

OPTIMIZING THE EXPLOITATION OF AGRICULTURAL SYSTEM TRACTOR-DIGGING SOIL MACHINE FOR PREPARING THE GERMINATION BED IN GREENHOUSES

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Abstract: *In this paper we study the theoretical and experimental possibility for improving the exploitation indicators of the agricultural system formed by the U 455L tractor and the MSS-1.40 soil digging machine, at preparing the germination bed in greenhouse work. The coefficients of: work trips, working time management, specific road and work capacity were analyzed for two movement variants in a standard greenhouse. The experimental researches were made in the greenhouses of FAREL IMPEX SRL vegetable farm from Acăţari in Mureş County. The exploitation indicators of this agricultural system were better in the case of moving method with long turns.*

Key words: *greenhouse, germination bed, exploitation indicators, optimization.*

1. Introduction

The exploitation indicators for the agricultural system of the germination bed in greenhouses' preparation characterize the movement methods' efficiency in the greenhouse area. The optimization of exploitation indicators is connected to the cinematic optimization of the agricultural system in greenhouses [4].

During work, the soil working tractor-machine agricultural system covers important distances for soil preparation, makes turns at the sections' limit and moves from a lot to another inside the farm. The movement of the working organs in transport position is considered lair movement and represents unproductive

time, therefore research is made so that in exploitation, this time be as reduced as possible [1].

In greenhouses the lair movements are influenced by: the agricultural system turning radius, the turn's type at the lots' limit and the lots' dimension.

The turning radius R_i of the agricultural system formed of the wheel tractor and the worn machine is determined with the relation:

$$R_i = L \cdot \operatorname{ctg} \alpha + \frac{A}{2} \text{ [m]}, \quad (1)$$

where: L is the tractor wheelbase, in [m]; A - the tractor gauge, in [m]; α - the turning angle (Figure 1).

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The sweeping radius R_m is determined with the relation:

$$R_m = \sqrt{R_i^2 + L_m^2} \quad [\text{m}], \quad (2)$$

where: L_m is the distance from the center of the motor tractor wheel to the machine dimension extreme point on the longitudinal direction, in [m].

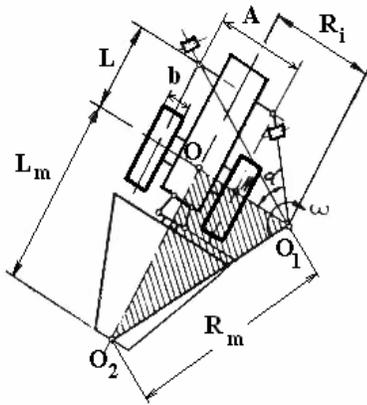


Fig. 1. The turning scheme of the agricultural system with worn machine

The turning type is determined by the working condition and by the agricultural system constructive characteristics. In greenhouses the turning strip width is of 3 m. Because it is narrow, the turnings are complicated because of the existence of pillars that the machines can often hit. For these reasons choosing the turning type requires much discernment. In greenhouses the 180° turns are applied, with the change of moving direction, with crossed loop (Figure 2), but also 90° turns without crossed loop [2].

The length of road spaced by the agricultural systems for turns at lot limit is calculated with the help of the minimum turning radius R_i , according to the relations:

$$L_{i180} = 2 \cdot C_1 \cdot R_i \quad [\text{m}], \quad (3)$$

and

$$L_{i90} = C_2 \cdot R_i \quad [\text{m}], \quad (4)$$

where: C_1 is the multiplication coefficient of the minimum turning radius in case of turning with the change of movement direction, $C_1 = 2.5 \dots 3.5$; C_2 - the multiplication coefficient of the minimum turning radius in the case of 90° turn without loop, $C_2 = 1.6 \dots 1.8$.

