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TMA EXPLOITATION INDICATORS FOR MECHANIZED DRILLING OF PITS FOR PLANTING FRUIT

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Abstract: *Performing works with the land where a lot of mechanical work is engaged, such as making pits for planting fruit, needs to be mechanized. This replaces human labour with a tractor-machine aggregate with an increase in productivity and thus makes the process cheaper. For the proper selection of individual means of mechanization, it is important to determine the optimal agrotechnical parameters of their application. Proper selection and use of mechanization tools for planting have a decisive influence on the intensity and progress in cultivation technology. Defining energy and exploitation parameters of tractor-machine aggregates during mechanized construction of pits is the subject of this research. The pits are intended for individual planting of fruit seedlings as well as the installation of trellis poles. The test results of the tractor-machine aggregate show that the lowest driving force engaged for drilling was achieved in the field and was 6.36 kW for the excavated pit with the depth of 885 mm and with a diameter of 520 mm, the number of revolutions of the drill was 93 rpm and drilling was achieved in 27 s. The highest driving force for drilling was engaged in field III, which was 30.8 kW for the excavated pit 780 mm deep with a diameter of 490 mm, the number of revolutions of the drill bit was 111 rpm and drilling was realized in 30 s. The results obtained in these tests show that the consumption of motor power largely depends on the type of soil, the quality of previous soil preparations and the number of revolutions of the tractor PTO shaft. The time required to move the aggregate from one to the next drilling site is crucially influenced by the terrain configuration, the state of soil preparation and the skill of the tractor driver and auxiliary worker.*

Keywords*:* *tractor-machine aggregate, hole drill, spiral drill, aggregate productivity, exploitation parameters*

1. INTRODUCTION

Establishing good-quality perennial crop plants also implies rational engagement of human labor and machinery means. Soil preparation and the very process of raising plants is a complex and elaborated work that requires a great deal of mechanical work. When raising perennial crop plants, digging holes, as a basic operation, includes the greatest part of the human and machinery work. Mechanization of this process is most often achieved with a tractor unit, consisting of a tractor equipped with a connecting machine whose element is in the form of one or more helical drills. For machines with one helical drill that is aggregated with light tractors of up to 24 kW, the unit can be operated by only one worker [16]. Labor costs for this operation depend on the quality of soil preparation during pre-tillage. Great mechanical and human work is engaged to perform these works [5]. In areas of arid climate where irrigation is not present, the plantings or the planting should be performed in autumn in order to achieve the best possible effect of receiving planting material. For these fruit growing conditions, it is necessary to perform quality basic and additional tillage [15] in order to sufficiently accumulate and rationally consume soil moisture.

The process of excavating holes for planting represents the cultivation of the soil at greater depths, due to which over two thirds of the total energy consumed during planting is spent on drilling holes [16]. Pre-tillage has the greatest influence on the use of machine work as well as on the total engagement of energy when drilling holes [14]. In addition, it has a great influence on the use of machinery [13] in the formation and exploitation of land and infrastructure.Modernization of the fruit growing technology is primarily related to the implementation of new techniques and machinery in the production process, regardless of the fruit species [11].

The use of appropriate technical means in raising crop plants enables cost reduction and ecological preservation of land [2]. The development of agricultural techniques, and especially information and communication technologies, have significantly improved agricultural machinery [9]. The transition from conventional to new technological procedures in primary production should be achieved gradually [6], using scientific and professional knowledge. By choosing technological procedures and adequate machinery, it is possible to achieve greater economic and energy efficiency [8], while preserving the environment and land.

The obtained results in specific production conditions [9], indicate the possibility of energy savings and increase the productivity of aggregates in works with the soil.

The transition from conventional tillage to reduced tillage [7] imposes the need for better quality in deeper planting in order to achieve the best possible rooting and development of plants. And especially with the introduction of zero tillage, in order to reduce soil degradation in productive soils [3] and [4], it imposes the need to achieve quality shaking of the soil in the zone of the root system by making holes. Some experience in practice shows [1] that when drilling holes, the speed of the drill should be 60-70rpm, where one hole takes 30-40 seconds, which is 90-120 holes per hour, which multiplies productivity. The development of technology [10], and especially information and communication technologies, have significantly improved agricultural mechanization.

