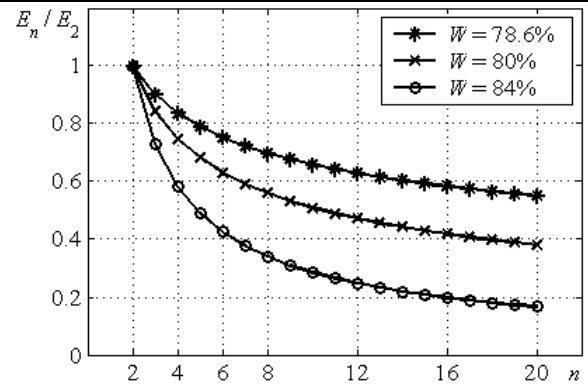


Fig. 1 Reduction of energy consumption for the distribution of liquid feed with an increase in the number of feedings per day: E_2 , E_n – power consumption when feeding twice a day and n times per day respectively; W – feed moisture.

3. Conclusion

PLC of the automatic feed distribution control system can take over the functions previously performed by personnel, including:

- mathematical calculation of feeding doses, including their optimization;
- control of food consumption;
- warning the farm staff about the need to diagnose the state of animals;
- logging the data parameters of the process of feed distribution.

In the mechanization era of the agro technical production, an increase in labor productivity was associated with an increase in equipment power and performance. The exclusion of the staff personnel from the management of the process of feeding pigs allows increasing the time duration of feed distribution and therefore to reduce the equipment performance and power and metal consumption. For example, when feeding several times a day (up to 20 times), a reduction in a single dose of feed distributed can significantly (up to 5 times) reduce the amount of metal required for the mixing baths and group feeders. If the feed distributed to feeders is not eaten in 30 – 40 minutes then the next feed dose can be adjusted or a warning signal for diagnosing the condition of the animals in this group box can be generated.

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A COMPARISON ON HARVEST TECHNOLOGIES USED IN OLIVE HARVEST

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Abstract: Olive cultivation is a traditional symbol of the Mediterranean climate zone. It is important to harvest the olive fruit at the appropriate time and to collect the whole product without damaging the trees during this harvest. Damage of fruits during harvesting directly affects the product quality and thus the producer's earnings. There are three main technologies commonly used in olive harvesting. The first of these; It is a hook type olive harvesting machine that performs the harvesting process by giving vibration to tree branches. Secondly; combs type are harvesting machines that vibrate given directly to the fruits and also the leaves and thin branches. The third is the trunk shaker type olive harvesting machines which take action from the tractor and vibrate to the trunk of the tree. In this study, some olive harvesting machines used in Turkey are compared in terms of performance and efficiency. Within the scope of the study, both domestic production and imported technologies are included. As a result, it has been found that the shaker type olive harvesters have a higher performance as expected. In contrast, the cost of this technology is higher than other olive harvesting technologies. Comb type olive harvest technologies are left behind in terms of performance compared to other harvest technologies. However, the costs of these machines are much cheaper than other olive harvesting technologies. On the other hand, it causes more damage to fruits and leaves.

KEYWORDS: OLIVE, HARVEST, HARVEST TECHNOLOGY, HARVEST PERFORMANCE, HARVEST DAMAGE

1. Introduction

Olive cultivation is a very important symbol for the Mediterranean basin [1] and has an important place in the economies of Mediterranean countries. Olive cultivation is carried out in the Mediterranean countries with the presence of 890 million olive trees on an area of approximately eight million hectares in the World [2]. Located in the Mediterranean basin olive cultivation in Turkey is carried out on 1836935 hectares. This area is an important area of agriculture, industry and trade with 172 million olive trees [3]. Olive production in Turkey is especially intensive in Balıkesir, Manisa, Canakkale, Izmir, Aydın, Hatay and Gaziantep [4,5]. Turkey grain olive production is made from Aydın (17.8%), Manisa (12.0%), Muğla (11.4%), Izmir (11.2%), Balıkesir (9.6%), Çanakkale (3.8%), Hatay (6.2%), Bursa (5.1%), Gaziantep (5.0%) and Mersin (4.6%), respectively [6]. Figure 1 is given in olive production in Turkey.



Fig.1. The olive producing regions in Turkey [7]

Harvesting of Olives can be done by hand or by using machines. Manual harvesting is very exhausting and due to the need for intensive labor, it leads to high costs. In contrast, harvesting with machinery is a more economical method. There are several types of machines used in olive harvesting. Although these machines are produced by different countries, they are mostly manufactured by machine manufacturers in olive producers' countries. One of these countries is Turkey.

In this study, it was aimed to compare the technical characteristics of different model machines used in olive harvest and manufactured by different companies in terms of the damage caused by trees, leaf dump, harvest fruit ratio and work capacity.

2. Material and methods

Olive harvesting machines are divided into three categories. These are hook type olive harvesting machines, comb type olive harvesting machines and trunk shaking type olive harvesting machines.

Hook Type Olive Harvesting Machines; engine, motion transmission pipe, transmission, shake arm and shrink hook consists of a total of five parts. In the scope of the study, a total of three models of olive harvesting machines were used, two different designs. In two of them, the gearbox is located next to the shrink hook (Figures 2 and 3) and one in the engine (Fig. 4). The shrink hook ring gaps were 40 mm (Figure 5) and 36 mm (Figure 6) in the first two, respectively, and 65 mm (Figure 7) in the other.



Fig.2. Hook type olive harvesting machine - Code: A1



Fig.3. Hook type olive harvesting machine - Code: A2



Fig.4. Hook type olive harvesting machine - Code: A3



Fig.5. Hook type of hook type olive harvester - Code: A1



Fig.6. Hook type of hook type olive harvester - Code: A2



Fig.7. Hook type of hook type olive harvester - Code: A3

Comb Type Olive Harvesting Machines; There are four parts; control unit, handle, engine-transmission unit and shaking unit. They usually feed on a battery. The most obvious features are that they are lighter than other olive harvesting machines. Three different models of comb olive harvesting machines were used in the scope of the study (Figure 8-10). The types of combs of these machines are given in Figure 11-13. The comb openings are 208-480 mm, 230-515 mm and 190-450 mm minimum and maximum according to the shape order [11-13].



Fig.8. Comb type olive harvesting machine - Code: B1



Fig.9. Comb type olive harvesting machine - Code: B2



Fig.10. Comb type olive harvesting machine - Code: B3

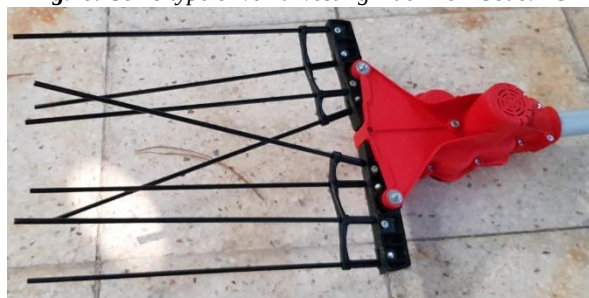


Fig.11. Comb type of comb type olive harvester - Code: B1



Fig.12. Comb type of carded type olive harvester - Code: B2



Fig.13. Comb structure of carded type olive harvester - Code: B3

Trunk shaker type Olive Harvesting Machines; There are basically three parts to the tractor, including the connection points to the tractor, the motion transmission system and the part that contacts the tree trunk. It takes his movement from the tractor. The most prominent features are that they get the movement from the tractor and they are heavier than other olive harvesters [14,15]. Two different model trunk shaker type olive harvesting machine was used (Figure 14-15).



Fig.14. Trunk shaker type olive harvesting machine - Code: C1



Fig.15. Trunk type olive harvester - Code: C2

The machines and general dimensional features used in the research are given in Table 1.

Table 1. Olive Harvest Technologies [8-15]

Code No	Machine Type	Weight (kg)	Width (mm)	Height (mm)	Length (mm)
A1	Hooked-1	14	270	580	3530
A2	Hooked -1	12	250	280	3000
A3	Hooked -2	13	265	300	2800
B1	Comb	2,9	110	280	2350-3180
B2	Comb	2,7	190	265	2270-3590
B3	Comb	2	355	280	2120-3620
C1	Trunk	1570	2440	1600	4700-6700
C2	Trunk	56	270	580	3530

Olive harvesting machines were subjected to laboratory experiments and application experiments. In laboratory experiments, the following structural characteristics of olive harvesting machines were investigated.

These;

- Technical specifications
- Chassis shape and strength
- Materials forming the machine and their strength,
- The nature of the links,
- The strength of the materials connected to the motor shaft,
- The structure and disassembly of the connection system,
- Ease of use in shaking,
- Job security features.

Application experiments were conducted in an olive garden. The performance of machines in different olive density trees was investigated. The ease of use and business success of the machines were examined. The performances during the pouring of the material from the tree were observed and the damages occurring in the new shoots in the olive branches were examined. During the harvest, damage to the branch and leaf casting were investigated.

3. Results and discussion

Laboratory experiments; technical characteristics, chassis shape and strength, the materials forming the machine and their strength, the quality of the connections, the strength of the materials connected to the motor shaft, the structure and disassembly of the connection structure, ease of use in shaking and the safety features are observed to be suitable.

Application experiments were repeated in different trees where olive fruit is frequent and infrequent. During the performance measurements of the Machines, The Lost times caused by the operator were not taken into account. The results obtained from the application experiments are given in Table 2 and Figure 16.

Table 2. Application test results

Code No	Damage in wood (%)	Leaf casting (%)	Non-harvestable fruit (%)	Min. Working efficiency (kg/h)	Max. Working efficiency (kg/h)
A1	3,1	2,2	7,1	385	550
A2	1,5	2,1	2,9	395	585
A3	2,3	1,4	10,1	374	515
B1	4,1	7,1	8,2	161	225
B2	4,1	7,2	4,1	125	220
B3	2,9	2,2	7,3	120	230
C1	2,5	2,5	3,1	918	1498
C2	1,3	3,1	3,3	610	900

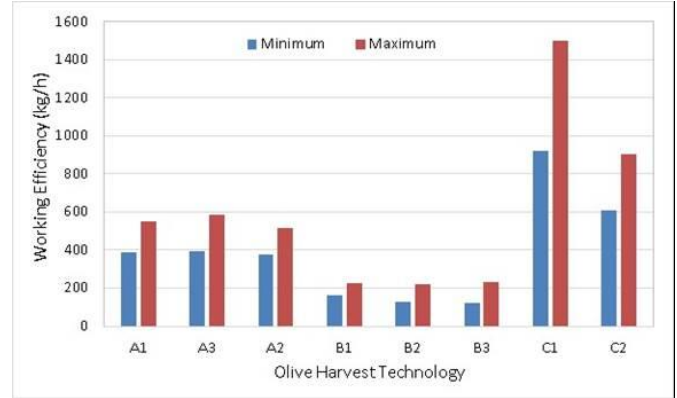


Fig.16. Results of work performance in olive harvesting machines

During the experiments, the machines worked without causing any dysfunction. At the end of this study, there was no excessive wear on the processing organs of the machines. During laboratory and application experiments, there was no problem in the machines as a functionally and structurally.

4. Conclusion

In this study, the damage caused by olive harvest machines in trees and leaf casting rates are analyzed, it is observed that comb type harvester machines have more damage to trees than other Harvester types. The best harvest success in terms of the fruit remaining in the tree was obtained from the trunk-shaking type olive harvesting machines.

In this study, it was found that trunk shaking type olive harvesters have a better work performance in terms of work performance than other types of harvesters.

The success of the C1-coded harvest machine was found to be 50.5% higher than the C2-coded harvest machine in the fruit trees and 66.4% higher than the fruit trees in the fruit trees.

In terms of work performance, comb olive harvesting machines have lower values than other types of harvesting machines. There was no significant difference between the B1, B2 and B3 type harvesting machines in the evaluation of the comb olive harvesting machines. In contrast, the difference between the minimum and maximum work performance of the B1 type harvesting machine is lower than the other two.

Hook Type Olive Harvesting Machines; In terms of work performance, it has a better performance than comb type of olive harvesting machines. However, work performance is lower than trunk shaker type harvesters. The success of A1-coded harvesting machine compared to A3-coded harvesting machine was found to be 2.9% higher in rare trees and 6.4% higher in common trees. The work performance of A2-coded harvesting machine was found to be 5.6% higher in the trees whose fruit is rare compared to the A3-coded harvesting machine and 13.6% higher in the trees whose fruit is frequent. The main difference of the A1 and A2 coded hook type olive harvesting machines with the A3-coded hook type olive harvester is that the transmission is positioned close to the hook. This situation has a positive impact on performance.

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RESEARCH OF SURFACE-PLANE AND SPACE-DEEP INTERACTION OF NEEDLE WITH SOIL

ИССЛЕДОВАНИЕ ПОВЕРХНОСТНОГО – ПРОСТРАНСТВЕННОГО ВЗАИМОДЕЙСТВИЯ ИГЛЫ С ГРУНТОМ

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Abstract: The purpose is to reduce the energy costs of soil tillage by developing more accurate methods for assessing the effectiveness of surface-plane and space-deep interaction of the needle with the soil. It is noted that the result of the interaction of the round needle of rotary harrow with the soil, there is a hole of regular shape with an ellipse at the base. The change in the semi-axis of the ellipse formed at the soil-air interface is analyzed. The developed method improves the accuracy of forecasting and evaluating the effectiveness of the rotary harrow needle interaction with the ground. The method creates the prerequisites for improving the quality and energy indicators of the technological processes of soil treatment with rotary harrows

KEYWORDS: NEEDLE OF A ROTARY HARROW, INTERACTION OF NEEDLE WITH SOIL, COEFFICIENT OF SURFACE-PLANE INTERACTION, SPATIAL-DEEP INTERACTION

1. Introduction

The natural and climatic conditions of the present are characterized by the formation of a dense soil crust on soils subject to wind erosion. This soil crust makes it difficult to germinate, damages the root system of plants, increases evaporation of moisture. For early-spring, pre-sowing and post-harvest small surface loosening of the stubble background, especially dense soil crust, effective tools with needle-like working bodies.

The reduction of terms and a significant improvement in the quality of execution of soil tillage technological processes are an important reserve for improving the efficiency of land resources and increasing the yield of agricultural crops [1]. Known implements with needle working units are intended for early-spring, pre-planting and shallow surface tillage of stubble in areas with soils that are prone to wind erosion. They have a low productivity, and an increase in the speed of their movement leads to a sharp decline in quality [2]. Rotary harrow tillage enhances soil organic C, total N and P and microbial C, N, and P stocks in comparison to moldboard plough management [3]. Soil processing is done without bringing from the depth wet soil layers to the surface, thus maintaining the humidity in the soil for good seed germination [4]. In studies [5] it was noted that with the increase in the depth of the tooth disc movement in the soil and the translational speed of the movement of the aggregate, the efficiency of the needle discs increases due to the increase in the vertical component of the total disk speed.

Existing needle harrows are not used in operations of the pre-emergence and after-sowing harrowing of cereals crops, as their working units are not adapted to working conditions at not great depths [6]. Therefore, the research is aimed at improving the qualitative and energy performance of soil tillage technological processes in needle harrows with variable angle of needle sharpening under conditions of their application for shallow surface fractures in the climatic zones that are prone to wind erosion.

The analysis of the condition of soil treatment with needle harrows showed that there are grounds to conclude that the selected directions are legitimate, the relevance and feasibility of carrying out research and the perspective of the formulated goals and objectives of research, which are aimed at improving the qualitative and energy performance of soil tillage technological processes in needle harrows with variable angle of needle sharpening, especially in the conditions of their application for small loosening of soil [7].

The work [8] deals with the motion of a disk whose axis is included in five disks with axes rigidly connected to the common axis holder, so that all disks move in the same direction and at the same height as the axis holder.

Under such conditions, the disk with the center C moves along with the other disks moves so that the velocity v_C of the center C is

directed horizontally. The authors analyzed both the insignificant depth of immersion of needles in the soil, and the case from the deepening into the soil of two needles simultaneously (Fig. 1).

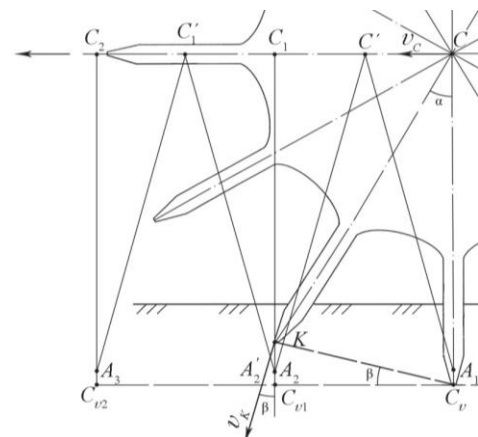


Fig. 1. A scheme for analyzing the motion of a disk of a needle harrow, whose axis is connected to the axes of other disks and the depth of needle immersion, is significant

It is noted that the smaller h_K , the smaller the angle β . As h_K is reduced to 0, the angle β becomes also equal to zero, and the velocity v_K will be directed vertically downward, that is the puncturing of the soil will be carried out vertically. Under such puncturing conditions, the friction force of the needle with the soil will be less than for the angle β greater than zero

Increasing the depth of processing does not lead to a change in the nature of the needle disk movement on the soil. However, the load on needles increases, which destroy a much larger number of soil particles than in cases of not significant depth of processing.

The velocity vector v_K of the point K (Figure 1) of the needle is directed at an angle β to the vertical. This angle β affects the conditions for puncturing the soil and is defined as:

$$\beta = \arcsin \frac{h_K}{2 \cdot r_D \cdot \sin \frac{\alpha}{2}}, \quad (1)$$

where: h_K – height of the point K above the line $C_v C_1 C_v$ (m); r_D – radius of the harrow disk with the needles (m); α – angle between the needles CK and CC_v .

The result of the harrow depends on the degree of synchronization of the needles of different disks on the soil. So, if the lower needles of the discs simultaneously sink into the soil, there will be a simultaneous piercing of the soil surface with these needles, and the pressure is equal to the soil resistance to deepening

the needles. If the needles of different disks do not fall down into the soil at the same time, the needles of different disks will alternately sink into the soil, while the piercing pressure will also be equal to the soil resistance, but the puncturing of the soil will be random and depend on the position of the needle disks relative to each other before piercing.

It should be noted that in the case of using a harrow with synchronous operation of the disks in the section and small values gravity force of the discs with needles, turning the disks by 30° will result in several simultaneous punctures of the soil, and the rest of the time there will be no puncture of the soil. With such harrow work and rigid connection between the disc axes, the force acting on the needles during their immersion into the soil is equal to the gravity of the harrow section. And a force acting on each disc (and thus on the needle which plunges into the soil) is equal to the section gravity force divided by the number of disks in it.

The angle of rotation of the disk for piercing the needle and leaving the needle is called the piercing angle. In existing harrows, this angle is theoretically equal to 30° of which half is used to dip the needle into the soil, and the other half is used to exit it. In general, this angle can be 36° or 45° . However, at a piercing angle of soil 30° , the piercing frequency is higher than in other cases (angles of 36° or 45°). That is, the piercing angle 30° is the most rational.

In studies [6] the interaction of the needle harrow with the soil in the case when the needle pierces it and carries out the motion strictly vertically is considered in detail. This is a somewhat simplified view of the movement of the points of the needle as a result of its interaction with the soil. However, under certain conditions and at the phase of needle entry into the soil and at the phase of its exit, there may be processes that will differ from those taken. That is why research of the processes of interaction between the needles of a needle harrow and the soil under conditions when the phases of entry and exit from the soil are considered in a plane that differs from the general accepted idea (vertical movement of the needle at all phases of its movement in the soil) is quite important and urgent task.