2. Material and Method

2.1. Theoretical Research of the Exploitation Indicators

The theoretical study of the agricultural system cinematic for preparing the germination bed is made for a bloc greenhouse with the following constructive characteristics: length - 160 m, width - 63 m, 50 - lots (one lot dimension: 63x3.2 m²). On each lot there are 21 bays.

The bloc greenhouse has a moving alley through its center (Figure 2). The movement of tractor-soil digging machine system in greenhouses is made according to the scheme presented in Figure 2. The tractor enters the protected area alley, afterwards it enters backwards in the right part of the first lot, and then it follows the cinematic indicated by the arrows.

The turns are made with the change of the moving direction, because the pillars of the protection area will not be hit when cornering.

Two moving methods of the agricultural system during germination bed preparing work in greenhouses, which are presented in Figure 2a and 2b are analyzed. In case of Figure 2, a cinematic, the agricultural system turns at lot limit by going round the greenhouse pillar on a longer trajectory. In the cinematic presented in Figure 2b, the turns are made closer to the greenhouse pillars, the lair movement distance being shorter.

According to the representation form Figure 2, for both movement methods there

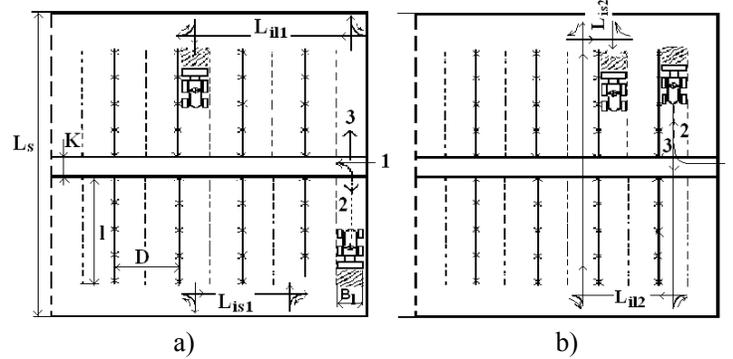


Fig. 2. Tractor-soil digging machine system cinematic in greenhouses:
a) long trajectory; b) short trajectory

is a turning method with long L_{il} and short L_{is} distance in changing movement direction.

The exploitation indicators of tractor-soil digging machine system for preparing the germination bed in greenhouses are [3]:

- working movement coefficient;
- specific working road coefficient;
- used time coefficients;
- working productivity coefficient.

Working movement coefficient of the agricultural system is a parameter which appreciates the movement methods efficiency. As the value of the working movement coefficient approaches 1, the movement and the turning method are more efficient. The optimal values are situated between 0.9...0.95.

$$S_g = (N - 1) \cdot L_{il} + (N - 2) \cdot L_{is} + 8 \cdot L_{t90} + 2 \cdot N \cdot K + 2 \cdot l \quad [\text{m}]. \quad (7)$$

The notations in relations (6) and (7) correspond to those from Figure 2 and have the following significations: N is the number of worked lots; l - the effective worked distance, in [m]; D - the width of one lot, in [m]; L_{il} - the length of the covered distance for a long turn, in [m];

This coefficient is calculated with the relation [5]:

$$v = \frac{S_l}{S_g + S_l}, \quad (5)$$

where the notations have the following significations: v is the working movement coefficient; S_l - distance covered during work movement by the agricultural system, in [m]; S_g - distance covered during lair movement by the agricultural system, in [m].

The values of the work and lair movement distances are calculated with the relations:

$$S_l = 2 \cdot 2 \cdot N \cdot l + 4 \cdot N \cdot D \quad [\text{m}], \quad (6)$$

L_{is} - the length of the covered distance for a short turn, in [m]; L_{t90} - the turning length of 90°, in [m]; K - the alley width, in [m].