2. MATERIAL AND METHODS

Testing of the tractor drill, product of the company "Lemind Proleter" Leskovac, was performed according to the methodology of the Institute for Mechanization of the Faculty of Agriculture - Zemun, using laboratory-field and operational tests, whereby the functionality, properties and quality of this machine were determined throughout the all test phases. Field tests were performed on the test field "Radmilovac" of the Faculty of Agriculture on undulating terrain, at an altitude of about 71m. The geographical position of the crop plants was determined by the moderate continental climate, and the dominant type of soil was the brown soil [13] with certain varieties and the occasional appearance of degraded chernozem. Soil moisture was very low, as the test was performed during the dry season. The drill was tested in a unit with an IMR 65 tractor.

Technical characteristics of the drill

Mode of aggregation with the tractor...................................... in three points

Maximum drilling depth.. 1100mm

Working tools.. spiral drill

Maximum drill diameter.. 800mm

Worm gearbox with gear ratio... i = 1 : 6,3

Mass.. 132kg

Basic technical characteristics of the Rakvica 65 tractor important for the operation of the drill:

Nominal power (at 2300 min^{-1} of the motor)........................ 47kW

Minimum specific fuel consumption.................................... 234g/kWh

Maximum engine torque (at 1350 min^{-1}).............................. 217,5 Nm

Mass without ballast.. 2600kg

Length with weights on the front axle.................................. 3420mm

Width.. 1900mm

Height up to top of the muffler... 2300mm

Distance between front and rear axles.................................. 2050mm

Torque on PTO shaft.. Nm

During the operational tests under certain working conditions, indicators were taken such as: chronography of working hours, time required for drilling one hole, time for transition of the unit from one to another drilling position at intervals of 6x6m, depth, diameter, hole filling, fuel consumption, performance or number of holes drilled in 1 hour of gross, net and actual working time. The determination of the engaged tractor engine speed was performed according to the formula:

$$N = \frac{M_O \cdot n_p}{1323{,}8}\ [kW]$$

where: M_o - torque measured on the PTO shaft; n_p- PTO’s number of revolutions.

In addition to all this, during the testing, observations were made about the suitability of the drill for handling, adaptation to various field conditions, the strength of the structure itself, safety at work, etc.

In the laboratory-field tests, in addition to other parameters, the motor power consumption of the tractor for drilling holes on 4 differently treated terrains and at different number of revolutions of the tractor PTO shaft was determined.

Fig. 1 test preparation unit
and speed sensor"

Fig. 2 Position "Torque
DMN 10 in the unit

Fig. 3 Unit of measure with display

Fig. 3 The drilling process

Table 1. Type of terrain depending on the method of cultivation

Terrain code	Pre-tillage	Soil moisture up to [%]	Terrain configuration
a. In laboratory-field tests			
I	Plowing to a depth of 28 cm. Additional tillage performed well	7,1	Not expressed
II	Not performed (wasteland)	8,2	-
III	Plowing to a depth of 28 cm. Additional tillage not performed	9,1	Micro relief expressed as a consequence of poor tillage
IV	Not performed (wasteland)	8,3	-
b. In exploitation tests			
I	Deep plowing at depths up to 600cm. Additional tillage performed	12,3	Not expressed
II	Deep plowing at depths up to 60 cm. Additional tillage is not performed well	10,5	Micro relief expressed as a consequence of poor tillage
III	Plowing to a depth of 30 cm. Incomplete additional tillage	11,8	Micro relief uneven
IV	Plowing twice at 20 and 30cm depth. Additional tillage performed well	12,5	Microrelief partially expressed
V	Not done (plot with uncut stumps)	13,8	-

To measure the resistance and number of revolutions of the drill, the “Torque and RPM sensor” DMN 10 was used, which was mounted directly on the tractor shaft and on which a cardan shaft was mounted to drive the drill. The value of the torque expressed in Nm and the number of revolutions in rpm are read directly on the display of the unit. Registration of the tractor PTO speed of the readings on the "tracometer" of the control panel. Duration time in the experiments was measured using a stopwatch.