According to the results of research [9], it was established that the main factors that influence the determination of the required force for deepening the needles of the needle harrow in the soil are: the depth λ of the needle immersion, the angle of friction of the needle along the ground, and the angle characterizing the taper of the needle. In addition, the force needed to deepen the needle into the soil depends on the hardness of the soil, that is, on its mechanical composition and moisture content. However, the existing technologies of mechanical tillage do not provide for the use of needles for high moisture soil values.

It is established that the work W is the larger, the more the number of disks, the number of needles on the disk, the pressure of the needles on the soil and the penetration depth λ [8].

2. Purpose of the study

The aim of the study is to reduce the energy costs of soil tillage by developing more accurate methods for assessing the effectiveness of surface-plane and space-deep interaction of the needle with the soil.

Based on the analysis carried out and in accordance with the purpose of this work, the following research tasks are formulated:

- determine the features of the interaction of the needle with the ground in phases, both the indentations and its exit from the soil;
- analyze the surface-plane and space-deep interaction of the needle with the soil, and develop a mechanism for evaluating such interaction.

3. Material and methods

The object of study is the technological processes of treatment, the soil and the working bodies of the rotary harrow, methods for evaluating the effectiveness of the interaction of the needle with the ground. The subject of the research is the interaction of the working

bodies of the rotary harrow with the soil, the effect of its parameters on the indicators of the efficiency of the technological process of tillage.

Theoretical research are based on the basic principles of theoretical mechanics, the theory of mechanisms and machines, differential calculus and mathematical modeling of needle movement of any shape and design at various phases of its interaction with the soil (entry and exit from it)

The analysis of the operation of a needle harrow is carried out under such assumptions:

- the harrow with discs and needles is considered as a body moving along the traction unit (tractor) to the left horizontally, with the disk axes perpendicular to the plane of motion, and the disks with needles rotate counter-clockwise around their axes;
- the lower right needle that emerges from the soil does not affect it, and the force of attraction is transferred, mainly, to the needle that contacts the soil.

4. Results and Discussion

Consider the interaction with the ground points of the lateral surface of the needle, subject to moving its lower point along the vertical axis of symmetry formed by the needle hole.

The disk with needles of the needle harrow moves uniformly and rectilinearly with speed V_D . In Fig. 1 shows the scheme for piercing the soil with a needle. The moment of the beginning of the interaction corresponds to the instantaneous position OA . When the center of the disk B is moved to the position O_2 , the needle is immersed to a depth y_1 . This corresponds to O_1A_1 (Fig. 2). If the center of the disk occupies the position O_2 , the needle will be deepened to the maximum depth y_{max} (O_2A_2). The vertical position of the needle ends the phase of its entry into the soil and it begins to move in the opposite direction. We note that the stage of penetration of the needle into the soil is characterized by a gradual increase in the resistance to movement of the needle. In position A_2 at depth y_{max} these forces reach a maximum value. The exit of the needle from the soil (movement on the section A_2A) rightly does not take into account the influence of the resistance forces to the movement of the needle. Note that the section OO_2 – the distance that the disk passed in time t_1 is equal to the distance $AA_2 = y_{max} = OO_2 = V_D t_1$.

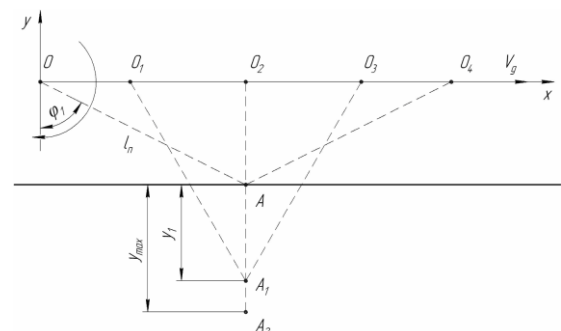


Fig. 2. Trajectory needle OA given its interaction with the soil

The peculiarities of the interaction of the needle with the soil on the phases, both the indentations and its emergence from the soil, include the presence of flattening (dents), which are formed on the soil surface in the direction opposite to the needle movement. In the case of the movement of the needle during the phase of entry into the soil, the observed flattening occurs from the side of the acute angle of contact with the soil. In the conditions of the needle exit from the soil, the flattening will appear on the other side of the funnel formed by the needle. In conditions of penetration of the needle into the soil in the form of a rod, a funnel (hole) formed by the results of such interaction can be represented as a cylinder. In case of penetration into the soil of a cone-shaped needle, the figure formed as a result of such interaction with the soil will represent a cone with a circle at the base. With increasing depth of penetration of such a needle, the area of the base of the cone will grow. According to the results of observations under conditions of real operation, the interaction of the needle of any shape and design with

the soil leads to the appearance on its surface of a figure close in shape to the ellipse. Moreover, in the phase of the needle entering the soil in the direction opposite to the motion, a semi-ellipse is formed, whose small semi axis is equal to the radius of the conical (cylindrical) part of the needle that penetrated the soil. The semi major axis of the semi-ellipse depends on the parameters of the needle, their number on the disk, the depth of penetration of the needle into the ground. Leaving from the soil, the needle on its surface leaves the flattening in the form of the second part of the semi-ellipse. The needle forms a funnel (trace), which represents a cone with the vertex A_2 , which is based on an ellipse.

In accordance with the known dependences [10] and our assumptions, we note that the doubled product of the small semi-axis of the ellipse is equal to the diameter of the needle, which is deepened into the soil. As is known, the ellipse is a closed figure in the plane, which can be obtained as the intersection of a plane and a circular cylinder, or as an orthogonal projection of a circle onto a plane. The circle is a special case of an ellipse [10].

In the case of the vertical position of the needle (O_2A_2) in Fig. 1 the area of its contact with the ground is a circle whose radius is equal to the radius of the part of the needle immersed in the soil.

The area of the ellipse (the hole formed by the penetration of the needle into the ground) will be determined by the dependence. The value of the area is affected both by the parameter a and by the characteristic of the needle (r_n). In general, the parameter a is the semi major axis of the ellipse depends on the characteristics of the needle, the depth of its immersion in the soil.

With Fig. 2 it follows that the beginning of the contact between the needle and the soil is characterized by the moment when the point A of the needle touches it. Under such conditions, it follows from the triangle ΔOAO_2 that, $OO_2 = l_n \cdot \cos \varphi_1$, where φ_1 is the angle of inclination of the needle to the soil, characterizing the beginning of the contact of the needle with it. Then

$$y_{\max} = l_n \cdot (1 - \cos \varphi_1) \quad (2)$$

where: $y_{\max}$ – depth of penetration of the needle into the soil;

l_n – distance from the center of the disk to the top of the needle.

The process of interaction between the needle and the soil occurs in three directions. A flat figure (circle, ellipse) is formed on the soil surface and this interaction can be classified as surface-planar. Due to the penetration of the needle into the soil along the vertical axis of symmetry of the hole, space-deep destruction of the soil takes place. The evaluation of the functional capacity of the harrow should be carried out by the total (integral) exponent, which generalizes the two types of interaction. Surface-planar fracture can be estimated from the area of the near-flatness (the figure of an ellipse (circle) on the surface of the soil). The volume of the figure formed in the soil by the results of the penetration of the needle into it is an indicator characterizing the efficiency of the space-deep interaction of the needle with the soil.

According to the results of the interaction of the needle, which has a circular cross-section with the soil, a hole of regular shape is formed, at the base (on the surface of the soil) which will not be a circle, but an ellipse.

Let us consider the case of the interaction of a cone-shaped needle with the soil (a cone-shaped needle consists of a cone and a cylindrical part). Only the cone-shaped part of the needle penetrates the soil (Fig. 1). As noted above, the disc of a harrow with needles carries out a complex movement. Due to the realization of such a needle movement, its end (the extreme point of the needle) will constantly move along the vertical axis. The phase of the needle entering the soil (in Fig. 2) corresponds to the left part: the position of the needle O_1A_1 – the beginning of the contact, O_2A_2 – intermediate position, O_3A_3 – maximum immersion of the needle in the ground. The phase of needle exit from the soil corresponds to the right on the vertical axis in the part of the figure: O_4A_4 is an intermediate position. In the vertical position O_3A_3 , point B_3 characterizes the point of contact between the needle and the soil. The penetration of the needle into the soil takes place in such a way that the movement of the extreme point of the needle A_1 is carried out along the vertical (y -axis), from the beginning of the contact of point A_1 (Fig. 2) to the position A_3 – the coincidence of the axis of

symmetry of the needle and the vertical axis y . During the movement of the harrows section its needles carry out by a compound motion: translational with velocity V_D (center O_1) and rotational with angular velocity around center O_1 . The beginning of the contact of the needle with the soil occurs at the moment when the point of the needle A meets the soil – position A_1 (Figure 2). After that, the axis of needle rotation will move to position O_2 , and its lower point will occupy the intermediate position A_2 . Under such conditions, the lateral surface of the cone-shaped part of the needle, deforming the soil, will occupy a position corresponding to the point B_2 . We note that the trajectory of contact point between the needle and the soil at the air-ground interface will be characterized by the following features: first the distance from the point of the primary contact (A_3) to the left part of the needle will increase with penetrates into the soil (point B_2), then, reaching a maximum, this distance will decrease, and in the vertical position of the needle it will be determined by the radius of the circle of the cone-shaped part of the needle that penetrated into the soil. The contact of the needle with soil takes place in a circle with a radius equal to $A_1B_3 = r_{nC}$ in the vertical position of the needle. The taper angle of the needle is $2\alpha_1$.

From the triangle $A_3B_3A_1$ we determine the depth of penetration of the needle into the soil:

$$A_1A_3 = y_{\max} = r_{nC} \cdot \operatorname{ctg} \alpha_1 \quad (3)$$

where: α_1 – the angle between the altitude and slant height of cone of needle; r_{nC} – radius in the vertical position of the needle.

When the needle penetrates the soil, its O_1A_1 axis is inclined to the surface at an angle β_1 , and the lateral surface is φ_1 . That is $\beta_1 = \varphi_1 + \alpha_1$. In the intermediate position of the needle O_2A_2 , the O_2A_2 axis is inclined to the soil surface at an angle β_2 , and the lateral surface is φ_2 respectively (Fig. 3). And $\beta_2 = \varphi_2 + \alpha_1$. In the vertical position, the axis of the needle O_3A_3 coincides with the vertical, the angle $\beta_3 = 90^\circ = \varphi_3 + \alpha_1$, where φ_3 is the angle between the lateral side of the conical part of the needle and the soil in the position of maximum needle location in it. Thus, the angle β varies in the interval:

$$\beta_1 \leq \beta \leq \beta_3, \text{ or } \varphi_1 + \alpha_1 \leq \beta \leq 90^\circ = \varphi_3 + \alpha_1 \quad (4)$$

where: φ_1 – the angle of inclination of the needle to the soil; α_1 – the angle between the altitude and slant height of cone of needle; β – angle of the needle axis to the soil surface at the time of penetrates; φ_3 – angle between the lateral side of the conical part of the needle and the soil in the position of maximum needle location.

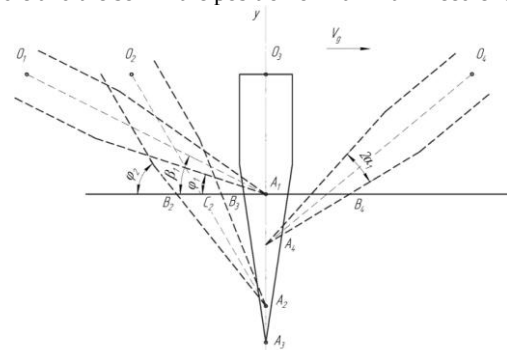


Fig. 3. Regulation needle O_1A_1 given its interaction with the soil

Using the known equation of the ellipse, and taking $b = r_{nC}$ is the radius of the needle part, plunged into the soil, a is the maximum distance from the point, plunged into the soil in a position where this point begins to enter the soil, that is the semi major axis of the ellipse, we get:

$$B_2A_1 \cdot \operatorname{ctg}(90^\circ - \varphi_2) = C_2A_1 \cdot \operatorname{ctg}(90^\circ - \beta_2) \quad (5)$$

where: β_2 – angle of the needle axis to the soil surface at the intermediate position; φ_2 – angle between the lateral side of the conical part of the needle and the soil in intermediate position

Using the notation that is inherent in an ellipse, we get: $B_2A_1 = a$, and $C_2A_1 = c$. Then, in accordance with the well-known dependence of the ellipse $a^2 = b^2 + c^2$, we get: $a^2 = (B_2A_1)^2 = b^2 + c^2 = r_{nC}^2 + c^2$. Whence

$$B_2 A_1 = \frac{r_{nC} \cdot \operatorname{tg} \beta_2}{\sqrt{\operatorname{tg}^2 \beta_2 - \operatorname{tg}^2 \varphi_2}} \quad (6)$$

In accordance with accepted assumptions, the value of $B_2 A_1$ determines the size of the semi major axis of the ellipse formed by the results of the interaction of the needle with the soil. This ellipse, as noted above, is formed at the soil-air interface. Parameter r_{nC} is varies from zero in the beginning position of the contact and to some value that characterizes the depth of penetration of the needle into the ground. The angle β_2 varies according to (4).

Determine the area of the ellipse as the area of the figure, which formed the needle by the results of penetration into the soil as

$$S_{el} = \pi \cdot a \cdot b = \pi \cdot \frac{r_{nC}^2 \cdot \operatorname{tg} \beta_2}{\sqrt{\operatorname{tg}^2 \beta_2 - \operatorname{tg}^2 \varphi_2}} \quad (7)$$

where: S_{el} – area of the ellipse (m^2); a – semi-major axis of the ellipse (m); b – semi-minor axis of the ellipse (m).

The change in the area that was formed on the surface of the soil will be estimated by the index of the difference in the areas of the ellipse and the circle with the radius r_{nC}

$$\Delta S_{SP} = S_{el} - S_c = \pi \cdot \frac{r_{nC}^2 \cdot \operatorname{tg} \beta_2}{\sqrt{\operatorname{tg}^2 \beta_2 - \operatorname{tg}^2 \varphi_2}} - \pi \cdot r_{nC}^2 = \pi \cdot r_{nC}^2 \cdot \left(\frac{\operatorname{tg} \beta_2}{\sqrt{\operatorname{tg}^2 \beta_2 - \operatorname{tg}^2 \varphi_2}} - 1 \right) \quad (8)$$

where: S_c – area of the circle with the radius r_{nC} (m^2). Adopt

$$k_{SP} = \frac{\operatorname{tg} \beta_2}{\sqrt{\operatorname{tg}^2 \beta_2 - \operatorname{tg}^2 \varphi_2}} - 1 \quad (9)$$

where: k_{SP} – coefficient of surface-plane interaction of the needle with the soil. Expression (8) takes the form:

$$\Delta S_{SP} = \pi \cdot r_{nC}^2 \cdot k_{SP} = S_c \cdot k_{SP} \quad (10)$$

The space-depth interaction of the needle with the soil is estimated by the change in the volume of figures that were formed from the penetration of the needle into the soil.

$$\Delta V_{SD} = V_{KE} - V_{KC} = \frac{1}{3} \pi \cdot r_{nC}^2 \cdot y_{\max} \cdot k_{SP} = V_{KC} \cdot k_{SP} \quad (11)$$

where: ΔV_{SD} , V_{KE} , V_{KC} – the volume change, the volume of the cone with the base ellipse and the volume of the cone with the circle at the base, respectively (m^3).

It should be noted that the main factors that influence the determination of the required force for deepening the needles of the needle harrow in the soil are: the depth of the needle's immersion, the angle of friction of the needle along the ground, and the angle characterizing the taper of the needle. In addition, the force required to deepen the needle into the soil depends on the hardness of the soil, that is, its mechanical composition and moisture content.

It is established that the interaction of the needle of any shape and design with the soil leads to the appearance on its surface of figure close in shape to the ellipse. Moreover, in the phase of the needle entering the soil in the direction opposite to the motion, a semi-ellipse is formed, whose small semi axis is equal to the radius of the conical (cylindrical) part of the needle that penetrated the soil.

The semi major axis of the semi-ellipse depends on the parameters of the needle, their number on the disk, the depth of penetration of the needle into the ground. Leaving from the soil, the needle on its surface leaves the flattening in the form of the second part of the semi-ellipse. The needle forms a funnel (trace), which represents a cone with the vertex, which is based on an ellipse.

The developed method improves the accuracy of predicting and evaluating the efficiency of interaction rotary-harrow needle with soil. The method creates the prerequisite s for reducing the energy costs of soil cultivation.

The use of research results in the practice of agricultural enterprises makes it possible to solve the key task - to increase production efficiency through the management of technological processes, using machines and implements adapted for specific production conditions, as well as methods for their evaluation.

The developed theoretical background complements the existing experimental methods for determining the indicators of soil quality, thereby increasing the accuracy of assessment and experimental determination of the indicators of the quality of the implementation of the technological process of tillage.

4. Conclusions

1. It is noted that the result of the interaction of the round needle of rotary harrow with the soil, is a regular-shaped hole with an ellipse at the base.

2. Theoretically justified and noted that in the phase of needle entry into the soil in the direction opposite to the movement, a semi-ellipse is formed, the small semi-axis of which is equal to the radius of the conical (cylindrical) part of the needle, which penetrates the soil. The semi-major axis of the semi-ellipse depends on the parameters of the needle, their number on the disk, the depth of penetration into the soil. In the phase of emergence from the soil, the needle on its surface also forms a semi-ellipse.

3. The method has been developed and the coefficients for estimating of surface-plane and space-deep interaction of the needle with the soil are theoretically justified, which makes it possible to improve the accuracy of forecasting and evaluating the effectiveness of the interaction of the needle of rotary harrow with the soil. Space-deep interaction is estimated in terms of the change in the volume of a figure, which is formed from the results of needle penetration into the soil. The method creates the prerequisites for improving the quality and energy indicators of the technological processes of soil treatment with rotary harrows, especially under conditions of their application for the shallow surface soil fracturing in the climatic zones that are prone to wind erosion.

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OVERVIEW OF SESAME RESEARCH IN BULGARIA

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Abstract: Mechanized harvesting of sesame is not solved problem in many places in the world because of significant losses of seeds. The essence of the problem consists in the fact that sesame capsules release seeds due to a slight mechanical impact or by the wind when ripening. For solving the problem in Bulgaria the sesame research is conducted in two directions. The first is selection sesame varieties, suitable for mechanized harvesting and the second is adaptation of existing equipment and development of new for harvesting sesame seeds. In 2015 has been developed a method for assessment the susceptibility of sesame genotypes for mechanized harvesting of the seed. The method is based on an impact of a pendulum and on calculation of three indices. The first index is a criterion for self releasing of seeds from capsules, the second index is a criterion for retention seeds in capsules and the third index - for strength of the link between seeds and placenta. The method was applied to assess the susceptibility of sesame varieties for mechanized harvesting as well as to choice parental pairs in the selection of new sesame genotypes. A lot of new sesame genotypes have been selected and they have higher indices then existing. Representative studies for mechanized harvesting the seed have been done through five different technologies and machines in Bulgaria. The best results are shown by the two new developed devices. The first is for feeding sesame stems into harvesting machine. It squanders 3.4 times less sesame seeds than the grain harvester Wintersteiger - Hege 160 at parallel harvesting of hybrid f3/361-6-3 at seed moisture content of 8.9%. The second is for inertial threshing of sesame seeds. It threshes over 95% of seeds of non-shattering varieties Aida and Nevena without reducing their germination at seed moisture content from 12.2 to 13.3% while the conventional thresher decreases germination with 27%. The productivity of the conventional thresher is 1.4 times higher than that of the inertial thresher. The total power consumed by the inertial thresher is 4.81 times smaller than by the conventional thresher, because it does not deform stems and capsules during operation.