The turning length in case of the agricultural system cinematic presented in Figure 2a is calculated with the relations:

$$L_{il} = 2 \cdot C_1 \cdot R_i + \left[3 \cdot D - 2 \cdot \left(\frac{B_m}{2} + S_{prot} \right) \right] \quad [\text{m}], \quad (8)$$

$$L_{is1} = 2 \cdot C_1 \cdot R_i + \left[2 \cdot D - 2 \cdot \left(\frac{B_m}{2} + S_{prot} \right) \right] \quad [\text{m}]. \quad (9)$$

The turning length in case of the agricultural system cinematic presented in Figure 2b is calculated with the relations (10) and (11):

$$L_{il2} = 2 \cdot C_1 \cdot R_i + \left[D + 2 \cdot \left(\frac{B_m}{2} + S_{prot} \right) \right] \text{ [m];} \quad (10)$$

$$L_{is2} = 2 \cdot C_1 \cdot R + 2 \cdot \left(\frac{B_m}{2} + S_{prot} \right) \text{ [m],} \quad (11)$$

where: B_m is the working width of the soil working machine, in [m]; S_{prot} - the width of the pillar protection area, in [m]; R_i - the minimum turning radius, in [m].

Turnings of 90° without loop are executed at soil working in the turning area, their length is calculated with relation (4).

The specific working road is the coefficient that highlights the length of the

covered road at worked surface unit. It is calculated with the formula:

$$\gamma = \frac{S_l + S_g}{N \cdot D \cdot L_s} \text{ [m/m}^2\text{]}, \quad (12)$$

where the notations correspond to those from Figure 2 and have the following significations: L_s - greenhouse width, in [m]; S_l - distance covered during work movement by the agricultural system, in [m]; S_g - distance covered during lair movement by the agricultural system, in [m].

Table 1
Calculus elements for the mathematical model of the exploitation indicators in greenhouses

Constructive elements		Calculated elements		
l , [m]	27		Long trajectory	Short trajectory
D , [m]	3.2	C_1	3.5	
K , [m]	3	C_2	1.8	
S_{prot} , [m]	0.2	Long turns of 180° , [m]	$L_{il1} = 30.2$	$L_{il2} = 27.4$
N	9	Short turns of 180° , [m]	$L_{is1} = 27$	$L_{is2} = 24.2$
B_m	1.4	Turns of 90° , [m]	$L_{r90} = 5.8$	
R_i , [m]	3.2	S_g , [m]	585	543
L_s , [m]	63	S_l , [m]	1087.2	1087.2
Exploitation indicators				
Working movement coefficient			0.65	0.67
Specific working road coefficient, m/m²			0.92	0.90

The theoretical study of the working movement and specific working road coefficients for the two movement methods of the agricultural system for preparing the germination bed in the bloc greenhouse are presented in Table 1. The calculus elements and the value of the exploitation indicators are calculated with the mathematical relations (5) and (12) for the case of soil preparing in 9 lots.

Working movement coefficients are more favorable as they are approaching the value of 1. The calculated values for the real cases presented in Table 1 do not fall in the optimal values interval of 0.90...0.95. Distance covered during lair movement at turns is bigger comparing to the distance covered during work.

The exploitation coefficients theoretically studied presents improvements in the case

of the moving method with shorter turning trajectory, but there is danger of touching the pillars during turns.

Used time coefficients characterize the working process through the machine

construction and driver skill [7]. Their calculation is made with the help of working time elements presented in Table 2.

Used time coefficients are more favorable as they approach the 1 value.

Used time coefficients for preparing the germination bed in greenhouses Table 2

	Definitions	Relations/Notations
Worked time elements	Work time, [min]	T_1 base time
	Time belonging to the base time, [min]	$T_2 = T_i + T_g$ secondary time
	Turnings time, [min]	T_i
	Alley crossing time + lair movement time, [min]	T_g
	Productive time, [min]	$T_{01} = T_1 + T_2$
	Maintenance works time, [min]	T_3
	Total work time, [min]	$T_{02} = T_1 + T_2 + T_3$
Exploitation indicators		
Used productive time working coefficient		$K_{01} = T_1/T_{01}$
Total used time working coefficient		$K_{02} = T_1/T_{02}$