3. RESULTS AND DISCUSSION

3.1. Technological process of drill operation

The practical procedure of the work with the drill is as follows:

- positioning the tractor in such a position that the tip of the drill comes exactly above the marked place for drilling,

- moving the drill backwards by 3 to 5^o from the vertical position, which best ensures vertical drilling of holes,

- activating the coupling of the tractor's PTO shaft and putting the drill into operation,

- easy movement of the hydraulic lift lever of the tractor and lowering the drill to the working position.

By lowering the drill put into operation, it begins to penetrate the soil, during which the cutter blades cut off the layers of soil and the spiral accepts them and throws them to the surface of the soil around the hole.

There are two ways to drill holes: single-phase and multi-phase. In the multi-phase mode, when the drill reaches half the depth of the hole, by acting on the handle of the hydraulic lift lever of the tractor, the drill rises and throws around the hole all the soil that was caught by the spiral. After that, by lowering the hydraulic lift lever, the drill is lowered into the hole again. In the field conditions of compact soils, this way of working is recommended, but it requires a more experienced and trained tractor driver. In the single-phase mode, which is recommended for lighter terrains and lands, the work is done in one go. As soon as the drill reaches a certain depth, by acting on the handle of the hydraulic lift lever of the tractor, it rises and spirals out the rest

3.2. Results of the laboratory-field tests

- *3.2.1. Motor power input for drill operation*

The results obtained in these tests are shown in Table 2. The required motor power largely depends on the type of soil, the quality of pre-tillage and the number of revolutions of the tractor's PTO shaft.

Tests in the field have shown that the engine power consumption of the tractor ranges from 5,08 to 8,94kW. In this field, the tractor engine was running at 1000, 1500 and 1800rpm. In experiments on the fields II, III, and IV, the measurement of engine power consumption was performed at 1890rpm of the PTO shaft.

The results presented in Table 1, show that the power consumption of tractors on field II ranges from 21,12 to 22,58 kW, on field III from 23.65 to 25,59kW, on field IV from 21,98 to 23,05 kW, where also an overload of the tractor engine occurred. Based on that, it can be stated that a tractor with an engine power over 30kW is needed to work on drilling the holes in insufficiently cultivated or uncultivated terrain. For medium and easily arable and well-prepared soils, the IMT-533 tractor or the Fe-35 tractor, which belong to the category of light tractors, can be used reliably.

In this way, the quality of drill operation in these conditions is the best. When the drilling of one hole is final, the coupling of the tractor drive shaft is disconnected and it is moved to the next drilling site.

Table 2. Test results of tractor aggregate In laboratory-field tests

No.	Drilling time per hole [s]	Hole depth [cm]	Hole diameter [cm]	Number of revolutions on the tractor's PTO shaft [o/min]	Drill speed [o/min]	PTO torque [Nm]	Power required to drive the drill. [kW]
Ground I							
1	22	85,6	51,0	716	113	16,53	8,94
2	24	76,9	51,2	716	113	13,77	7,45
3	24	81,9	50,0	540	86	16,20	6,61
4	19	76,5	52,0	540	86	16,00	6,53
5	28	90,1	51,7	360	57	20,63	5,61
6	27	88,4	52,0	360	57	18,68	5,08
Ground II							
1	47	85,6	48,5	716	113	40,52	21,92
2	44	78,8	49,5	716	113	39,05	21,12
3	59	77,5	49,6	590	93	50,66	22,58
Ground III							
1	30	78,0	49,0	700	111	48,39	25,59
2	29	75,0	49,8	719	114	43,54	23,65
Ground IV							
1	33	80,0	48,8	625	115	46,55	21,98
2	57	82,0	50,0	565	89	53,37	22,78
3	63	90,0	50,0	575	91	53,07	23,05

- *3.2.2. Quality of drilled holes*

Analyzing the basic criteria, a tractor drill gives a satisfactory quality of drilled holes. They are vertically well oriented in the soil, are usually circular in shape and relatively clean, which in this case corresponds to agro-technical requirements. In Table 1, the basic parameters are given, which show that the depths of the holes are in the range from 75 to 92cm, the diameters from 48.5 to 52.0cm, soil scattering is relatively small and ranges from 6.6 to 36.2%. There was a higher degree of soil scattering somewhere, primarily due to the unsuitable number of revolutions of the drill, then due to poor pre-tillage, insufficient cleaning of the veins, the degree of humidity, terrain configuration, training of the tractor driver, etc.