Keywords: SESAME, MECHANIZED HARVESTING, METHOD OF ASSESSMENT, BREEDING

1. Introduction

The sesame (*Sesamum indicum* L) is known as the oldest oil crop in Bulgaria. The seeds are used as raw material for preparation of oil, food, cosmetics and medicines. Now the country has shortage of sesame seeds and annually imports from China, India, Ethiopia, Sudan and other countries. In the past the sesame fields occupied 3% of agricultural land in Bulgaria but now they are 0.06%. The main reason for this negative statistic is the significant loss of seed at mechanized harvesting, which is a problem worldwide.

For solving the problem in Bulgaria is conducted sesame research in two directions:

- Selection sesame varieties, suitable for mechanized harvesting. Research is done at Institute of Plant and Genetic Resources - Sadovo since 50 years.

- Adaptation of existing equipment and development of new for harvesting sesame. This direction of research is conducted at Agricultural University - Plovdiv from 15 years.

The aim of the paper is review the results of sesame research in Bulgaria in recent years.

2. Results from selection and breeding of sesame varieties, suitable for mechanized harvesting

1. Results of selection and breeding of sesame varieties

1.1. Origin of Bulgarian sesame varieties

In the beginning, Bulgarian sesame researchers thought that an effective mechanized harvesting of seeds is possible only for varieties whose do not shatter the capsules at ripening (Georgiev, 2000; Georgiev, 2002; Georgiev et al., 2008). For that purpose in 1989 at the Institute of Plant Genetic Resources - Sadovo was imported a non-shattering sesame sample № 87010 from the Institute for Oilseeds in Krasnodar, Russia. It has been included in hybridization with Bulgarian breeding lines in order to create new sesame generation, suitable for mechanized harvesting with grain harvesters. The first hybrid materials were with the following adverse signs:

- Deformed thick stems;
- Semi-upright central stem with low-lying capsules and sloping side branches;
- Thickening of central stem with strong shortened internodes in the top part of the plant and accumulation of large number of small capsules;

- Abnormal number and underdeveloped side branches located on the top of plants;

- Leaves with strongly altered form, similar to those damaged by herbicides;

- Large flowers with extra appendages as parts of petals;

- The top of the plants ends with 4 - 5 short branches with a minimum number of capsules;

- Large percentage of aborted capsules;

- Strong susceptibility to diseases.

Many of these undesirable traits were removed after multiple selection, reciprocal crosses and inclusion of new breeding sesame lines (Georgiev et al., 2014). They have low yield and long drying period on field and for this reason was recommended usage of defoliant (Stamatov, 2010). In spite of all, from 25% to 50% of capsules did not allow threshing and mechanically damaged seeds reached 50 % (Ishpekov et al., 2008; Ishpekov et al., 2012; Ishpekov et al., 2014). As a result was created the first Bulgarian non shattering variety named Victoria.

1.2. Approaches in breeding of new varieties

Bulgarian hybridization program started in 2006 and in the beginning has not been paid due importance to selection of parental pairs. As straight and reciprocal crosses were included varieties with shattering and non-shattering capsules. For parents were selected breeding lines with non-shattering capsules and without side seam. The selection of breeding lines and varieties with shattering capsules was carried out only according with potential for high yield. The assessment of obtained progeny also was not sufficiently substantiated. The selection approach has been changed after identification of the attached placenta in capsules of Aida variety in 2011. The selection of parents has already based on the suitability for mechanized harvesting combined with high yield (Georgiev et al., 2011; 2012; Stamatov and Deshev, 2010; 2012). The breeders discovered that the hybridization of non-shattering genotypes without side seams leads to unsatisfactory results. It was found that the desired features in terms of the architecture of capsules occur in the progeny F2. The selection of newly established materials was carried out by signs responsible primarily for the architecture of capsules. By subjective assessment was sought:

- Capsules with a small hole at the top;
- Capsules, whose side seam ends to the middle of its length;
- The membranes that are securely attached for placenta;
- Capsules that are narrowed on the top.

• Seeds that are firmly attached to the placenta and plant tilting do not lead to releasing of seeds at maturation.

The suitability of sesame varieties for mechanized harvesting was assessing in real field conditions through determining the qualitative indices of grain harvesters. This requires a large sesame field, a large team of staff and researchers, expensive grain harvester in busy period and big consumption of time. The main conclusion was that this approach slows the selection process therefore the sesame breeder needs of method for assessing the susceptibility of varieties for mechanized harvesting of seed in early stage of the selection.

1.3. Bulgarian method for evaluating the susceptibility of sesame varieties to mechanized harvesting

In 2014 has been developed a subjective independent method for assessment the susceptibility of sesame genotypes for mechanized harvesting of seeds by Ishpekov and Stamatov (2015b). Its purpose is evaluating effects of placenta attachment, of membranes and of capsule shape on percentage of released seeds through objective criteria (Ishpekov et al., 2015a). The method includes preparing of materials, seed retention test and capsule crash test and requires 100 capsules of each variety - one week before opening their tips. Capsules are cut off from the middle zone of stems of different plants. Such amount of capsules is necessary for assessment genotypes at three values for moisture content of seeds. Capsules are cut while they are completely closed and are packed in paper bags by fours. The bags have been left in the laboratory until the opening the tips of capsules, which is a sign for starting of experiment

The method is conducted through an experimental system which consists of a pendulum apparatus and an electronic system for measuring and recording the angle of rotation of the pendulum (Fig. 1).

The apparatus consists of base 1 on which is mounted a support 2 and a pendulum bar 3 with the plate 4. The scale 14, with trigger 15 positioned is fixed to the support 2. It serves for fixing the pendulum at assigned angle and for its releasing after starting the measurement. The electronic system consists of an incremental encoder - 11, electronic counter USB-1208HS-2AO - 10 (www.mccdaq.com) and a computer - 8.

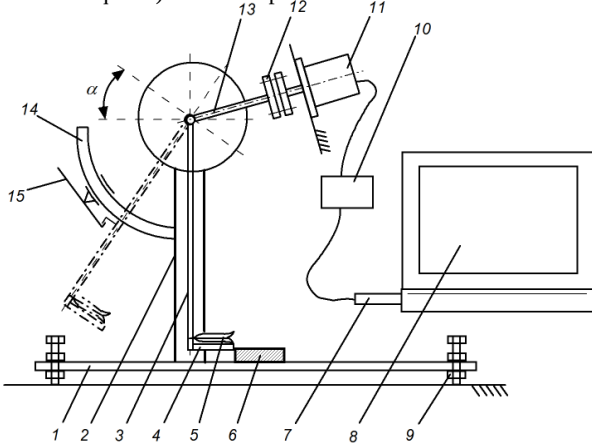


Fig. 1 Experimental system for investigation releasing of sesame seeds from capsules

1 - fundament, 2 - support, 3 - pendulum bar, 4 - plate, 5 - tested sesame capsules, 6 - anvil, 7 - USB port, 8 - computer, 9 - leveling screws, 10 - USB-1208HS-2AO, 11 incremental encoder, 12 - clutch, 13 - pendulum shaft, 14 - scale, 15 - trigger.

The seed retention test begins after sticking four sesame capsules 5 on the plate 4 when the pendulum is at equilibrium position (Fig. 2). The electronic system is started and the pendulum with the examined capsules is deviated and locked at the assigned angle through the scale 14. After a second the pendulum is released by the trigger 15 and it is hit to the anvil 6, which does not contact with capsules. The pendulum shaft 13 rotates the encoder's rotor 11 through the clutch 12. The signal is read by an electronic counter USB-1208HS-2AO and is delivered to computer - 8 via USB. The

signal is displayed through a virtual instrument, which had been developed in the environment of LabView (www.ni.com/labview), (Fig. 3).

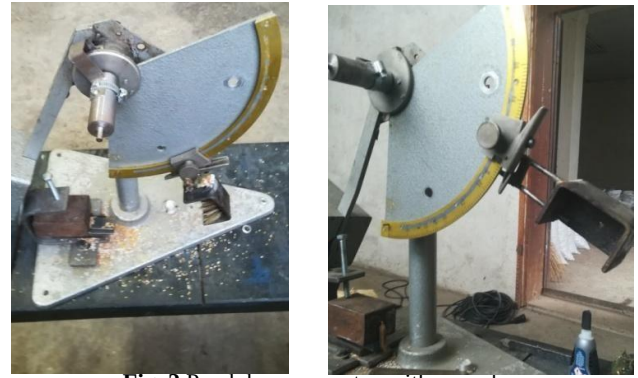


Fig. 2 Pendulum apparatus with capsules
a) At seed retention test b) At capsule crash test

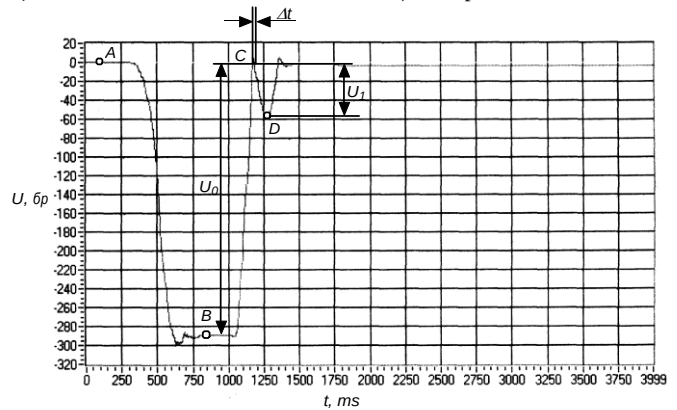


Fig. 3 Graph of the signal from experimental system
Point A - the pendulum is contacted with the anvil in the equilibrium position; B - the pendulum is diverted on 29°; C - impact of the pendulum into the anvil; D - the maximum deviation of the pendulum after the collision; U_0 - indication of the measurement system before the release of the pendulum; U_1 - indication of the measurement system at the pendulum rebound; Δt - the duration of the impact.

Due to the impact, each seed in capsules have loaded with the following inertial force

$$F_{in} = m_c a_{in}, \quad (1)$$

where:

m_c is the average mass of a sesame seed, kg;

a_{in} - the acceleration, which was given to the seed, $m s^{-2}$.

In this case, it is calculated as follows

$$a_{in} = \frac{(v - 0)}{\Delta t}, \quad (2)$$

where:

v_0 is the capsule velocity just before impact, $m s^{-1}$;

Δt - the duration of impact, $s \cdot 10^{-3}$. The impact duration is read from the signal of measuring system.

The plate velocity before impact is calculated as follows

$$v_0 = l_b \cdot \omega_0, \quad (3)$$

where:

l_b is the length of pendulum bar 3, m;

ω_0 - the angular velocity of pendulum before impact, s^{-1} . It is determined as a function of the work done by the pendulum at falling from angle α -

$$\omega_0 = \xi \cdot \sqrt{\frac{l_b \cdot g \cdot (1 - \cos \alpha) \cdot (m_b + 2m_p)}{R_{cl}^2 m_{cl} + R_{enk}^2 m_{enk} + l_b^2 \left(m_p + \frac{m_b}{3} \right)}} \quad (4)$$

where:

ξ is the coefficient for accounting the friction losses in the bearings of pendulum and of incremental encoder;
 g - the gravity acceleration, $m \cdot s^{-2}$;
 m_b - the mass of pendulum bar, kg ;
 m_p - the mass of plate with tested capsules, kg ;
 R_{cl} - the radius of clutch, m ;
 m_{cl} - the mass of clutch, kg ;
 R_{enk} - the radius of encoder's rotor, m ;
 m_{enk} - the mass of encoder's rotor, kg .

The seeds leave capsules due to the inertial force and are impossible to collect them. Their quantity is determined indirectly by weighting of:

m_0 - the mass of tested capsules before test, g ;
 m_{c1} - the total mass of seeds, which fall down as a result of slow rotation of the capsules with the tip down, g ;
 m_{gl} - the mass of glue, g ;
 m_3 - the mass of capsules after impact, g ;
 m_{c2} - the mass of seeds, retain in capsules after impact, g ;
 $m_2 = m_0 - m_{c1} + m_{gl}$ - the total mass of tested capsules and of glue, g .

The mass of the seeds leaving capsules due to inertial force is:

$$m_{c3} = m_2 - m_3$$

The total mass of seeds -

$$m_c = m_{c1} + m_{c2} + m_{c3}$$

Three indices have been introduced:

$$i_1 = \frac{m_{c1}}{m_{c2} + m_{c3}} \quad (5)$$

$$i_2 = \frac{m_{c2}}{m_{c1} + m_{c3}} \quad (6)$$

$$i_3 = \frac{m_{c3}}{m_{c1} + m_{c2}} \quad (7)$$

The first index i_1 is a criterion for self releasing of seeds by the capsules. The second index i_2 is a criterion for retention seeds in capsules. The third index i_3 is a criterion for the strength of link between seeds and placenta. The varieties with high values of the index i_1 are unsuitable to mechanical harvesting due to self release of seeds. The varieties with high values of index i_2 allow threshing of seeds after breaking capsules only. The high value of index i_3 is indicative of suitability for harvesting seeds without breaking of capsules namely by conventional threshing. The results of application seed retention test are shown in Figures 4 and 5.

The second test is for crashing of capsules and begins after sticking a capsule on front side of the anvil (Fig. 2). It allows studying the shock and shattering resistance of the capsules that remain closed at maturation (Ishpekov et al., 2008). The appropriate shock impulse for releasing seeds from closed capsules is in the range from 45 to 0.65 $kg \cdot m \cdot s^{-1}$ and is given by a striker with 5 mm width. This test is applied for genotypes with high index i_2 and low i_3 . The genotypes 240, 460, 463, 464, 465 and 504 were subjected to this test at seed moisture from 6.6 to 7.2%. The results show that the highest percentage of seeds is released by the shock impulse in the range - $S = 0.35 - 0.40 \text{ kg} \cdot m \cdot s^{-1}$ (Fig. 6). On shock impulse over 0.45 $kg \cdot m \cdot s^{-1}$, the percentage of released seeds decreases, because they left in capsules and are severely damaged (Figures 7 and 8). These genotypes are characterized with tightly adhering membrane and with narrowing the walls of capsules. On one hand, this prevents the release of seeds due to shaking of plants, but on the other hand it causes losses from bad threshing and from mechanical damage of seed.

The developed method can be used for the following purposes:

- To assess the susceptibility of sesame genotypes for mechanized feeding of stems and for threshing of capsules.
- To select the appropriate way of threshing, this can be with or without breaking the capsules.
- For choosing of parental pairs in the selection of new sesame genotypes, which are intended for mechanical harvesting.

- To synthesize the appropriate mechanical impacts for feeding of stems without seed loss and for threshing seeds without their mechanical damage. That is usually done at construction and adaptation of harvesters.

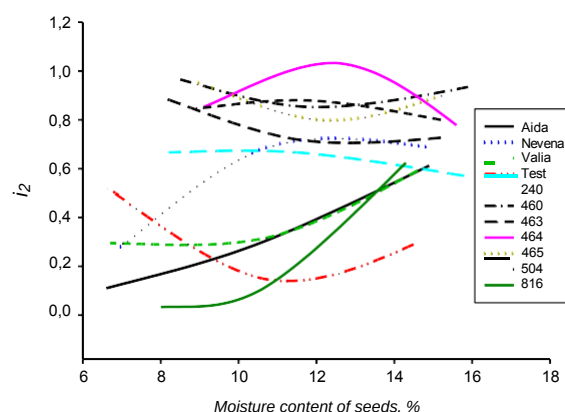


Fig. 4 Index i_2 depending on the moisture content of seeds for tested varieties at inertial force $F_{in} = 5 \cdot 10^{-4} \text{ N}$.

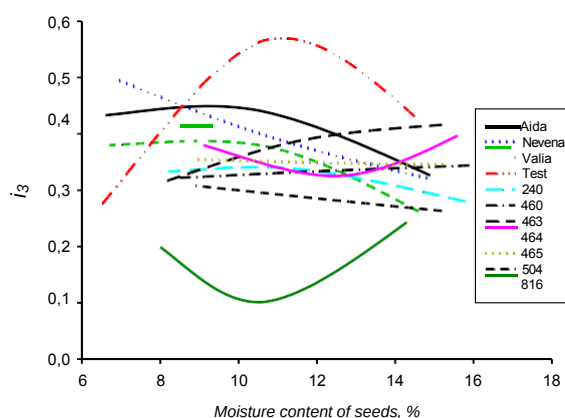


Fig. 5 Index i_3 depending on the moisture content of seeds for tested varieties at inertial force $F_{in} = 5 \cdot 10^{-4} \text{ N}$.

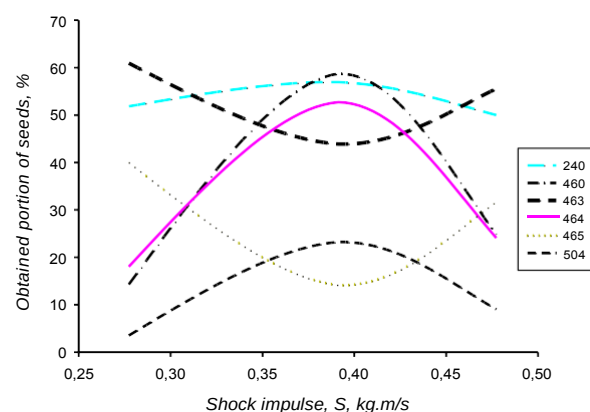


Fig. 6 Proportion of released seeds depending on given shock impulse on a capsule - S



Fig. 7 A capsule damaged by a shock impulse



Fig. 8 Seeds damaged by the shock impulse

1.4. Indices of Bulgarian sesame varieties

The mentioned Bulgarian method has been applied for 3 years. The result is obtaining genotypes with indices i_2 and i_3 , which are higher than those of varieties, selected before applying the method. From Table 1 is evident that the new hybrid f3/361-6-3 has index $i_3 = 3.694$, which value is 8.2 times higher than that of the Aida variety and the hybrid f2/365-28 has index $i_2 = 3.423$, which value is 10.1 times higher than that of the Nevena variety.

The results obtained show not only the varieties that are suitable for mechanized harvesting of seeds but also the appropriate ways for their threshing. More over, genotypes with high values of i_2 produce low seed yield and those with high values of i_3 are high-yielding. This assessment enables the selection of parental pairs and offspring selection. The negative relationship between yield and high index i_2 and the positive between high index i_3 and yield allows selecting high-yielding sesame forms suitable for mechanized harvesting (Stamatov et al., 2017).

Table 1 Progeny of different sesame generations

No	Progeny	Mass of seeds in a plant, g	Mass of seeds in a capsule, g	i_1	i_2	i_3
Varieties, selected before applying the method and tested in 2014						
1	Aida	12.7	0.087	1.19	0.18	0.45
2	Nevena	13.5	0.081	1.50	0.34	0.37
3	Valia	16.6	0.098	4.81	0.18	0.02
Genotypes, selected after applying the method and tested in 2017						
1	f3/361-7-3-1	3.52	0.085	3.87	0.58	2.64
2	f2/364-15	12.8	0.082	0.31	0.33	3.40
3	f3/361-6-1	10.2	0.188	0.97	0.38	2.18
4	f2/364-18	3.18	0.225	1.21	1.49	1.39
5	f3/361-7-8-1	16.0	0.200	7.02	0.03	2.77
6	f4/355-2-1	9.8	0.250	1.56	1.56	2.76
7	f2/364-20	15.2	0.187	4.44	0.40	0.47
8	f3/361-6-3	14.7	0.182	0.84	2.56	3.69
9	f2/365-27	15.0	0.250	3.15	0.60	0.66
10	f2/365-28	4.3	0.055	0.39	3.42	3.10

2. Results of mechanized harvesting of sesame seed

Most of field operations for sesame growing allow conducting by conventional mechanization in this figure tillage, sowing, plant protection and irrigation. But most of fields are harvested manually worldwide. Small percentage of sesame fields is harvested by grain harvesters with significant losses of seeds.