Working capacity of the agricultural system for preparing works of the germination bed in greenhouses Table 3

	Definitions	Notations/Relations
Working capacity	Working capacity in the base time, [m ² /h]	$W_1 = 60 \cdot S_1 \cdot B_m/T_1$
	Working capacity in the production time, [m ² /h]	$W_{01} = 60 \cdot S_1 \cdot B_m/T_{01}$
	Working capacity in a hour , [ha/h]	$W_h = 600000 \cdot S_1 \cdot B_m/T_{02}$
	Working capacity in a shift $t_{shf} = 8$ h, [ha/shf]	$W_{shf} = 600000 \cdot S_1 \cdot B_m \cdot t_{shf}/T_{02}$

For different works these coefficients have values between: 0.75...0.78 for plowing aggregates; 0.70...0.90 for harrowing aggregates; 0.70...0.80 for fertilizer aggregates; 0.45...0.60 for harvesting aggregates [3].

Working productivity is the indicator which expresses the working volume made by an agricultural system in a time unit (hour or change). Working capacity at simple mobile agricultural works is calculated with the relations presented in Table 3.

For increasing the agricultural system work capacity it is necessary to meet the following requirements:

- complete use of the total working time for each shift;

- superior organization of technical maintenance for working process and equipments.

2.1. Theoretical Research of the Exploitation Indicators

Working methodology regarding research of the exploitation indicators for germination bed preparing machinery in greenhouses is presented in Figure 3 [6].

The determination of the used time coefficients and working productivity coefficient for the agricultural system for germination bed preparation was made in FAREL IMPEX S.R.L vegetable farm greenhouses from Acățari, Mureș County. The cinematic of the agricultural system

formed from U-445L tractor and MSS-1.40 soil digging machine was observed. The greenhouse dimensions were: 60 m length; 63 m width; 50 lots; 63x3.2 m² one lot area; 21 bays on one lot.

Time measurement was made through

timing: effective works, turnings, alley crossing, machinery maintenance and lair movement, in two movement variants, specified above and named in this work: long cinematic variant and short cinematic variant.

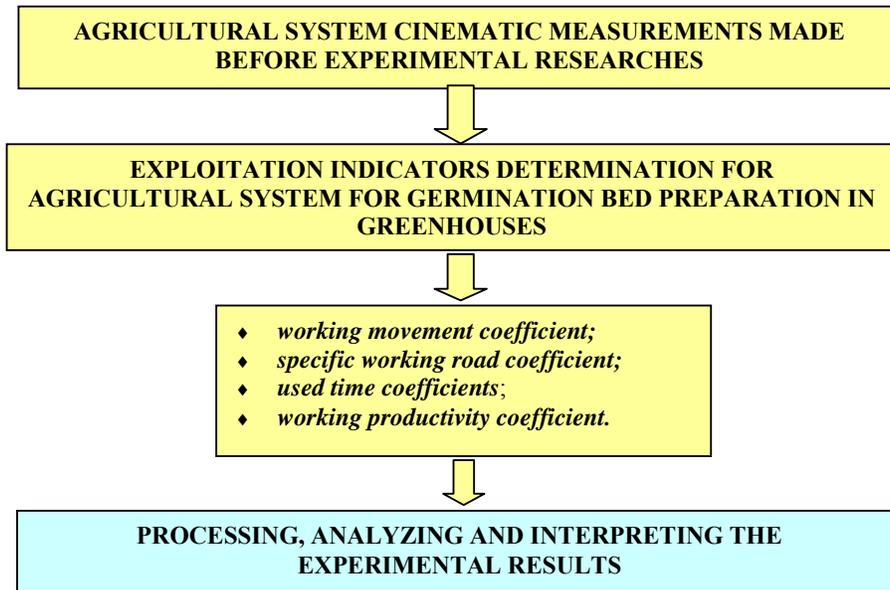


Fig. 3. *Experimental researches methodic regarding the exploitation indicators of the germination bed preparing machinery in greenhouses*

3. Results and Discussions

The measured and calculated working time elements for germination bed preparation in

greenhouses with MSS-1.40 soil digging machine are presented in Table 4.