The number of revolutions of the drill is crucial when drilling holes. On filed I at 113rpm the soil scattering is only 8.8%, and at 86rpm the soil scattering suddenly increases and climbs to 22.0%, while at 57rpm the soil scattering increases even more and amounts to 36.2%. This is explained by the fact that at a higher number of revolutions, due to the action of centrifugal force, its spiral completely throws the soil from the hole and better scatters it around at the surface, as well as by the fact that the drill drills the holes more compactly. Poor pre-tillage of the land and insufficient clearing of veins, caused in some fields the soil scattering problem which ranged from 14 to 36%. On well-prepared and cleared soils, and at higher humidity (from 17 to 20%), soil scattering is the lowest in percentage.

Table 3. Quality and chronography of aggregate operation during machine drilling of pits

Quality of excavated holes			Unit performance during operation with 6x6m hole arrangement					
Soil scattering		Raised land above the hole cm	hour of gross work		hour of actual work		hour of actual work	
Depth cm	From the depth of %		Pieces	ha	Pieces	ha	Pieces	ha
16,4	13,7	15,8	69,9	0,25	90,0	0,32	156,0	0,56
37,2	32,7	21,7	35,7	0,13	60,0	0,21	100,0	0,35
21,5	19,7	19,9	55,4	0,20	74,5	0,26	130,0	0,46
12,9	12,9	23,9	43,6	0,15	56,7	0,20	82,1	0,29
16,0	19,7	24,0	40,8	0,14	49,8	0,18	75,8	0,27
11,0	11,1	22,6	56,5	0,20	80,2	0,28	135,1	0,48

3.3. Operational tests

These tests were performed under the conditions set out in Table 1. The drill in the unit with the IMR-65 tractor worked for 5 days, of which 2 days with a drill 130cm long and 3 days with a drill 110cm long. During these tests, in addition to the tractor driver, an auxiliary worker also joined the test, and his task was, in cases of drill congestion, to eliminate the delay as soon as possible.

At the time of these tests, the tractor engine was running at 1500 to 1900rpm, at which mode the best quality of holes was obtained. The results achieved in these operational tests are presented in Table 3.

- *3.3.1. The effect of the unit at work*

Determining the performance and thus the productivity of units on individual terrains was obtained on the basis of performed chronographies that had the time structures shown through the examples in Tables 4 and 5. From the results shown in Table 3, it can be seen that the average time required to drill a hole in different terrains is from 23.0 to 47.9s. The least time spent on this was in field I, and the biggest in field IV. The lowest amount of time was achieved on the deep plowed soil at a depth of up to 60 cm, and the highest on the ground that was plowed at a depth of 30 cm. After this depth of 30cm, the drill found a very hard layer of earth, which is why the time spent on drilling holes was higher. The highest work performance was achieved in field I, and the lowest in fields II and IV. The work performance ranged on average from 35.7 to 69.6 holes for 1 hour of gross working time, 49.8 to 90.0 of net and 75,8 to 115.0 for 1 hour of actual work.

On field III, due to soil scattering, they resorted to removing the "plug", i.e., raising the drill at the moment when it reaches the desired depth with its tip, during which the stuck mass of soil is taken out together with the drill bit, so that it remains clean and with compact walls.

The time required to move the unit from one to the next drilling site is also a significant factor in achieving the effect of the machine drilling of holes. This time ranges from 16.6 to 24.7s with a spacing of 6x6m of planting. This was influenced by: the configuration of the terrain, the state of soil after the pre-tillage and the competence of the tractor driver and auxiliary worker.

According to all the above, the machine drilling of holes for seedlings is economically completely justified and should therefore be applied in practice wherever there are conditions for it.