In the recent years many sesame varieties assigned for mechanized harvesting have been selected in Bulgaria. According type of capsule at maturation they are of two groups:

- Variety Viktoria which has closed capsules.
- Varieties Nevena, Valya, Aida, that open the tip of capsules, but the seeds remain attached to placenta.

From 2010 to 2018 many representative studies for mechanized harvesting the seed of both types of varieties have been done by five different technologies and machines.

First technology: One-phase harvesting with grain harvester;

Second technology: Two-phase stem harvesting and threshing:

- First phase: Cutting and draying of stems;
- Second phase: Stems threshing.

Third technology: Two-phase capsules harvesting and threshing:

- First phase: Collecting capsules from plants, while they are on root;

- Second phase: Draying and threshing capsules;

Fourth technology: One-phase harvesting of seeds with knocking machine;

Fifth technology: One-phase harvesting of seeds through two new devices developed at Agricultural University – Plovdiv. First device is for feeding sesame stems into harvesting machine and second is an inertial thresher.

2.1. Results from the first technology

The representative study the indices of grain harvester require its adaptation and namely manufacturing and installing of a few tools (Trifonov et al., 2013):

- A tool for collecting samples from harvested seeds (Fig. 9).
- Two self unscrew canvases for collecting samples from the cleaner and from the straw walker (Fig. 10).



Fig. 9 Tool for collecting samples from harvested seeds



Fig. 10 Two self unscrew canvases for collecting samples from the cleaner and from the straw walker

The following main indices were obtained during harvesting varieties Viktoria and Nevena at moisture content of seeds between 8 to 14.8%:

- Losses by the header 17 - 22 %.
- Losses by the thresher 2 - 3 %.
- Mechanically damaged seeds by the thresher 23 - 50 %.
- Germination of harvested seeds 40 - 56 %.

The main conclusion is that the losses by the header grow when the moisture content of seeds is under 10 % and the losses by the thresher grow when the moisture content of seeds is over 10 %.

2.2. Results from the second technology

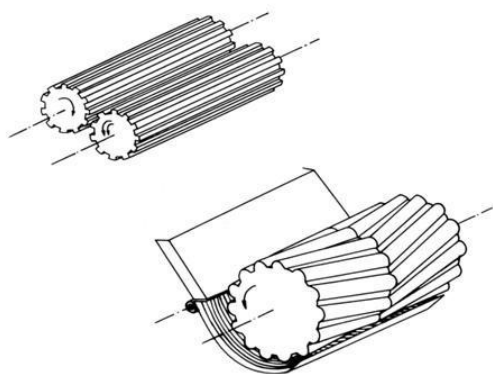
In the first phase green stems are cut by conventional cutter bar and after that they are dried on field. In the second phase the dried stems are threshed by MSSZK which has been developed at Rousse University (Fig. 11). The main differences of the MASZK from conventional thresher are in two sets of drums, which work consecutively. The first set includes two aluminum crushing drums, and the second - a rubbery threshing drum.

The following indicators were obtained at threshing Viktoria variety which has closed capsules at full maturity and moisture content of seeds 6.1%:

- The portion of threshed seeds 91.07%;
- Seed germination 65 - 85 %.
- Small productivity;
- High energy consumption;
- Requirement for thin sesame stems;
- Suitable for breeding.



a) General view



b) Two sets of threshing drums

Fig. 11 The thresher– MSSZK

2.3. Results from the third technology

It is characterized with two-phase harvesting and threshing of capsules. During the first phase the capsules are harvested from the plants, while they are on root by an experimental finger device, developed at Agricultural university of Plovdiv (Fig. 12). After drying down the harvested capsules are threshed by MSSZK (Figure 11). The main results obtained at harvesting capsules of Viktoria variety with 8.7 % moisture content of seeds are:

- The percentage of harvested capsules is 87.8 %;
- The impact of the fingers is from down to up and is applied to the bottom of capsules. It causes releasing of seeds from majority of capsules.



a) General view



b) Before capsule harvesting



c) After capsule harvesting

Fig. 12 Experimental device for harvesting sesame capsules from plants on root

2.4. Results from the fourth technology

It is one-phase harvesting of seeds by an experimental knocking machine, developed at Agricultural University – Plovdiv (Fig. 13). A parallel study for harvesting Aida variety by hand and by the mentioned machine was conducted in 2013. At moisture content of 11.4% the percentage of harvested seed are:

- At one-way manual harvesting - 69.1%;
 - At one-way harvesting by knocking machine - 73.4%.
- The rest of seeds are the total losses from harvesting.



a) The machine device during operation



b) The field after harvesting sesame seeds

Fig. 13 Experimental knocking machine for harvesting sesame capsules from plants on root

2.5. Results from the fifth technology

This technology is new and is not fully completed. The harvesting of sesame seeds is in one phase and is conducted by two new experimental devices, developed at Agricultural University - Plovdiv. The first device is for feeding sesame stems into harvesting machine which structure is shown in Fig. 14. The specific for the new finger device is:

- The plants are caught laterally not from the top like by the combine reel;
- The cutting of stems is after tilting over the combine platform.
- The feeding of stems into harvester is without any shocks and vibrations of plants.
- The position of the collecting surfaces is changeable for stems with different habitus.

- The device allows adjusting the angle of stems toward platform at moment of their cutting from roots.

several times before cutting them off the root. This causes releasing of seeds, detaining over the bar and after accumulation - falling down on soil surface (Fig. 16).

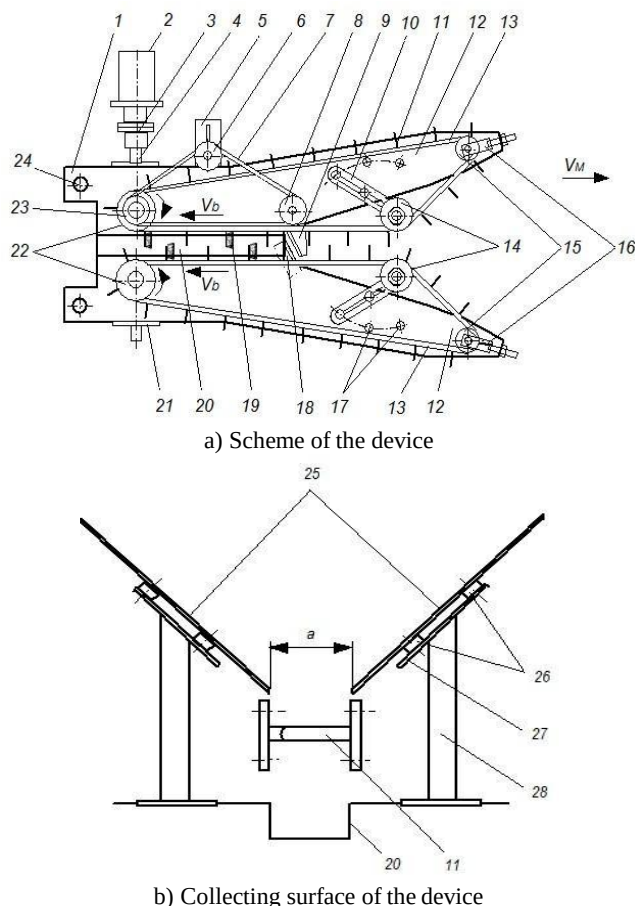


Fig. 14 Scheme of the finger device for feeding sesame stems into harvesting machine (Patent pending)

1 - platform, 2 - hydro motor, 3 - connector, 4 - shaft, 5 - plate, 6, 8, 15, 22, 23 - chain wheels, 7, 13 - chains, 9 - rotary blade, 10 - adjusting plate, 11 - fingers, 12 - consoles, 14 - guide rollers, 16 - screw tensioners, 17 - fixing hole, 18 - contrary blade, 19 - brushes, 20 - central groove, 21 - bearings, 24 - connection openings, 25 - collecting surface, 26 - beam, 27 - support plate with channel, 28 - stand.

The main results obtained by the new finger device at feeding stems of Aida variety with 9.7 % moisture content of seeds are:

- It achieves the minimum percentage of seed losses of 2.5% in working mode with kinematic coefficient 1.33 and forward speed of 0.83 m s^{-1} .

- The increasing of forward speed from 0.63 to 1.33 m s^{-1} leads to growing up of both the device productivity from 1.59 to 3.35 ha h^{-1} for each harvested row and the seed losses up to 5.25%, although the kinematic coefficient remains constant.

A parallel study was conducted with the hybrid f3/361-6-3 at seed moisture content of 8.9% with the aim to determine the seed losses by the new device and by the Wintersteiger - Hege 160 grain harvester (Figures 15 and 16). Both machines move with the forward speed $v_M = 1.33 \text{ m s}^{-1}$ as well as the kinematic coefficients of the harvester reel and of the device feeding chains were equal to 1.33. Under these conditions, the new device squanders 8.8% from the yield and the Hege 160 harvester - 30.2%, which is a difference of 3.4 times. The new feeding device is designed for harvesting one row, but it can be used as a base for building multi - rows header for each grain harvester.

Significantly higher losses by the combine harvester are rooted in inappropriate impact of the reel and of the cutting apparatus on sesame plants (Langham, 2014; Naydenov et al., 2016). The reel wedges between central stem and capsules or branches as a result of which it bends the stems to soil surface. The cutter bar shakes stems



a) By the grain harvester Wintersteiger - Hege 160



b) By the new finger device
Fig. 15 Seed losses

The second device is for inertial threshing of sesame seeds (Fig. 17). The main unit of the thresher is a rod spindle 5, which performs asymmetric angular vibrations. They are composed of consecutive spins in two directions - toward the entrance and toward the exit of the thresher. The angular amplitude toward the exit is larger than amplitude toward the entrance. It is due to the action of the one-way clutch 3 and spring 4, which reduce angular amplitude toward the entrance (Ishpekov S., et al., 2015b).

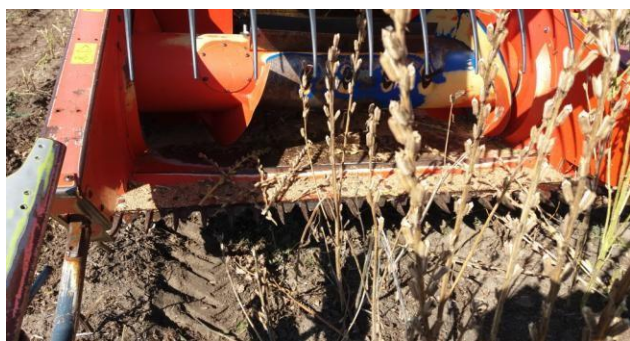


Fig. 16 The cutting apparatus is another source of seed losses by the grain harvester

In operation the stems are fed over grill 8 manually and then fall between rods of the spindle 5. It gives angular vibrations and simultaneously moving them toward the exit of the thresher. Due to vibrations the seeds leave capsules and fall into the bag 7 and stems 9 leave the thresher without being deformed. In this case, the seeds detachment is mainly due to the inertial forces that are created and transmitted to stems and capsules through the rod spindle 5. Therefore, this kind of threshing of the seed is called inertial. It does not require the breaking of the capsules for detaching the seeds, which is a significant difference from the threshing in the grain harvesters.

The indices, obtained by the inertial thresher, by the conventional thresher and indices of manually threshing of sesame from one variety and equal moisture of the seeds have been compared. The developed device threshes over 95% of seeds from the non-shattering varieties Aida and Nevena without reducing their germination at seed moisture content from 12.2 to 13.3%, which is two times higher than recommended for harvesting sesame with grain harvester. The portion of the impurities in threshed mixture is from 20.99 to 38.41 percent depending on varieties (Fig. 18).

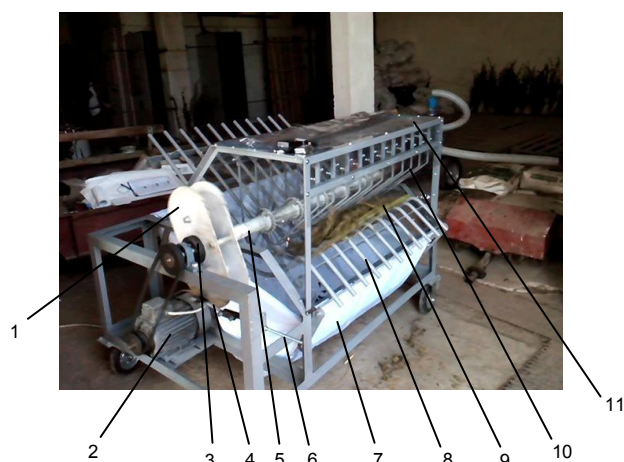


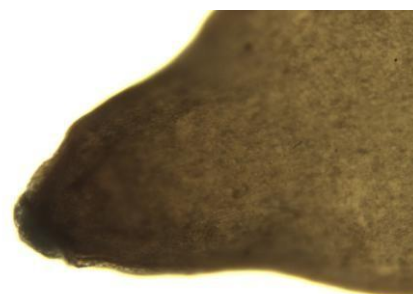
Fig.17 Inertial thresher (patented)

1 - pulse Chalmers mechanism, 2 - electric motor, 3 - one-way clutch, 4 - spring, 5 - rod spindle, 6 - stretching screw, 7 - bag for threshed material, 8 - grill, 9 - sesame stems, 10 - cleaners, 11 - lid

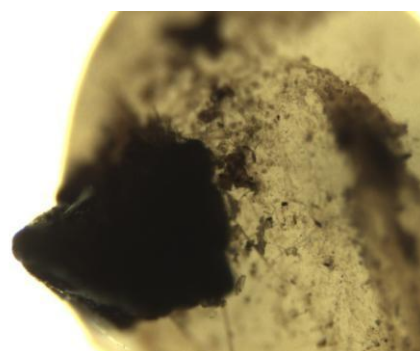
The conventional thresher decreases 27% germination of seeds with 13.3% moisture content due to mechanical damaging, which is also the main reason for development of seed diseases during storage (Fig. 19). The impurities in the threshed mixture are 56.5%, half of which does not allow separation by the conventional grain cleaner. The productivity toward 1 m working width of the conventional thresher is 1.4 times higher than of the inertial thresher and is due to the different principles of threshing in both mechanisms. The total power consumed by the inertial thresher is 4.81 times smaller than by the conventional thresher with the same productivity, because it does not deform stems and capsules at releasing seeds, while in classic thresher this is inevitable (Zaykov et al., 2017).



Fig. 18 Components from threshing stems in the bag of the inertial thresher



a) Threshed by the inertial thresher



b) Threshed by the grain harvester Wintersteiger - Hege

Fig. 19 Sesame germs 25 days after threshing

Conclusions

Selection improvement of Bulgarian sesame forms shows progress in increasing the ability of new breeding materials to retain the seeds in capsules at maturation. As a consequence of proper approach when selecting the parents of hybrid offspring have increased the indexes i_2 and i_3 due to changed anatomical features of sesame capsules. The indices evidence that the new offspring are more susceptible for mechanical harvesting as well as for threshing without destroying capsules. Till now have been selected three sesame varieties suitable for mechanized harvesting, as well as a large number of breeding lines. They are high-yielding and showed good susceptibility to harvest by combine harvester and also by the new device for feeding sesame stems and by the inertial thresher.

Five different technologies and machines for mechanized harvesting of sesame seed have been developed and evaluated in Bulgaria from 2010 to 2018. The most perspective is the one-phase technology which performs by two successively operating new devices. The first is a device for feeding sesame stems into harvesting machine which catches the plants laterally not from the top like the combine reel. During a parallel study with the hybrid f3/361-6-3 at seed moisture content of 8.9% and forward speed 1.33 m s^{-1} the new device squanders 8.8% of the yield and the Hege 160 harvester - 30.2% which is a difference of 3.4 times. The second device is an inertial thresher which threshes over 95% of seeds from the non-shattering varieties without reducing their germination at seed

moisture content two times higher than recommended for harvesting sesame with grain harvesters. The conventional thresher decreases 27% germination of seeds with 13.3% moisture content. Its productivity is 1.4 times higher than of the inertial thresher and is due to the different principles of threshing in both mechanisms. The total power consumed by the inertial thresher is 4.81 times smaller than by the conventional thresher with the same productivity, because it does not deform stems and capsules at releasing seeds. Both developed device are suitable alternative for the cutter bar and the thresher of conventional grain harvesters especially for conditions with high humidity in maturation season. They can be used for manufacturing of new machine for harvesting sesame or to change the existing header and thresher.

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DEVELOPMENT OF PNEUMATIC SEEDER FOR SOWING GRAIN CROPS

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Abstract: One of the main ways of obtaining high yields is a method of sowing and technology for its implementation. At present in the world practice, the creation of high-performance and adapted to certain soil-climatic conditions, sowing units is moving in two directions: increasing the degree of combination (versatility) of sowing machines and the use of centralized tanks for seeds and fertilizers, and pneumatic sowing systems.

However, models of seeders with CVS do not fully meet agro technical requirements for uniformity of sowing between coulters and are aggregated only with a specific tractor class, while having a high cost and low annual load.

In this connection, the creation of high-performance and adapted to certain soil and climatic conditions of Kazakhstan is very relevant.

KEY WORDS: SEEDER, COMBINED, COULTERS, SOWING MACHINE, WIDE-SPREADING, SOWING, PROCESSING.

Pneumatic grain seeders with centralized dosing and pneumatic transportation of seeds to the coulters are most effective in wide-span seeders. The use of one centralized bunker significantly reduces the time for refilling and servicing the unit, which creates prerequisites for an increase in labor productivity at sowing.

Pneumatic drills are produced by many firms in Canada, Europe, USA, Australia and Russia. Most seeders use original sowing systems, differing in design and process flow diagrams [1,2,3].

The development of sowing units (complexes) are engaged in many firms from near and far abroad (John Deere, Morris, Flexi, TechArtCom, etc.) [4].

The basis of foreign CVS is based on the Accord pneumatic seeding scheme, which cannot provide the necessary uniformity of seed distribution between coulters $\pm 3\%$ and fertilizers $\pm 10\%$. Pneumatic conveying and distribution of sowing materials in the above drills on the coulters are random processes and depend on many uncontrollable factors: variation of the speed of the air carrier medium, difference in the length of the pneumatic conductor, various physical and mechanical and aerodynamic properties of seeds and fertilizers, etc.

The same sowing complexes with the Central Vacuum System were developed in Russia: "Uralets" - PPA-5.4; PPA-7.3; PBRA-14.7; "Yaroslavich" - PPA-7,2P; Kuzbass - PK-4,2 [5].

The leaders in the development and production of such seeding machines in the world are the firms Accord, Amazonen, Horsch (Germany), John Deere (USA), Flexi-Coil (Canada), POTTINGER (Austria), etc. [2, 3]. None of these models of seed drills with CVS did not fully meet agro technical requirements: it did not provide the necessary uniformity of seeding between the coulters. Due to the design features of the tillage part, these complexes are aggregated only with a specific tractor class, have a high cost and low annual load.

In this regard, there is a need to create a high-tech, wide-gripping, pneumatic seed drill for sowing crops, adapted to the soil-climatic, organizational and economic conditions of Kazakhstan, ensuring high quality of both sowing and tillage and, a reduction in comparison with similar operating costs.

Based on the analysis, we selected the following constructive-technological scheme of the seeder: central coil metering unit, pneumatic distribution over the coulters, three-section frame with coulters, drive of the metering units from the pneumatic wheel, hydraulic drive of the fan, figure 1.

The wide-area pneumatic seeder for sowing crops with automated control of the technological process consists of sowing and embedding parts. The sowing part consists of a frame with support wheels, a hydraulically driven fan, bunkers for seeds and fertilizers,

a sowing unit, pneumatic materials ducts, distribution heads and seed tubes. The lining part consists of a three-section frame, support wheels, coulters and a packer roller.