Working time elements served for calculating the used working time and

Table 4

Measured and calculated working time elements for germination bed preparation in greenhouses with MSS-1.40 soil digging machine

Notations		Long cinematic		Short cinematic	
		Measured values	Calculated values	Measured values	Calculated values
		N = 9 lots		N = 7 lots	
Working time elements	T_1 base time, [min]	74.5		68	
	T_2 secondary time, [min]	54		48	
	T_{01} production time, [min]		128.5		116
	T_3 maintenance time, [min]	15		25	
	T_{02} total work time, [min]		143.5		141

Exploitation indicators for MSS-1.40 soil digging machine in greenhouses Table 5

Notations/Relations	Long turns cinematic	Short turns cinematic
Real coefficient for the use of productive working time, $K_{01} = T_1/T_{01}$	0.580	0.585
Real coefficient for the use of total working time, $K_{02} = T_1/T_{02}$	0.519	0.482
Working capacity in base time, W_1 , [m ² /h]	1225.56	1042.52
Working capacity in production time, W_{01} , [m ² /h]	711.06	610.75
Working productivity in a hour, W_h , [m ² /h]	636.70	502.69

working productivity indicators for soil digging machine. These indicators are presented in Table 5.

The used time coefficient characterizes the working process due to machinery structure and to the operator's qualification. Their calculus is made with the help of time elements presented in Table 5.

Working productivity coefficient is the indicator which expresses the work volume realized by an agricultural system in a time unit. It is calculated with the formulas presented in Table 3 and the values presented in Table 5.

Exploitation indicators' variation, determined through experimental research, of the soil digging machine in the case of these two movement methods are presented in Figures 4 and 5.

4. Conclusions

- Used working time coefficients are favorable if they are approaching the value of 1. In case of germination bed preparation with the soil digging machine this coefficient does not fall in the optimal interval values of: 0.90...0.95, instead it is situated between 0.580...0.585. This fact is explained by frequent turns and crossing due to the construction and geometrics of greenhouses.

- The real coefficient for the use of productive working time, K_{01} , is higher in the case of short turns cinematic, but the real coefficient for the use of total working

time, K_{02} , is more favorable in the case of long turns cinematic. This is explained by the fact that at short turns cinematic the stops were more frequent, hence the maintenance time, because the agricultural system came very near the greenhouse pillars sometimes hitting them.

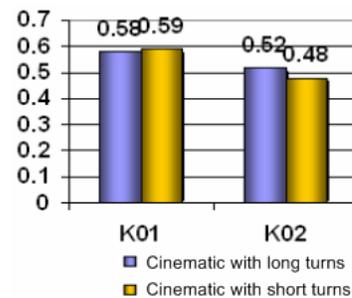


Fig. 4. Used working time coefficient variation during germination bed preparing in greenhouses with MSS-1.40 machine

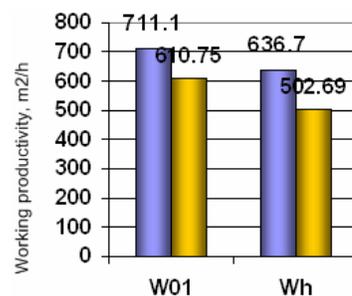


Fig. 5. Working productivity variation during germination bed preparing in greenhouses with MSS-1.40 machine

- Working capacity in production time, W_{01} and working productivity in an hour, Wh have more favorable values in the case of long turns cinematic (Figure 5).

- MSS-1.40 soil digging machine in greenhouses presents more favorable exploitation indicators in the case of long turns movement method.

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