Table 4. Time structure when drilling holes with a tractor drill in the field

Elements of working time	Utilization of working time			
	In total *[min]*	Share *[%]*	Average machine work per hole *[min]*	Average human labor per hole *[min]*
1. Production	**389**	**81,0**	**0,81**	**1,62**
1.1. Productive drilling	143	29,8	0,35	0,70
1.2. Non-productive				
a) Moving the unit	227	47,3	0,42	0,84
b) Turning the unit in furrows	19	3,9	0,04	0,08
2. Non-productive	**65**	**13,5**	**0,13**	**0,26**
2.1. Preparations	35	7,3	0,07	0,14
2.2. Rest	30	6,2	0,06	0,12
Losses	**26**	**5,4**	**0,05**	**0,10**
3.1. Delay for improper installation of the drill	14	2,5	0,02	0,04
3. 2. Defect on the unit	12	2,9	0,03	0,03
In total	**480**	**100**	**0,99**	**1,98**

- *3.3.2. Tractor fuel consumption in the unit*

The basic parameters that affect fuel consumption are the condition of the terrain, which is defined by the type of soil on which the specific resistances depend and their impact on the value of torque that should be overcome by the drill during operation. The value of resistance is crucial for the intensity of mechanical tillage of the soil, the presence of stumps, veins and other foreign bodies in the soil. Fuel consumption per unit time also depends on the performance of the unit, i.e. the active time during which drilling is performed, which is influenced by the speed of revolutions of the PTO shaft, which is reflected through defined engagement of drilling power. When defining fuel consumption per excavated hole, the direct effect has the performance that depends, in addition to the mentioned conditions, on the terrain relief, the speed of moving the unit, the training of the operator, the reliability of the unit, etc. In the performed experiments, the fuel consumption also changed in accordance with the mentioned parameters, because it was the lowest in field I and amounted to 8.76kg/ha and the highest was in field IV, where the consumption went up to 17.26kg/ha. The almost double fuel consumption per unit of working time, when drilling holes in field IV, is explained by the fact that the land is a wasteland or uncultivated.

Table 5. Time structure when drilling holes with a tractor drill in the field II

Elements of working time	Utilization of working time			
	In total *[min]*	Share *[%]*	Average machine work per hole *[min]*	Average human labor per hole *[min]*
1. Production	**389**	**81,1**	**1,6**	**2,82**
1.1. Productive drilling	168	35,0	0,94	1,70
1.2. Non-productive				
a) Moving the unit	203	42,2	0,52	0,94
b) Turning the unit in furrows	19	3,9	0,14	0,18
2. Non-productive	**65**	**13,4**	**0,13**	**0,26**
2.1. Preparations	35	7,3	0,07	0,14
2.2. Rest	30	6,2	0,06	0,12
Losses	**26**	**5,5**	**0,07**	**0,10**
3.1. Delay for improper installation of the drill	14	2,9	0,04	0,06
3. 2. Defect on the unit	12	2,6	0,03	0,04
In total	**480**	**100**	**1,8**	**3,18**

4. CONCLUSIONS

Using the established facts based on the performed tests, the following conclusions can be made:

- The manual work in the process of making holes for planting perennial crop plants as well as setting the trellis pillars should be completely replaced by machinery work:
- The quality achieved by mechanized drilling of holes satisfies agro-technical requirements and is therefore better in relation to manual work, especially when it comes to holes of greater depth.
- The productivity of mechanized drilling is 15 to 20 times higher than manual excavation.

- From an economic point of view, this way of drilling holes is multi-faceted, because in addition to better quality, it brings savings of 11.5 to 41.8 per hole.
- Handling and working with this drill is much simpler and does not require greater technical knowledge, but only a little more training and competence of the tractor driver.
- As a drive unit, tractors with simple equipment can be used, where the presence of a shaft is required, as well as tractors of lower power

In addition to the above, in order to achieve the highest possible quality of drilled holes, which is reflected in the lowest possible soil scattering during drilling in heavy and poorly prepared soils, a multi-phase method should be applied with more frequent removing and lowering of the drill into the soil.

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