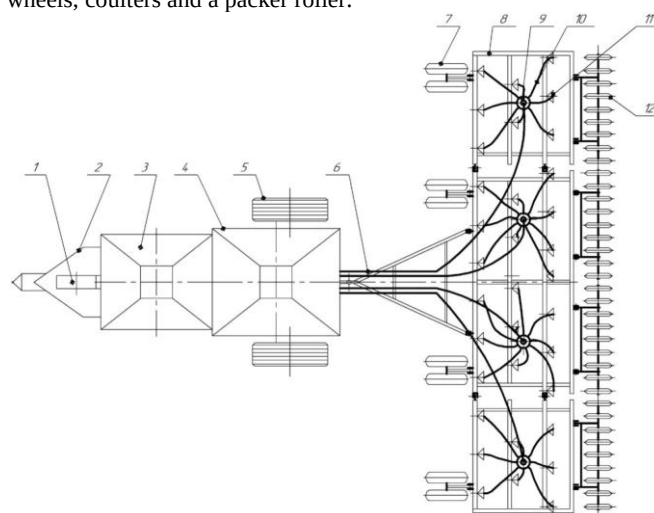


Figure 1- Constructive and technological scheme of the pneumatic seeder

1-fan; 2-frame; 3-bunker for fertilizers; 4-bunker for seeds; 5,7-support wheels; 6- pipelines; 8-embedding part frame; 9- distribution head; 10-seed tubes; 11- coulters; 12- rollers

The pneumatic sowing system includes a hopper 1, a central coil sowing device 2 consisting of a coil, a shaft and a framework with supports; the material pipe 4, where the bulk material enters and acquires speed from the air flow generated by the fan 5; air distributor 6, where the air flow from the fan is distributed through the main material pipelines; distribution head 7, where the division of the transported air flow of seed material along the seed tube to the coulters. The device works as follows. When you turn on the drive mechanism, the coil makes a rotational movement. Bulk material from the hopper 1 by gravity enters the sowing unit 2, i.e. in the grooves, which captures the seed, and a continuous stream sends (transports) to the four main material lines 4, the air flow generated by the fan 5, and by distributing the air flow in the air distributor 6 on three main material lines, picking up the seed, transports the seed to distributor head, where the seed distributed over the seed tube goes to the coulters.

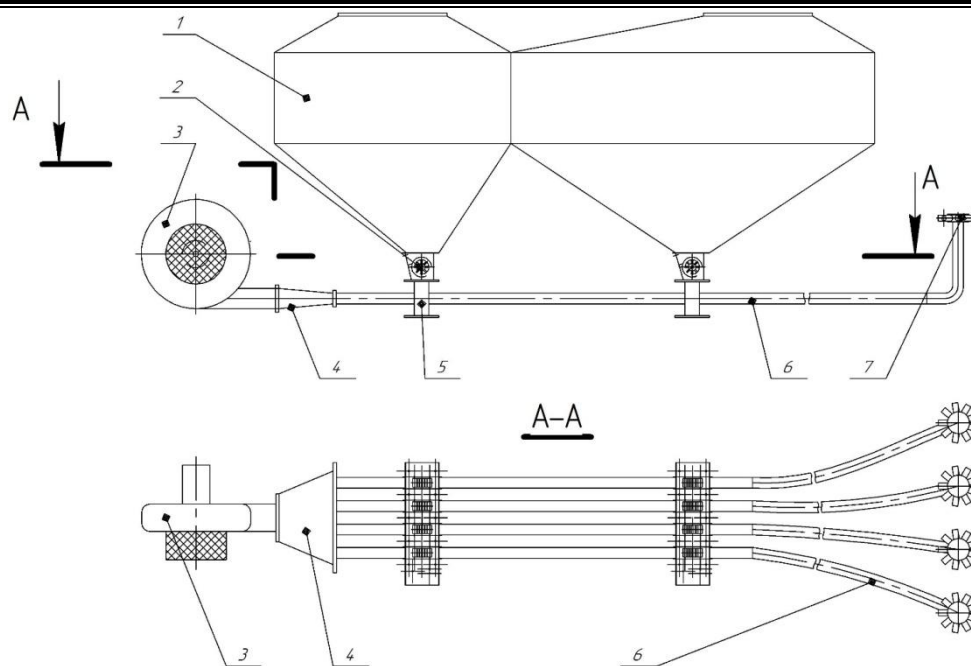


Figure 2 - General view of a seed metering system with a central coil feeder

1 – bunker; 2 – coil seeding machine; 3 – fan; 4 – air distributor; 5 – intake chamber; 6 – trunk pipelines; 7 – vertical distribution head.

The sowing machine must create a uniform and continuous flow of seeds, ensure a stable sowing of the established norm regardless of the speed of the seeder, degree of filling, tilting, and vibrations of the box when moving across the field, not damaging the seeds. Sowing devices must be universal, simple in design and have reliable and convenient adjustment of the seeding rate.

It is established that the optimal diameter of the coil is $d_k = 50$ mm, 5 - 70 mm [6]. Taking $d_k = 50$ mm and the thickness of the dike between adjacent grooves $\Delta b = 1.5$ mm, based on the known expressions [6] we get the number of grooves equal to 8 and the length of the coil $L_c = 50$ mm. The remaining dimensions of the coil apparatus are taken constructively.

In pneumatic sowing systems high pressure centrifugal fans are used. The initial data for the selection of the fan are the air velocity at the outlet of the neck, the required mass of air supplied to the channel, and the total pressure that the fan must create. Having calculated these parameters [7], we determine the loss factor K_v and select the fan with the following design parameters [7] by the dimensionless characteristic of the fans: a blade wheel diameter of 300 mm; internal diameter of a wheel is 102 mm; blade length 40 mm; diameter of the outlet 150 mm.

The diameter of the main material pipeline is assumed to be 63.5 mm [7], the dimensions of the distribution channel are 21.5 * 21.5 mm, and the diameter of the seed tube is 26 mm.

The analysis of the arrangement of the coulters and the size of the drill frame: AGROMASTER and Kuzbass (Russia), 424 Massey-Ferguson, USA, TC-3, CD-4 Hestair, Bamlett, Vel, Amazone (Germany), "Kuhn" (France), "Morris", "Bourgault" (Canada), "Great Plains", "John Deere", "Sunflower" (USA), "Dolbi", "Crucianelli" (Argentina) made it possible for us to choose the following planter frame scheme: a cultivator with a width of 8.25 m, consisting of three sections - the central and two side.

Cultivator with a width of 8.25 m, consisting of three sections: the central and two sides. All frame sizes are defined. The distance between the rows made up 550 mm and between the coulters in the rows is 700 mm. The length of the side section is 1976 mm and width is 1715 mm. The length of the central section is 3890 mm and the width is 1715 mm.

In the developing planter, the cultivator undercarriage has a width of 8.25 m and includes eight pneumatic support wheels, which make up four pairs. The hitch of a seeder-cultivator with a width of 8.25 m includes two side and two transverse beams and a tab.

From the analysis of the technological schemes of the packing organs of the seeders of the near and far abroad, the scheme of the packing organ, the wedge-shaped roller of the seeder was chosen. Wedge-shaped rollers using spacers are assembled on the shaft in the battery, two spacer rollers have bearing assemblies. The battery of rollers is installed in a frame that has a hinge for mounting the transport wheel and is attached to the main frame of the drill. The diameter of the roller is 550 mm, the width of the roller is 122 mm and the distance between them is 22.8 cm. The width of the battery is 2.05 m.

At present, a prototype model of the planter has been manufactured, which in laboratory tests showed high quality indicators: uniform distribution of seeds over the area and uniform depth of seed embedding that meets agrotechnical requirements presented to sowing machines.

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ACOUSTIC CAVITATION IN GRAIN SPROUTING

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Abstract: Feeding of rooster sires with sprouted grain significantly increases their productivity. A new acoustic cavitation method of intensification of grain sprouting process is offered. In water sound waves are created. When passing sound waves in water in a vacuummetric phase liquid is broken off with formation of cavitation cavities. These cavities collapse in a manometrical phase of a sound wave. Influence of the collapsing cavitation cavities causes a stress of biological object, its fast awakening and the accelerated development. At the same time there is a heating and decrease in viscosity of liquid substances, increase of speed of chemical, physical, biological processes. Massage action from a collapse on membranes of cages strengthens diffusion and a metabolism through membranes and in cages. Dynamic impulses kill pathogenic microorganisms, and without chemical reagents and at low temperatures ($20^0 - 30^0$), that is without destruction of protein and mechanical damages etc.

Wheat seeds were treated in the passive zone of a vortex cavitator. This resulted in germinating ability increase on the third day from 43% to 88%, or in germination time reduction from three to one day along with the quality level comparable with the control lots.

Germination ability of vortex cavitator-treated seeds at all modes, except for $t=50^0$, exceeds the germination ability of control lots sprouted with a traditional method.

Excess germination ability of the treated seeds in relation to the control lots is 200%, thus assuming a twofold feed quality improvement.

Germination ability of vortex cavitator-treated seeds after the first sprouting day is comparable with the control lot germination on the third day. This gives the possibility to reduce technological process time up to one day with the existing quality level.

Irrigation of seeds treated in a vortex cavitator with water from the active cavitator zone increases germinating ability up to 97%, or reduces process time from three days to six hours providing the quality comparable with the original process.

In this method of processing some ways of impact on biological object are combined: soaking, thermal influence, vibration, cavitation, diffusive, etc. All seeds processed on a cavitator have the raised development indicators in relation to seeds of control party including on viability, energy of germination, this grain positively influences efficiency of roosters.

KEY WORDS: ROOSTER SIRES, SEEDS, SPROUTING, VITAMINS, FEED, CAVITATION, GERMINATING ABILITY, TIME PERIOD

Introduction

The forage and the feeding make the most part of expenses in poultry keeping production. That's why a lot of attention in present time is paid to the elaboration of new technological norms and feeding regimes, methods of forage preparation which would permit to increase the poultry productivity and at the same time to reduce the forage and financial expenses. The optimum of daily feeding norms of sprouted grain for the rearing flocks and aged poultry of egg crosses are determined. These norms for the rooster sires did not exist before and now they permit to improve economic parameters in poultry keeping production.

One of the most perspective measures for the solution of technological problems in feeding is the grain sprouting and grain feeding to the rooster sires. It makes for the poultry reproductive capacity and for the increase of safe keeping of its livestock population. By using the grain sprouting the quantity of fertilized eggs increases in 3-5%, the hatchability - in 5-10%. The sperm quality improves considerably. It follows from the proceedings which were published.

By sprouting the chemical properties are changed considerably: the starch is hydrolyzed to dextrins and maltose, the proteins are separated to amino acids and amides, the fats - to glycerin and fatty acids. The concentration of free sugars in the grain increases by 10%, the volume of lysine - by 28%, of methionine with cystine - by 17%. The volume of B vitamins, E vitamins and carotinoids increases in dozens of times. The nutrients are better ingested by poultry organism while using the sprouted grain.

The results of research

However the grain sprouting is quiet labor-intensive and long. Its durability is 3-4 days. We studied and improved.

It's possible to reduce the durability and the labour-intensiveness of this process as well as to reduce the production surface and the quantity of the used package by using the new physical principals of the influence upon seeds [1], [2], [3], for example of the acoustic cavitation [4]. The acoustic cavitation is the

organization of sound waves passing through the liquid with established characteristics. The sound waves provides the alternation of the tension and vacuum in each point of the liquid. In vacuum phase the liquid is ruptured in the first turn in the stress concentrator so called germs (solid and gas microscopical inclusions). In the next phase - tension these ruptures (cavities) are collapsed. At that the cavity walls move towards each other in sound speed (1,5 km per second) and a high energy density is achieved in the collapse point. As a consequence the temperature achieves 6000^0 in this local space which size is several nanometers. The reflected waves appear, the wave interference from different sources takes place. It provides a full-length liquid deformation in microlevel. At that there is a regularity in the behavior of vacuum cavities. While living they interact with each other, with envelopes; they drift in the space by their proper way and everything takes place in all the treated volume of liquid with the frequency of 3 000 times per second.

When all the processes influence upon seeds there is at first a stress of biological object, its fast awakening and the accelerated development. Secondly there is a heating and decrease in viscosity of liquid substances, increase of speed of chemical, physical, biological processes. Massage action from a collapse on membranes of cages strengthens diffusion and a metabolism through membranes and in cages. The liquid collapse kills pathogenic microorganisms, and without chemical reagents and at low temperatures ($20^0 - 30^0$), that is without destruction of protein and mechanical damages.

A series of experiments in the stimulation of seed sprouting with using of vortex cavitator were made in NNSAA for further feeding of rooster sires in Linda Poultry Farm. It was done in order to make a practical verification of the received qualities.

The two-factor: matrix of influence degree and exposition time were made on the first phase of experiments. As while sound wave passing and the cavities collapsing the concomitant process of temperature increase of all the liquid volume and of seeds takes place the temperature may be a measure of interaction degree while making the treatment. The researches were done in temperature of 24, 30, 40 and 50 grades (Schedule 1).

Schedule 1 – Germination ability of wheat in different regimes and durability of cavitation treatment

First day								
Control - 6								
Temperature	0,5h	1h	1,5h	2h	2,5h	3h	3,5h	
1	2	3	4	5	6	7	8	
24 ⁰		26	24	19	33	32	24	
30 ⁰	21	54	9	25	16	34		
40 ⁰	20	46	17	51	33	36		
50 ⁰	4	2	6	4	8	0	0	
Second day								
Control - 43								
Temperature	0,5h	1h	1,5h	2h	2,5h	3h	3,5h	
24 ⁰		45	59	50	53	67	51	
30 ⁰	48	61	51	52	54	60		
1	2	3	4	5	6	7	8	
40 ⁰	40	63	39	54	71	51		
50 ⁰	21	7	8	8	9	14	5	
Third day								
Control - 43								
Temperature	0,5h	1h	1,5h	2h	2,5h	3h	3,5h	
24 ⁰		79	76	88	88	80	88	
30 ⁰	74	85	84	84	80	79		
40 ⁰	83	83	70	74	78	91		
50 ⁰	58	80	30	27	16	20	13	

The result of researches shows that there is an extremum in treatment durability argument in each temperature regime. In low temperature 24⁰ it corresponds a long treatment and in high temperature 50⁰ the best germination ability regime corresponds to the little treatment durability (Fig.1).

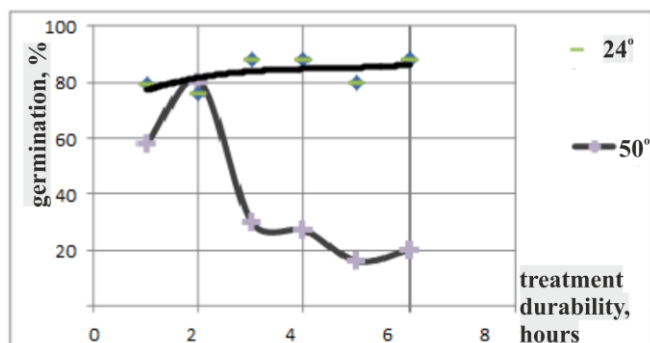


Fig. 1. The dependence of wheat germination ability (%) on the treatment durability (hours) in the vortex cavitator for the hot regimes 24⁰ and 50⁰.

The germination ability increases with the increase of treatment durability in low temperature regime. At that case the quantifiable value of the influence increases.

There is an excessive random of the variation energy in high temperature regime (30⁰, 40⁰) in grand expositions. In this case most likely it drives to mechanical, fatigue, immune informational and other destruction in the biological system though the received result is more than the control which 43%.

A similar result was received while solving other problems, such as intensification of seed sprouting and further development of wheat and barley [4], [5].

The increase of influence intensity till the temperature of 50⁰ stimulates more the seed awakens but the saturation point comes in lesser treatment durability 60 minutes. However the maximal result has a lesser value (Fig.2) in comparison with other regimes.

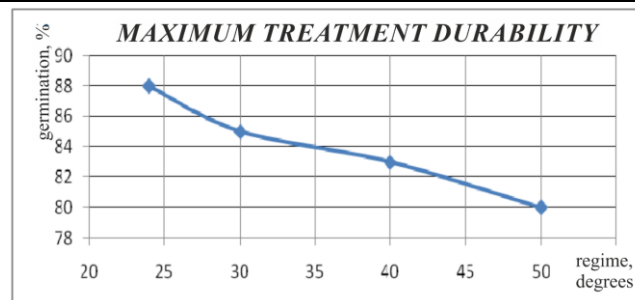


Fig. 2. The dependence of maximal wheat germination ability (%) in the vortex cavitator on the hot regimes of 24⁰, 30⁰, 40⁰, 50⁰.

The increase of exposition more than in 60 minutes results to the sum of hot and vibration influence exceeds the threshold level. In that case the depression and oppression of vital functions of awakened seed begin.

A practical conclusion of received results is so that the germination ability in the third day in all the expositions in temperature regimes 24⁰ - 40⁰ exceeds the germination ability in the inspection lot and in maximums it exceeds in more than two times as much. In this case the quantity and the quality of forages increase no less than half as much again.

While making the analysis of the germination ability in the first day the fact that attracts attention is so that there are treatment regimes in which the germination ability exceeds the control germination ability on the third day: when the treatment temperature is 30⁰ and durability is 60 minutes the germination ability is 54%. This circumstance presumes that the acceleration of sprouted grain forage production is possible.

Besides a supplement source for seed germination ability increase and plant development acceleration is discovered. It's a characteristics changement of water, which was treated in vortex cavitator. An additional series of experiments in which the water treated in the cavitator had been used for the further irrigation were made to establish the influence of this fact upon the seed germination ability.

In this case the seed lots were treated in cavitator during one and two hours in temperature regimes of 27⁰, 33⁰, 43⁰ (Schedule 2),

Schedule 2 – The dependence of water degree treatment (grade) on the germination ability (%) of the vortex cavitator treated wheat seeds.

Germination time period (hours), water temperature 27 ⁰ .					
Seed treatment durability (hours)	0	3	6	9	12
1	12	15	46	63	93
2	21	25	51	72	97
Germination durability (hours), water temperature 33 ⁰ .					
Seed treatment durability (hours)	0	3	6	9	12
1	8	13	67	72	92
2	12	20	46	69	91
Germination durability (hours), water temperature 43 ⁰ .					
Seed treatment durability (hours)	0	3	6	9	12
1	18	25	35	71	94
2	15	23	51	79	92

and after the cavitator treatment the seed were sprouted with irrigation with cavitator's water in the same regimes. The germination ability were fixed every three hours.

It was established on the basis of the experiments that:

- a part of seeds 12-20 % germinates in sprouts of ; 1-2 mm being yet in the cavitator;
- in 12 hours of sprouting the germination ability achieves the certified value of 92 -97% of seeds. It's 6 – 8 as much productive as if it was made by standard sprouting technologies (Fig.3);

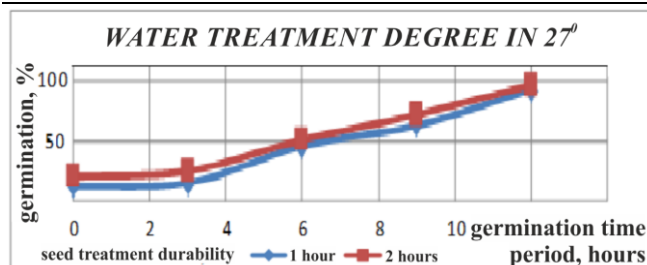


Fig.3. The speed of wheat seed germination ability increase (%) depending on sprouting durability for the water treatment degree in 27°.

- the germination ability of studied seeds achieves 51 – 67 % in 6 hours of sprouting which exceeds the germination ability in the third day of the current technologies in Linda Poultry Farm. That's why it's enough to sprout it with cavitator in 6 hours instead of 3 – 4 days to achieve a commensurable figure in the quality of forages from sprouted wheat. It decreases not only the time period but also the labour-intensiveness of sprouting and it decreases the cost of received production.

The seed vortex cavitator treatment is high-performance method of the intensification of seed awakens and the further development of plants. It activates bioactive substances. This method combines several ways of influence upon a biological object: irrigation, hot influence, vibrative, cavitational, diffusional influences etc. All the cavitator treated seeds have an exceeded index of development in comparison with the control lot seeds including index in germination ability, sprouting energy. This grain influences in positive upon the rooster productivity.

Conclusions.

1. The germination ability and the forage feeding power of the grains treated in the vortex cavitator in all the regimes besides $t=50^{\circ}$ increases.
2. The activity parameters of treated seeds in comparison with the germination ability of control lots achieve 200%. It presumes the increase of grain feeding power no less than half as much.
3. The germination ability and the feeding power of vortex cavitator treated seeds after the first day is comparable

with the germination ability of control lots of grains in the third day which makes possible to decrease the time period of technological process till one day saving the present quality level.

4. The irrigation of vortex cavitator treated seeds with water from active zone of the cavitator increases even more till 97% the germination ability and the feeding power of the seeds or it decreases the time period from three days to six hours in comparable with initial technological process quality.

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EVALUATION OF WORK QUALITY BASED ON THE LONGITUDINAL IRRIGATION UNIFORMITY

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Abstract: This article presents results of quality measurement of hose reel irrigation systems in farms dealing with cabbage and grain maize cultivation. Two hose reel irrigation machines RM 570 GX (with different manufacture dates 2001 and 2010) were examined in farm SUA, Ltd. Koliňany. The quality of work, based on value of longitudinal irrigation uniformity, was evaluated from two views. First quality parameter was aimed on correct functioning of irrigation technique from the point of winding hose speed. Second quality parameter was the change of irrigation rate along the hose. Irrigation system RM 570 GX (manufacture date of irrigation machine 2001) achieved the average value of winding hose speed $17.46 \text{ m} \cdot \text{h}^{-1}$ (calibrated winding speed $17 \text{ m} \cdot \text{h}^{-1}$) and the achieved irrigation uniformity coefficient was $C_u = 86.78 \%$. RM 570 GX (manufacture date of irrigation machine 2010) achieved the average value of winding hose speed $10.26 \text{ m} \cdot \text{h}^{-1}$ (calibrated winding speed $10 \text{ m} \cdot \text{h}^{-1}$) and the C_u coefficient was 92.85% . According to Christiansen, the standard value for irrigation uniformity coefficient was $C_u 90\%$ or more. Irrigation machine with the date of manufacture 2001 did not reach the desired value, therefore we recommended more frequent inspection and maintenance of irrigation techniques.

KEY WORDS: IRRIGATION MACHINE, LONGITUDINAL IRRIGATION UNIFORMITY, WINDING SPEED

Introduction

Slovak republic has limited mineral resources, but Slovakia has greatest wealth is water and soil. The idea „Sine aqua dees vita” means „Without water there is no life” and it expresses the unique position of water on Earth and its importance for humanity and nature. The water is used in agriculture for irrigation plants, therefore it is necessary to use it effectively and optimally (1,3,11).

The aim of irrigation is to supply the water to plants evenly over the entire cultivated area. Every plant must have enough of moisture to don't suffer of water deficit. It is essential that irrigation is carried out at the optimal time, optimal dose and in the right way. These conditions of quality shall ensure the irrigation technique. (7, 13)

In agriculture we understand irrigation as ameliorative processes. These processes leads to moistening the soil, vegetation or the ground layer of air in order to optimize production system to obtain high and permanent yields per hectare in crop production. (2, 5, 12)

Irrigation management has an impact on the agricultural economy. Therefore, precision of irrigation machines are very

important. If we use outdated and inaccurate machines then the consumption of irrigation water will rise and profits will be reduced. (4, 9, 10)

Materials and methods

1. Characteristic of agricultural subject and irrigation techniques

Available information and materials about the farm in Koliňany were gained in the VPP SUA Koliňany. Measurements on Koliňany's fields were carried out on two hose reel irrigation machines model RM 570 GX in combination with stand and sprayer Komet with nozzle diameter 22 mm.

2. Characteristic of work quality

a) Changing of hose winding speed

During these experiments, a speedmeter (designed and patented on the Department of machines and production bio systems, SUA Nitra in 2013) was used to measure and evaluate the longitudinal irrigation uniformity. This device, used to monitor the operating speed, consisted of measurement and evaluation sections. (Fig. 1).



Fig. 1 Measuring and evaluation sections of Speedmeter



There was also used an Incremental sensor 30 MOL 5V from company MEGATRON Germany (Fig. 2), which was used to measure the revolutions in measurement section.(14)



Fig. 2 Incremental sensor 30 MOL

Display section was made up of four LED displays, which is controlled by the main microprocessor. It was necessary to make a program to ensure the communication between this device and PC (Fig.3.).

b) Changing of irrigation rate along the hose

Irrigation rate along the hose was evaluated according to Christiansen. This methodology establish, that the standard value for irrigation uniformity coefficient has to be $C_u 90\%$ or more. Evaluation of irrigation by this method determines the standard ISO/DIS 7749/2 (6,8).



Fig.3 Program for communication

Calculation of irrigation uniformity coefficient:

$$Cu = 100 \cdot \left[1 - \frac{\sum_{i=1}^n |Vi - \bar{Vi}|}{n_1 \cdot \bar{Vi}} \right], \quad \% \quad (1)$$

Where:

Cu - irrigation uniformity coefficient, %

Vi - amount of water on elemental areas, mm

$\bar{Vi}$ - average amount of water, mm

n_1 - the number of equally sized elemental area,

$\sum_{i=1}^n |Vi - \bar{Vi}|$ - the sum of the absolute deviations from the mean

dose, mm (15)

Results and discussion

Agricultural subject and irrigation technique

Agricultural subject

Agricultural farm of Slovak University of Agriculture (VPP SUA Ltd.) was founded 07/01/2003. The sole shareholder and owner is Slovak University of Agriculture (below SUA). The main focus of the company, in addition to business, is a practical teaching, research, development and implementation of practical training for students of SUA in Nitra. The aim is also a complex preparation of graduates for success enforcement in the labour market.

The SUA manages the area of 2 127.89 hectares of agricultural soil, therefrom 2 038.37 hectares are arable soil. However more than 50% of soil is included into disadvantaged areas. The SUA focuses in crop production as densely-sown cereals, maize, sugar beet, oilseed rape, mustard, poppy, pumpkin and fodder for animals.

The source of water for the irrigation is the reservoir Koliňany. From the reservoir, the water is pumped to the water station and from the water station it is pumped to the hydrants on the fields. At full output of the water station can be connected even 10 irrigators at the same time.

Irrigation technique

In SUA Koliňany farm, the hose reel irrigators RM 570 GX 82 300 (manufacture dates 2001, 2010) (Fig. 4.) in combination with sprayer Komet TWIN 101/PLUS with diameter of nozzle 22 mm, were used for the measurement. A hose ratio length/diameter was 300 m /82 mm and it was same for both devices. Table 1 shows the technical parameters of irrigation machines RM 570 GX 82 300.

Tab. 1 Technical parameters of irrigation machines, RM 570 GX

S.n.	Parameter	Values	
1	Year of production	2001	2010
2	ID. number	570 218	570 563
3	Country of origin	Italy	
4	Hose diameter	82 mm	
5	Hose length	300 m	
6	Flow	19 – 48 m ³ .h ⁻¹	
7	Pressure	0,47 – 1,02 MPa	
8	Nozzle diameter	16 – 24 mm	
9	Weight with hose	1 400 kg	1 680 kg
10	Drum diameter	2 070 mm	
11	Length of bracket	5 000 mm	



Fig. 4 Hose reel irrigation machine RM 570 GX 82 300 (2001, 2010)

Table 2 shows technical parameters of sprayer. This sprayer was used for both irrigation machines. Diameter of nozzle hole is 22 mm. Technical and technological parameters of irrigation were changed by changing of the pressure in the sprayer and also by changing of the working flow and throw range was adjusted by changing the pressure.

Tab. 2 Technical parameters of sprayer Komet TWIN 101/PLUS

Komet TWIN 101/PLUS – 22 mm		
Pressure [MPa]	Flow [$\text{m}^3 \text{h}^{-1}$]	Throw range [m]
0,2	26,3	33,1
0,25	29,4	36,1
0,3	32,2	38,7
0,35	34,8	41,0
0,4	37,2	43,1
0,45	39,4	45,1
0,5	41,6	46,9
0,55	43,6	48,7
0,6	45,5	50,3
0,65	47,4	51,9


Fig.5 Sprayer Komet TWIN 101/PLUS

Characteristic of work quality

Changing of hose winding speed

The measurement was performed 21/07/2016. On the parcel, the seed maize was grown. Irrigation machines were not equipped with control electronics, e.g. manual control. The given situation was convenient for us because the speed index on the machines allowed only approximately adjustment of speed values. Adjusted speed was about 17 m.h^{-1} for first machine and 10 m.h^{-1} for second machine. A measuring system was located about 25 meters from the spool. Measurement of the first machine started at 9:15 AM. After completion of the measurement on the first machine, measuring device was moved to its position at second machine. Measurement of the second machine started at 0:15 PM. The weather conditions were suitable in terms of wind speed and in terms of temperatures - limits were adhered to the norm.

Electronic unit and the technical part of the measuring device was pre-set according to the diameter of the cylinder, which was placed in the construction part (cylinder circumference was set in the electronic unit to 143.8 mm). For the correct collection of the data and its subsequent evaluation it was necessary to set the interval for writing values to 1.5 minutes.

Figures 7 and 8 display graphic evaluation of results and Table 3 shows descriptive statistics for both investigated irrigators. Two extremes values are shown at Figure 7. The first extreme was recorded 6 minutes after the start of measurement. This extreme value was caused by the assembly mistake. That was a proof, that if we did not correctly fix device the variability of results will be significantly higher. That problem was solved by the stronger

anchoring of device. The opposite extreme, was recorded at 17.5 minutes after the start of measurement. This value could be caused by a technical error of irrigator during changing the thread on the reel at the moment when device wrote the speed value. Besides these extremes, the range of values moving around the mean value circa 1 m.h^{-1} . Linear assumption of further development of work speed was growing. Unevenness of running could be caused by soil inequalities, variations in resistance tripod and motor wear. Figure 8 shows that in the second measurement extremes values were not occurred. The average value of hose winding speed was 17.46 m.h^{-1} (machine - 2001, the value of coefficient of variation was 14.9%) and 10.26 m.h^{-1} (machine - 2010, the value of the coefficient of variation was 3.31%).


Fig. 6 Landscape, Speedmeter, rain-gauges

Tab. 3 Descriptive Statistics, speed of winding hose RM 570GX

Parameter	Value	
	2001	2010
RM570GX		
Average	$17,46 \text{ m.h}^{-1}$	$10,26 \text{ m.h}^{-1}$
Standard error	0,28	0,04
Median	$17,15 \text{ m.h}^{-1}$	$10,25 \text{ m.h}^{-1}$
Modus	$15,74 \text{ m.h}^{-1}$	$10,05 \text{ m.h}^{-1}$
Standard deviations	$2,60 \text{ m.h}^{-1}$	$0,34 \text{ m.h}^{-1}$
Range of values	$27,45 \text{ m.h}^{-1}$	$1,43 \text{ m.h}^{-1}$
Sum	1519 m.h^{-1}	$831,37 \text{ m.h}^{-1}$
Number of value	87	81
Minimum	$28,66 \text{ m.h}^{-1}$	$10,95 \text{ m.h}^{-1}$
Maximum	$1,21 \text{ m.h}^{-1}$	$9,52 \text{ m.h}^{-1}$
Coefficient of variation	14,90 %	3,31 %

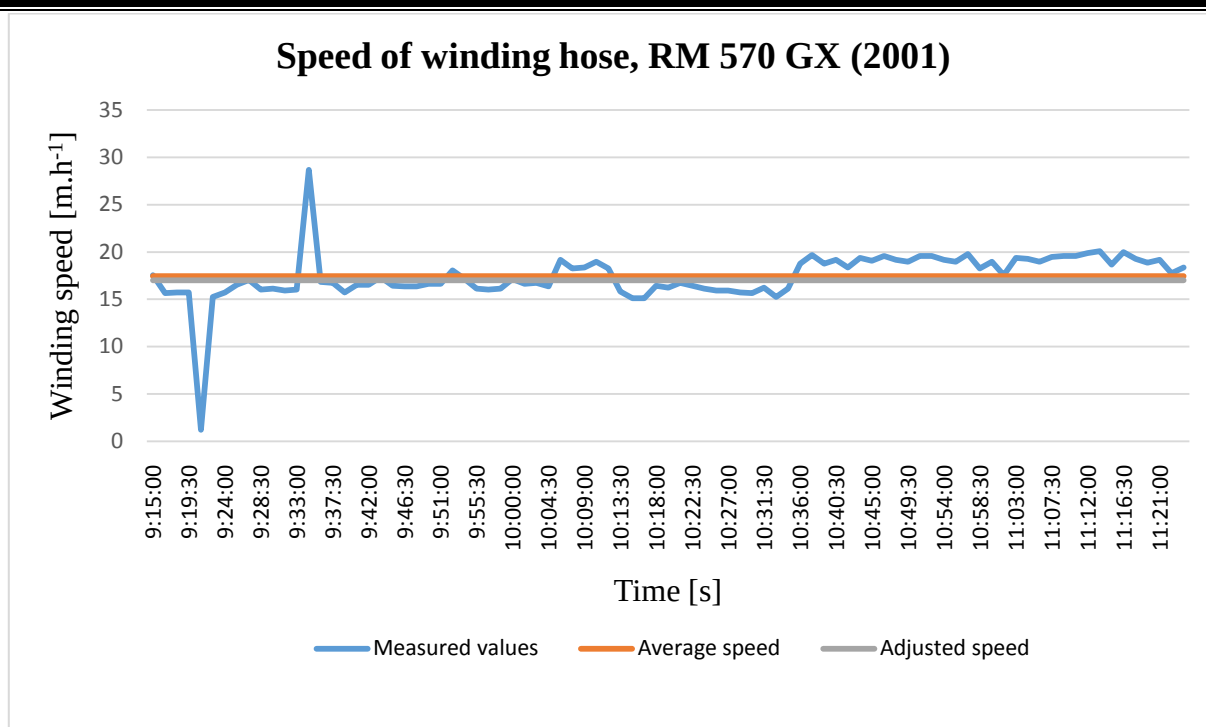


Fig. 7 Speed of winding hose, RM 570 GX (2001)

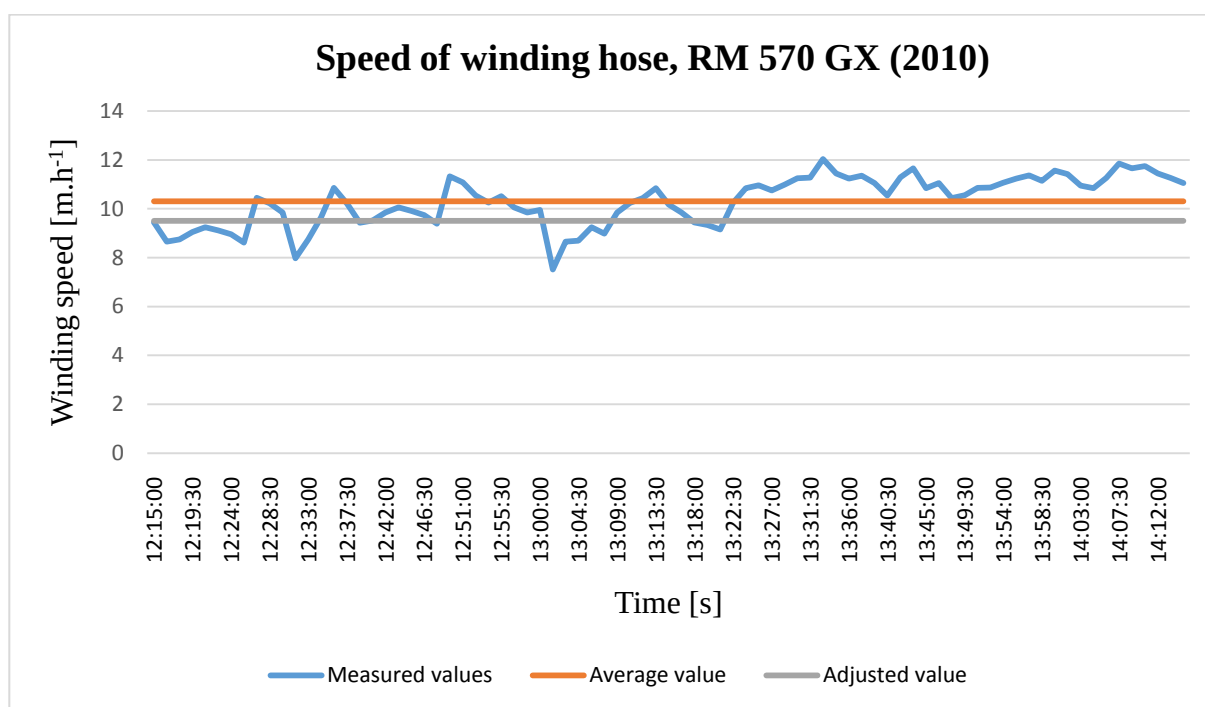


Fig. 8 Speed of winding hose, RM 570 GX (2010)

Changing of irrigation rate along the hose

Measurement of irrigation rate in individual rain-gauge containers was carried out by measuring cylinders. The measurement was performed according to the Christiansen methodology. Total examined length, where the measurement were conducted, in both cases was 29 m (the number of containers was 30 pieces with a pitch of 1 m). Sprayer sector was set on motion range 180 degrees. Manometer showed approximate values 0.5 - 0.6 MPa. The average irrigation rate was 31.28 mm for machine RM 570GX (2001) and 53.15 mm for RM 570GX (2010). According to Christiansen, the standard value for irrigation uniformity coefficient is C_u 90% or more. Irrigation machine RM 570 GX 2001 achieved 86.78% and RM GX 2010 achieved 92.85 %. Irrigation machine

with the date of manufacture 2001 did not reach the standard value, therefore we recommend higher frequency of inspections and better maintenance of irrigation technique.

The necessity of our research is supported by various authors. For example, Baker & Simoník (1989) claim, that efficiency of irrigation technique depends on the uniformity of the irrigation. The uniformity of irrigation depends on the distribution of water over the length of the watering belt. Also Látečka (2000) for example state, that the irrigation uniformity depends mainly on construction of irrigators, hydraulic losses, fluctuations of pressure in the inlet to the drum and also wind activity. These cause influent distribution of water on the irrigated strip.

Tab. 4 Descriptive Statistics, changing of irrigation rate RM 570GX

Parameter	Value	
	2001	2010
RM570GX		
Average	31,28 mm	53,15 mm
Standard error	0,84	0,77
Median	32,57 mm	53,62 mm
Modus	33,19 mm	54,28 mm
Standard deviations	4,59	4,23
Range of values	14,85 mm	15,67 mm
Sum	938,50 mm	1 594,62 mm
Number of value	30	30
Minimum	37,69 mm	60,12 mm
Maximum	22,84 mm	44,45 mm
Coefficient of variation	14,69 %	7,95 %
Irrigation uniformity coefficient	86.78 %	92.85 %

Conclusion

In conclusion of paper, we can write that we fulfil dedicated goals. As a goal we had the inspection of work quality of hose reel irrigation machines. The inspection was focused on the proper function of the winding system, thus changing of hose winding speed and also correct function of the irrigation dosing system, thus changing of irrigation rate along the hose.

The result of the examination are measured values and their evaluation and comparison with the standards. Irrigation machine RM 570GX from manufacture date 2001 had calibrated winding speed on 17 m.h⁻¹ and measured 17.46 m.h⁻¹ (coefficient of variation 14.9%) and achieved Cu 86.78%. Irrigation machine RM 570 GX from manufacture date 2010 had calibrated winding speed on 10 m.h⁻¹ and measured 10.26 m.h⁻¹ (coefficient of variation 3.31%) and we achieved Cu 92.85 %.

Winding technique on both machines worked correctly, however irrigation dosing system on irrigation machine with the date of manufacture 2001 did not reach the standard value, therefor we recommend higher frequency of inspections and better maintenance of irrigation technique. On the second machine, the values met the standard.

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IMPACT OF WATERING REGIMES ON APPLE YIELDS UNDER VARIOUS METEOROLOGICAL CONDITIONS AND MICRO IRRIGATION.

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SUMMARY: Analysis of meteorological factors shows that the temperature sums during the vegetation of the main crops grow but are relatively stable, ie. they are not a limiting factor for their normal growth and development. Rainfall, however, in terms of quantity and distribution changes in a considerably wider range over ten days periods, months and years. The instability of this meteorological factor predetermines irrigation as a major event of the agro-technical complex, which is decisive for the achievement of high and sustainable yields.

Increasing water deficit requires the use of water-saving irrigation technologies in the practice of irrigated agriculture and the conduct of research to optimize irrigation regimes in order to increase the efficiency of irrigation water used. One of the ways to achieve this goal is irrigation with reduced irrigation norms while preserving the number of waterings. The advantage of these reduced irrigation regimes is the saving of water at acceptable yield losses. Their application is warranted when there is a possibility of accurate dosing of irrigation water and the irrigations are of low cost.

In order to establish the irrigation regime of apples in drip irrigation, field experiments were carried out on the Chelopechene-Sofia experimental field. Irrigation is carried out with a drop in pre-watering humidity to 85% of WHC and variants irrigated by a reduction of irrigation rate with 20% and 40% compared to the variant irrigated at 100% WHC and non-irrigated variant.

The conducted irrigated regimes during the years have had an impact on the yields obtained, with the highest results being obtained for the irrigated variants with 100% irrigation rate and the lowest for the non-irrigated variants. The largest increase in yield was obtained in 2004 (characterized as dry), which is with 55% (apples) more than non-irrigated variants, and the smallest increase of 25% (apples) was obtained during the humid 2005.

INTRODUCTION

To determine the impact of drought on crop yields, yields are compared in irrigated and non-irrigated conditions. Thus, the impact of meteorological indicators on the development of crops during their vegetation period, according to the biological and physiological requirements during their individual development phases, is taken into account.

The optimal irrigation and irrigation norms mentioned in the literature are moving widely (Dochev, 1983) due to the dependence of these parameters on soil-climatic conditions, age, applied cultivation technology (Keeler, J., D. Karmelli, 1974). (Lazarov et al., 1982). (Kirilov, K., 1994) offer the best prerequisites for the application of the so-called broken irrigation regime by reducing the size of irrigation rates.

The advantage of these reduced irrigation regimes is the saving of water at acceptable yield losses. Their application is warranted when there is a possibility of accurate dosing of irrigation water and the irrigations are of low cost.

From the world's and our local science, it has been found that from applied techniques and technologies for irrigation of apples most suitable for their biological requirements with maximum efficiency of irrigation water is drip irrigation (Drupka, W., 1979). This mode of irrigation ensures that you get biologically optimized yields with high quality fruits and significant water savings. (Dochev, 1983), (Kuijesza, W., 1973)

The aim of the paper is to determine the influence of irrigation regimes on the yields of drip-irrigation grown apples in years with different weather conditions.

Material and method

In order to determine the influence of the irrigation regimes on the yields of dropped apples, studies of the experimental field of "Pushkarov" Institute - Chelopechene - Sofia (2001-2005) were carried out.

The following options were tested:

1. Non-irrigated option

2. Watering with irrigation rate 100% M;
3. Watering with irrigation rate of 80% M;
4. Watering irrigation rate 60% M.

Irrigation was carried out by surface drip irrigation with drippers KP - 4.6, perforated pipes between 0.60 m. The soil is leached chromic forest, slightly sandy loam in the ore layer formed on the base of an old deluvial cone of sediment materials. It is poorly stocked with nitrogen, on average with phosphorus and well stocked with potassium. On average, for the layer 0 - 60 cm, the soil has the following water-physical properties: WHC = 22.1%, wilting point humidity - 12.3% on absolute dry soil weight with WHC - 1.47 g / cm³. For the soil layer 0 - 100 cm, the same indicators have values: WHC - 21.8%, wilting point humidity - 12.3% and bulk density - 1.50 cm³. The soil is suitable for growing apples.

RESULTS

Meteorological conditions of the experiments

Regarding the amount and the distribution of rainfall during the April-September vegetation period, the conditions during the individual years are characterized by variety and appearance of extremes. According to the provision of rainfall, defined in the 1956-2005 series (Table 1 and Figure 1a), three of the years - 2001, 2002 and 2005 are humid, one - 2003 - average and one - 2004 - very dry. The July-August period for two of the years 2001 and 2004 is very dry, for two - 2002 and 2005 - humid and for one - 2003 - with average conditions (Table 1 and Fig. A humid spring was observed in 2001 and 2003, and a humid autumn in 2002. Summer droughts lasting more than ten days were observed throughout all the years of the surveyed period. Their manifestation is mainly in June (2002, 2003, 2004 and 2005), and only in two years (2001 and 2002) - in July. For some ten days periods in the years 2002, 2003 and 2005, the 10-day sums significantly exceeded the average multi-annual.

Table 1. Rainfall over apple vegetation period (2001-2005)

Periods	Total rainfall, mm					Rainfall factor security, %				
Year	2001	2002	2003	2004	2005	2001	2002	2003	2004	2005
m. IV – IX	358	418	329	258	765	37,1	17,3	59	94,6	1,4
Average multi-annual	365	365	365	365	365	-	-	-	-	-
m. VII – VIII	75	158	104	73	400	76,8	9,3	47	74,8	1,4
Average multi-annual	110	110	110	110	110	-	-	-	-	-

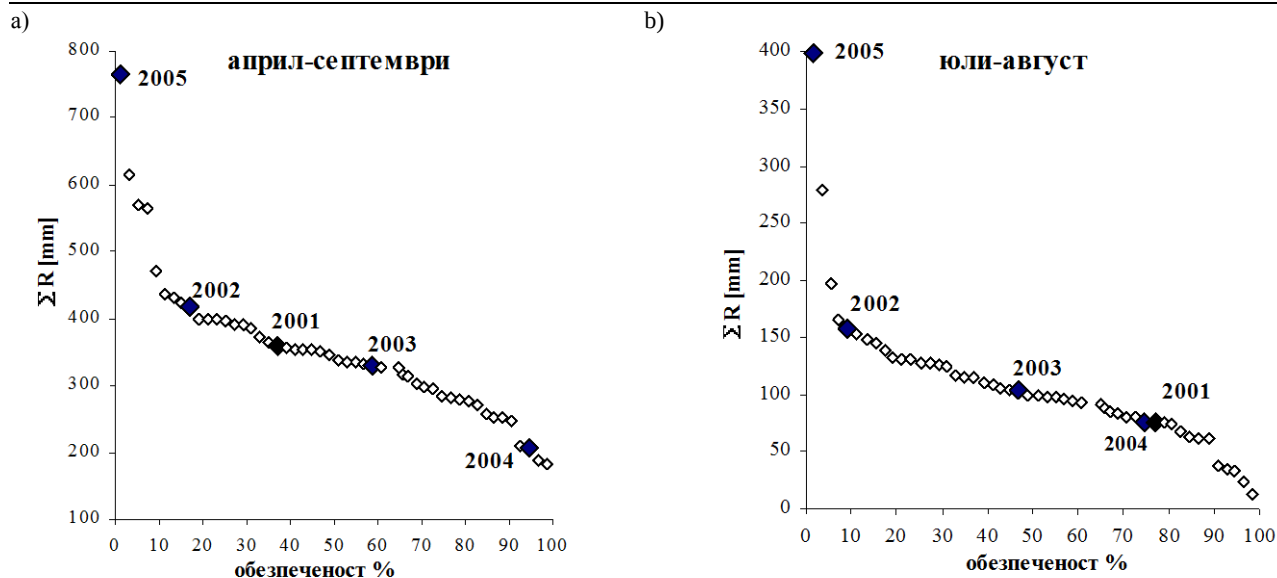


Fig. 1 Coverage curves for the fifty-year series (1956-2005) for the periods: (a) April to September; b) July-August

Air temperature and deficiency of water vapor saturation in the air affect the life cycle rates of the plant, including on the intensity of photosynthesis. The temperature sums for both the April-September and the July-August vegetation periods show that without exception the years are warm (Figure 2). In 2002 conditions were close to the average. The same shows the dynamics of ten-day

period temperatures compared to the average of the 1901-2005 averages. The smallest deviations are observed in 2001. The values for August and September 2002 are below the norms for these months. The ten-day period temperatures over the whole growing season of 2003, 2004 and 2005 significantly exceeded the relevant norms.

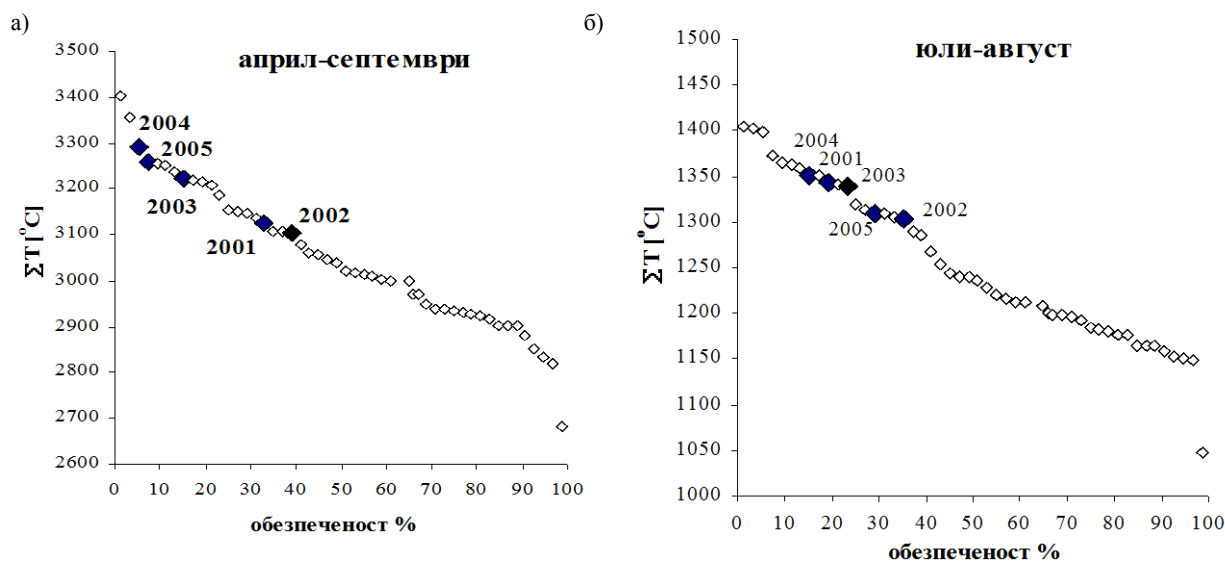


Fig. 2. Coverage of the temperature sums for the fifty-year series (1956-2005) for the periods: a) April-September; b) July-August

The need for irrigation to maintain optimum soil moisture in the 0-60 cm layer is mainly due to the quantity and distribution of rainfall during the vegetation period of the crop. The irrigations are realized with a decrease of the soil moisture in the layer 0-60 cm below 85% of the WHC.

The results of the five-year study show that the number of irrigations and the irrigation rate is determined by the weather conditions (precipitation) in individual years, with the number of irrigations for apples varies from 14 to 20.

The results obtained for the apple harvest during the various humid years show the influence of the irrigation regimes on its size. The greatest increase in yields was obtained during dry years (the July-August period for two years - 2001 and 2004 is very dry). The increase in yields is 55% (apples) more than the non-

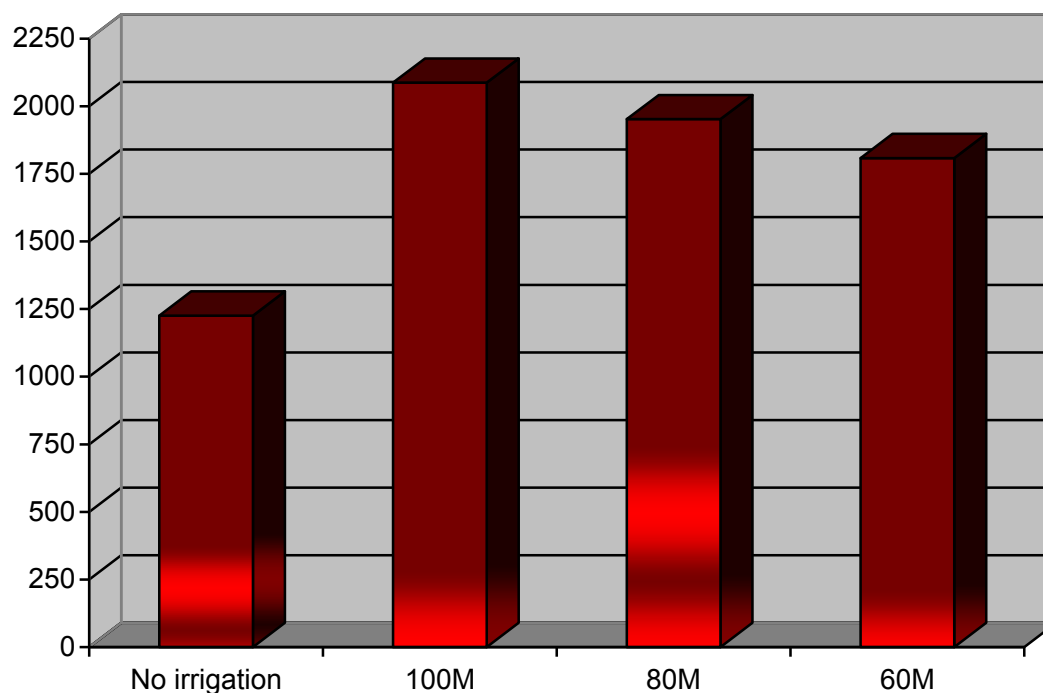
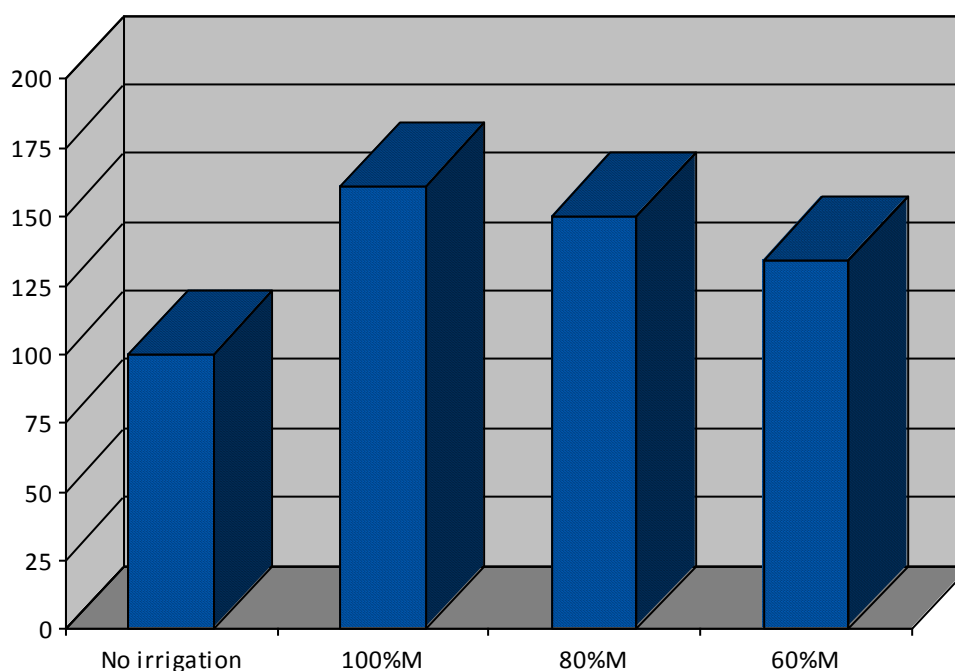
irrigated option, and the smallest increase of 25% (apples) was obtained during the humid 2005.

The irrigated regimes during the years also affected the yields obtained. Highest yields were obtained in the variants irrigated with 100% irrigation rate of 2087 kg / dca (apples) and the lowest in non-irrigated variants 1266 kg / dca (apples). Lowering the irrigation rate by 20 and 40% resulted in a 7% and 14% reduction in apple yields (Table 2, Fig. 3 and Fig. 4).

Of the tested irrigation regimes, most suitable biologically is the irrigation regime with the implementation of a 100% irrigation rate, which is recommended with a good water supply. In the case of a occurring water deficit, apply irrigation regime with a 20% reduction of the irrigation rate, where satisfactory yields are obtained.

Table 2. Yields of apples in drip irrigation conditions in the region of Sofia

Years	2001		2002		2003		2004		2005	
Variant	Yield kg/dka	Relative yield,%	Yield kg/dka	Relative yield %	Yield kg/dka	Relative yield, %	Yield kg/dka	Relative yield, %	Yield kg/dka	Relative yield, %
No irrigation	1567	100	704	100	1135	100	855	100	2070	100
100%M	2122	135	1769	251	1945	156	1866	218	2737	132
80% M	2053	131	1603	228	1828	143	1681	196	2592	125
60% M	2004	128	1421	202	1712	135	1459	170	2444	118


Table 3. Yields of apples in drip irrigation conditions average for the period 2001-2005.

Fig.4. Relative yields of apples in drip irrigation conditions and different irrigation rates, compared to the non-irrigated option, average for the period 2001-2005

CONCLUSIONS

1. The analysis of meteorological factors shows that the rainfall in the country is insufficient to satisfy the plants' requirements of soil moisture and the ten-day temperature values over the whole vegetation period exceed the respective norms. This requires optimization of the irrigation regime and the use of water-saving technologies for irrigation in the production of apples.
2. The highest increase in apple yields with irrigation was obtained during the dry years, which is 55% more than the non-irrigated option, and the smallest increase by 25% - during the humid 2005. The reduction of the irrigation rate by 20 and 40 % has led to a reduction in apple yields of 7% to 14%.
3. From the tested irrigation regimes biologically the most suitable is the irrigation regime with the implementation of a 100% irrigation rate, which is recommended under conditions of good water supply. In case of water deficit, the application of irrigation regime with a 20% reduction of the irrigation rate gives acceptable results.

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ASSESSMENT OF EFFICIENCY OF USING FEED PROTEIN PRODUCED BY PROCESSING MILK WHEY

ОЦЕНКА ЭФФЕКТИВНОСТИ ИСПОЛЬЗОВАНИЯ КОРМОВОГО БЕЛКА, ПОЛУЧЕННОГО ПЕРЕРАБОТКОЙ МОЛОЧНОЙ СЫВОРОТКИ

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Abstract. The relevant task of animal husbandry is to provide animals with high-quality and cheap feed protein. In this regard, a promising direction is the use of a protein feed additive, produced as a result of the microbiological synthesis of the yeast *Debaryomyces hansenii* var *hansenii* (D.f.v.) during the processing of milk whey. To assess the results of the applicability of this additive when feeding animals, comparative tests were carried out with chicken replacements. It was found that the introduction of domestic protein feed additive in the compound feed of chicken replacements, produced by processing milk whey, equal to the amount of fish meal (5%) according to energy and protein nutrition, contributes to an increase in the growth rate of young chickens by 5.2%; reduction of feed costs per 1 kg increase in body weight by 4.5%; a more active evidence of physiological maturation of young chickens (by changing the first-order flight feathers); and an evidence of sexual dimorphism (by the size of the caruncle) in comparison with the control group.

KEY WORDS: protein feed additive based on the milk whey (PFA-MW), feed protein, increase in body weight, chicken replacements, efficiency.

1. Introduction

An important problem in animal husbandry is the development of own sources of food protein for feeding animals. In this regard, a promising direction for solving this problem is the use of the milk whey [1]. State-of-the-art technologies of whey processing make it possible to solve only partially the problem of its use, because either they are not wasteless (production processes of lactose and biogas), or are low-tonnage (production of beverages and food protein), or are very expensive.

The purpose of this work was to study the efficiency of using protein feed additive based on milk whey (PFA-MW) in the feeding of chicken replacements.

2. Results and discussion

Scientific and economic research was carried out in the poultry farm. The object of research was chicken replacements of "White Hisex" cross from daily to 91-day-old.

To study the efficiency of using a protein feed additive based on milk whey (PFA-MW) in the feeding of chicken replacements, a protein feed additive based on milk whey was used [2]. PFA-MW has the following physico-chemical indicators: moisture content – max. 10.0%, crude protein content – min. 45.0%, raw fat content – max. 6.0%, ash content – max. 17.0% and contains 45% of protein. PFA-MW is a fine powder that looks no different from dry milk or dry milk whey.

It is known that not only biomass rich in protein and vitamins is accumulated in the process of vital activity of protein synthesizing yeast in the milk whey, but also a whole complex of biologically active substances – the products of their endogenous and exogenous activities, as a result of which the whey acquires qualitatively new properties, turning into a highly efficient biologically active feed product [3-5].

Feeding of young stock was carried out by complete feed with three-phase change of intakes: feed recipe KDP-2-1 at the age of 0-5 weeks, which contained 1210 kJ of metabolic energy (ME) and 19.3% of crude protein (CP); KDP-2-2 at the age of 5-10 weeks (1185 kJ of ME and 17.6% of CP); KDP-3 at the age of 10 weeks and until the end of growing (1160 kJ of ME and 14.9% of CP). Compound feeds were balanced according to a wide range of nutrients and biologically active substances. Scientific and economic experience was carried out according to the scheme presented in table 1.

Table 1 – Experience scheme

Groups	Number of heads	Feeding features
1st (control)	50	BCF * + compound feed according to growing phases, containing 5% of fish meal
2d (experimental)	50	BCF + 5 % of PFA-MW similar to the amount of fish meal in the control group

* BCF – Basic compound feed.

As a result of the experiment, it was found that at the daily age the body weight of both groups of chickens formed according to the principle of analogues was 36-37 g. Further, the growth rate of the chickens was differentiated as follows: chickens of the second group of the 42-day-old exceeded control in body weight by 14.4 g, and in the 91-day-old – by 53.6 g, or 5.2%, with a statistically significant difference.

During the growing of chicken replacements with limited feeding and sufficiently high livability (96% in both groups), it was found that the chicken replacements of the experimental group differed most in nutrient conversion of the compound feed, where by 4.5% less feed was used than in the control group for every kilogram of growth.

The decisive criterion for the applicability of various innovative developments in poultry farming is their economic efficiency. When growing chicken replacements of the egg direction of productivity, the components of production efficiency are indicators of livability, growth rate and feed costs per unit of weight body growth. Table 2 shows the calculations of the economic efficiency of production.

Table 2 – Calculations of the economic efficiency

Indicators	Groups	
	1st	2d
Initial number of heads, heads	50	50
Livestock preservation, %	96	96
Number of feeding days, days	4365	4378
Body weight of day-old chicks, g	36,3	36,5
Body weight of day-old chicks at the end of the experiment, g	1021,9	1075,5
Body weight growth of 1 head, g	985,6	1038,5
Gross body weight growth, kg	47,3	49,8
Additional growth, kg	-	2,5
Cost of additional growth, rubl.	-	4,25
Additional costs, rubl.	-	0,21
Additional profit, rubl.	-	4,04

Conclusion

Introduction of domestic protein feed additive in the feed of chicken replacements, produced by the milk whey processing, equal to the amount of fish meal (5%) according to energy and protein nutrition, contributes to an increase in the growth rate of chicken replacements by 5.2%; a reduction in the cost of feed per 1 kg of body weight growth by 4.5%; a more active evidence of physiological maturation of young stock (by changing first-order flight feathers) and an evidence of sexual dimorphism (by the size of the caruncle) in comparison with the control group.

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THE POLLUTION OF STREAMS AND WELLS

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Abstract: The article presents an example of producing a research paper by students aged between 14 and 15 years. Their research paper focused on examining the pollution of water sources in the vicinity of school. With the help of the colorimetric method we established the concentration of nitrates, nitrites, ammonium ions and phosphates as well as the pH value. In the National Laboratory of Health, Environment and Food they took care of the microbiological analysis of water. We found out that none of the samples were in compliance with the standards of the sanitary quality of water as regards their microbiological attributes. Nonetheless, chemical water attributes did not exceed the permitted levels set by regulations for potable water.

However, all of the analysed water samples could be used for irrigation and the watering of those plants that are further processed.

Keywords: CHEMICAL WATER ATTRIBUTES, MICROBIOLOGICAL WATER ATTRIBUTES, RESEARCH ASSIGNMENT.

1. Introduction

1.1 The significance of water

Planet Earth could be called the Water planet. Water is the basic constituent of our bodies, at the same time being the largest living space for numerous animal and plant species. For humans, clean fresh water is the precondition for survival, health and well-being. We use water in households for drinking and preparation of food, we use it to irrigate farmlands and to cool overheated machines. The flowing bodies of water can be harnessed to produce hydroelectric energy. Fishing is in many areas an important source of food.

Slovenia's wealth of water resources consists of rivers, springs, groundwater zones, waterfalls, natural and artificial lakes and the Adriatic Sea. High quality and healthy water resources are essential for our survival and development. The total length of Slovenian waterways is around 26 000 km, which implies more than a kilometre of watercourses per square kilometre of surface.

Water performs also other important functions. Oceans, or rather marine organisms (phytoplankton and other plants), produce a third of world's oxygen. At the same time they bind (in the same way as land plants) a significant portion of carbon dioxide, which is generated mostly by the combustion of fossil fuels. The dangerous consequences of warming the Earth's atmosphere are thus reduced to some extent.¹

Approximately 35% of tap water in Slovenia comes from surface waters, such as rivers and lakes, and 20% of the latter are under serious pollution threat. The remaining 65% of water comes from groundwater, which retains rainwater seeping into the soil. However, all water needs to be treated before consumption, as it may be contaminated with substances that can be washed into groundwater and surface water. These substances are various fertilizers, pesticides, toxic industrial chemicals or microorganisms, which enter water with human or animal waste.²

1.2 Water pollution

The households pollute water the most with laundry and faeces. The water used for washing the laundry contains polyphosphates, perborates and a number of other compounds, which in many places bypass treatment plants and thus pollute surface waters.

Agriculture pollutes water with artificial fertilisers, which are nitrogen, phosphorus and potassium compounds and are essential for the growth of plants. Nitrates and ammonium compounds are water-soluble. The industrial use of water is not limited to cooling. Some technological processes, such as washing, dissolution, dilution etc., are in most cases also done with water, and thus various other substances pass into water. The most problematic

are heavy metals, which are, at higher concentrations, very toxic to humans.³

1.3 Chemical parameters

The health adequacy of drinking water is determined by microbiological and chemical parameters. What follows is a list of chemical and microbiological parameters set for drinking water in accordance with Rules on drinking water.⁴

We have also added the description of the phosphate parameter, which is absent from the above mentioned Rules.

The pH value of water denotes its acidity degree or its degree of alkalinity. Rules on drinking water set the limit pH value at the range between 6,5 and 9,5.

Nitrates and nitrites are the natural form of nitrogen found in the environment. However, nitrates and nitrites appear also as a result of human activities: in artificial and natural fertilisers, municipal sewage and industry. In Rules on drinking water, the limit value for nitrate is 50 mg/L, and for nitrite, it is 0,50 mg/L.

Ammonia is well soluble in water, and ammonium ion (NH_4^+), which is determined by analyses, is produced on reaction with water. In Rules on drinking water, it is classified as one of indicator parameters, with the limit value of 0,50 mg/L.

Most **phosphates** enter water through the leaching of artificial fertilisers from farmland or through sewage which contains cleaners, washing powders and detergents. In unpolluted water, concentrations do not exceed the value of 0,1 mg/l. Rules on drinking water do not set any limit values.

1.4 Microbiological parameters

Escherichia Coli. These bacteria are always present in great numbers in human and animal faeces, sewage and in water contaminated with faeces. The presence of *E. coli* in drinking water proves without doubt that water has been fecally contaminated. The Rules on drinking water set the limit value for *E. coli* in drinking water at 0 /100 mL.

Enterococci. These bacteria, present in intestines or in human and animal faeces, are a reliable indicator of contamination with fecal matter. Since they are preserved in water for longer than *E. coli*, we consider their presence in drinking water, in which other bacteria has not been detected, to be older fecal contamination. According to Rules on drinking water, the limit value for enterococci in drinking water is 0/100 mL.

Microbial colony count at 22 °C. Using this parameter, we determine the number of bacteria which can be present in water as normal flora. Any sudden increase in the number of these bacteria can be an early indicator of disturbances at any point in the whole

system of drinking water supply. The temperature signifies the temperature at which we incubated them in the laboratory, implying also that these are primarily bacteria of non-fecal origin. The limit value for colony count at 22°C signifies, according to Rules on drinking water, "no abnormal change". The agreed limit value as regards the results of monitoring for colony count at 22°C is less than 100/mL.

Microbial colony count at 37 °C. This parameter determines the number of bacteria, which – as in the case of colony count at 22°C – indicates the efficiency of water treatment procedures, proliferation of bacteria in the water distribution network due to congestions or increased temperature, subsequent invasions of bacteria into the system etc. These data are the starting point for assessing the condition of the whole system. In comparison with colony count at 22°C, the number of colonies at 37°C helps us estimate whether we may be dealing with bacteria of fecal origin. The limit value for colony count at 37°C is less than 100/mL.^{5,6}

2. Experimental part

This article presents an example of writing a research assignment undertaken by students aged between 14 and 15 years. Their research paper focused on examining the pollution of water sources in the vicinity of school.

Ankaran is a town at the foot of the southern slope of the Muggia Peninsula. The latter is located in the Gulf of Trieste and extends between the Bay of Koper and the Bay of Muggia. The climate in Ankaran is submediterranean, characterized by long and hot summers, mild winters and frequent winds. Most precipitation is in autumn. In this region, people have always faced the lack of fresh water at the time of year when the growth of plants is at its most intense (spring and summer). To resolve this problem, the locals have always used all of the existing sources of fresh water available, i.e. streams and wells.

This is why we decided to examine the state of some small streams and wells situated in the close vicinity of our elementary school, their possible chemical and microbiological pollution and thus check water's suitability for watering vegetables or even drinking.

Sampling points are presented in the table below.

Table 1: Sampling points

Sample number	Sampling point
1	Stream SV od šole – Regentova ulica
2	Stream JZ od šole – nad šolskim igriščem
3	Stream Valdoltra - plaža
4	Stream Lazaret
5	Well v Mladinskem zdravilišču Debeli rtič
6	Stream Sv. Katarina
7	Stream Na Logu
8	Stream križišče Hrvatini
9	Well Jadranska cesta
10	Well Ivančičeva ulica
11	Stream Ivančičeva ulica

2.1 Hypotheses

Before the experimental work we have set the following hypotheses:

First hypothesis: Nitrates and nitrites do not exceed limit values.
Second hypothesis: The values of microbiological parameters are lower in wells than in streams.
Third hypothesis: The water from wells is fit for drinking as regards chemical and microbiological parameters

2.2 Structuring the experimental part

The experimental part of our research paper was divided in:

a) field work done in points for the abstraction of water.

At particular sampling points, we collected water into the beaker and immediately measured water temperature. Next, we collected two samples – one into a half-liter vial for chemical analyses and the other into a sterile plastic container for microbiological analyses. Both containers had been properly tagged beforehand.

We immediately put the plastic bottles into the cooler, refrigerated them overnight, and the next day we took them to the Centre for Microbiological Analysis of Food, Water and other Environmental Samples.

Samples for chemical analyses were refrigerated too, and the analyses were made the very next day.

b) Laboratory analyses done at school and at the Centre for Microbiological Analysis of Food, Water and other Environmental Samples.

2.3 Chemical analysis

Chemical analyses were done at school, in the Chemistry classroom.

Analyses were based on the colorimetric method – rapid tests for ions on the basis of specific colour reactions. The intensity of the sample's colour is compared to a ready-made colour scale with the help of which we read off ion concentration in the sample.

2.3.1 The work procedure

Water samples were analysed with the help of the reagent case for water analysis MACHERY NAGEL visocolor ECO Analysenkoffer.

The procedure for analysing any parameter is set out on the enclosed leaflet with a colour-comparing scale and manufacturer's instructions. For determining each parameter, we used two containers with water samples, one of which was a control sample.

Here is an example of procedure for **determining nitrates**:

First, we washed the two containers with sample water, to make results more precise. We then filled them with sample water to the 5 mL mark. One container with sample water was used for comparison. We added 5 drops of reagent NO₃-1 into the second container, closed the container and shook it well. Then we added a small spoon of reagent NO₃-2, stoppered the container, shook it for one minute and left it to stand for 5 minutes. After five minutes, we put both containers on the colour scale, compared them and read off the concentration of nitrate ions.

Depending on the concentration of nitrates, the water showed a more or less intense orange colouring. (see fig. 1). The result was recorded in a table (see Results).



Fig. 1: Determining nitrates

2. 4 Microbiological analyses

The Centre for Microbiological Analysis of Food, Water and other Environmental Samples provided the analysis of the following microbiological parameters: the presence of coliform bacteria, *Escherichia coli*, enterococci, the total bacteria count at 37 °C and the total number of bacteria at 22 °C. The results are given in point 2.5.

2. 5 Results of experiments

2. 5. 1 Nitrates in water

The results of nitrate analysis in water samples are shown in the table below. (see Table 2)

Table 2: Nitrate concentration in individual water samples

The water sample number	The concentration of nitrates NO ₃ ⁻ [mg/L]
1	20
2	10
3	10
4	10
5	1
6	20
7	20
8	5
9	5
10	1
11	30

The analyses' results indicate that least nitrates were present in sample 5 – the well v Mladinskem zdravilišču Debeli rtič and sample 10 – the well Ivančičeva ulica; namely, the concentration was 1 mg/L. The largest concentration was determined in sample 11 – the stream Ivančičeva ulica. In other samples, the nitrate concentration was 10 mg/L or 20 mg/L. According to Rules on drinking water, the limit value for nitrate is 50 mg/L.

2. 5. 2 Nitrites in water

The results of nitrite analysis in water samples are presented in the following diagram:

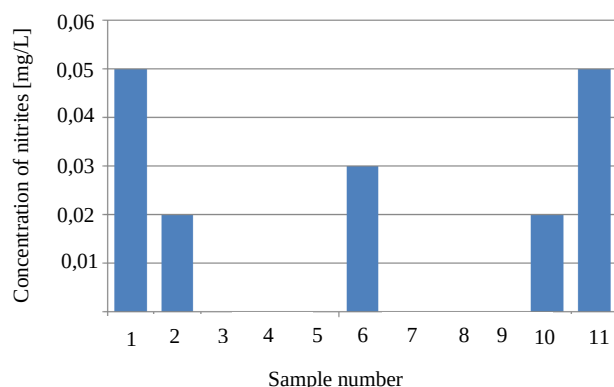


Fig. 2 Nitrite concentration in individual water samples

The results of analyses show very low nitrite concentrations in all samples. In more than half the samples, nitrites were not even registered, while in the rest of the samples concentrations did not exceed 0,05 mg/L. In Rules on drinking water, the limit value determined for nitrite is 0,50 mg/L.(see fig. 2)

2. 5. 3 Ammonium ion in water

The results of the analyses determining ammonium ion in water samples are shown in the table below. (see Table 3)

Table 3: Ammonium ion concentration in individual water samples

The water sample number	The concentration of ammonium ion NH ₄ ⁺ [mg/L]
1	0,2
2	0,2
3	0,1
4	0,1
5	0,1
6	0,1
7	0,1
8	0,1
9	0
10	0,1
11	0

The results of analyses point to the absence of any ammonium ions in sample 9 – the well in the Jadranska ulica as well as sample 11 – the stream in the Ivančičeva ulica. In the remaining nine samples, the determined ammonium ion concentration was 0,1 mg/L and 0,2 mg/L respectively. Rules on drinking water list ammonium ion among indicator parameters, with the limit value of 0.50 mg/l.

2. 5. 4 Results of microbiological analyses

The results of microbiological analyses are presented in the below table. (see Table 4)

Table 4: Results of microbiological analyses

Sample	Parameter				
	Coliform bacteria CFU/ 100mL	Escherichia coli CFU/ 100mL	Enterococci CFU/ 100mL	Total bacteria count at 37°C CFU/ mL	Total bacteria count at 22°C CFU/ mL
1	>100	>100	>100	>300	/
2	>100	>100	>100	>300	/
3	>100	>100	>100	>300	/
4	>100	10	13	>300	/
5	>100	30	24	>300	> 300
6	>100	>100	>100	>300	/
7	>100	20	10	>300	/
8	>100	40	26	>300	/
9	20	/	found	>300	> 300
10	20	/	found	>300	> 300
11	>100	20	>100	>300	/

The results of microbiological analyses indicate that all the examined water samples contain coliform bacteria. Nine of the samples contain also *Escherichia coli*, with the exception of sample 9 – the well in the Jadranska cesta and sample 10 – the well in the Ivančičeva ulica. The total number of microorganisms at 37 °C in all samples exceeded the value 300. According to Rules on drinking water, the prescribed limit value for *E. coli* in drinking water is: 0/100 mL, for enterococci it is: 0/100 mL, for the number of colonies at 22°C it is: less than 100/mL, and for the number of colonies at 37°C it is: less than 100/mL.

3. Discussion and conclusion

The experiments done showed us the following:

- The concentration of nitrates and nitrites does not exceed their limit values in any of the analysed water samples (it is less than 50 mg/L in the case of nitrates and less than 0,50 mg/L in the case of nitrites), which confirms hypothesis 1 (*Nitrates and nitrites do not exceed limit values*).

- The values of microbiological parameters in wells are similar to those in streams, which falsifies hypothesis 2 (*The values of microbiological parameters are lower in wells than in streams*.) We can thus infer that the wells from which we took samples are in contact with surface water. As the local households are supplied with drinking water of the Rižana water supply system, the water from the wells is not used for drinking any longer. This is the reason why their owners do not bother with their maintenance (burst water pipes, pollution with faeces).

- The values of chemical parameters do not exceed the limit values for potable water, while microbiological analyses showed that no water from these sources is fit for drinking. We thus refuted hypothesis 3 (*The water from wells is suitable for drinking as regards chemical and microbiological parameters*).

Research activity at all levels of education has recently become very important. Research makes it possible for students to understand natural sciences concepts through direct hands-on experience with materials, objects or other living beings, through consulting books, other sources and experts, as well as through continuous argumentation and exchange of opinions. Students are supervised and mentored through the process by the teacher. Research is also a goal that leads students towards grasping the nature of science and discovering how natural sciences work.

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