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Determination of qualitative working indices of harrows with elastic fangs

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Abstract. In modern agriculture, grinding, levelling, loosening the soil surface layer and weed destruction, with application in the vegetable and technical crops sector, are carried out by a wide range of agricultural machines generically called harrows. These operations must be carried out by splitting on the natural lines of cohesion and not by hitting, cutting, compressing, breaking, when everything turns to dust. The paper presents the field tests for a harrow with elastic fangs in order to determine the following qualitative work indices: degree of soil grinding, degree of plant damage, degree of weed destruction, degree of levelling, working depth and operating energy indices for the maintenance of corn and sunflower crops.

1 Introduction

The mechanical processing of topsoil is one of the most important land preparation operations for the cultivation of future crops [1].

Equipment for the primary soil processing, such as ploughs, chisels, rippers, etc., are widely used, but don't produce adequate loosening and fragmentation of topsoil. Secondary processing tools are generally towed by agricultural tractors and can be divided into two main categories: passive and active equipment. Passive tools, such as harrows or vibratory cultivators, only fragment the soil by absorbing power from the tractor's drawbar, while the active equipment is additionally operated, by the tractor's power take-off [2, 3]. Active and passive secondary processing equipment have been shown to have similar soil fragmentation efficiency [4, 5, 19].

The main objectives of the harrowing work are to achieve the control of weeds, the incorporation of vegetable residues and organic manure to improve soil moisture and fragmentation [6, 7, 8].

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Harrowing work (tillage) has also been identified as one of the operations that requires high costs of resources and management, such as the need for high-power tractors that involve high fuel consumption [9].

In modern agriculture, aspects related to energy conversion and mechanical efficiency are very important, because most agricultural machinery manufacturers focus on streamlining their products by designing new optimized shapes and using innovative materials to reduce wear and fuel consumption [10].

From an economic and environmental point of view, soil tillage operations in modern agriculture are also mandatory [11, 12].

Thus, experimental researches were undertaken in order to highlight the importance of working stability for soil tillage aggregates, in terms of quality of work and fuel consumption [13, 14].

Studies have been conducted on the automation of harrowing work [15]. Experimental researches have also been conducted, focusing on the physical and mechanical properties of soil tillage aggregates in order to define what parameters influence the germination and emergence of future plants [16].

In order to obtain uniform and healthy crops with minimal impact on the environment, aggregates with homogeneous dimensions should be made for soil tillage [17, 18].

The paper presents the field tests for a harrow with elastic fangs in order to determine the qualitative working indices as well as the exploitation energy indices during the maintenance of corn and sunflower crops.

2 Material and method

The harrow with elastic fangs is a machine carried on the tractor (driven from the power take-off), being intended for the maintenance of crops of straw cereals, corn, sunflower, beets, peas, beans, potatoes, rapeseed, vegetables, pastures, before and after conducting the sowing work.

Figure 1 shows the diagram of the harrow with elastic fangs used for experimental research.

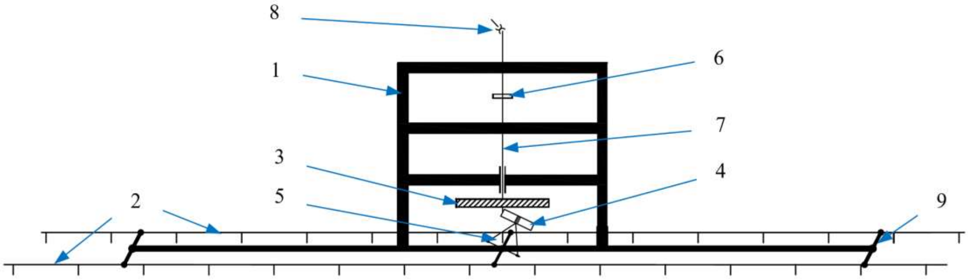

Fig. 1. Diagram of the harrow with elastic fangs
1 – frame; 2 – bank with elastic fangs; 3 – flywheel; 4 – oscillating washer; 5 – oscillating fork; 6 – flexible coupling; 7 – shaft; 8 – universal coupling; 9 – oscillating levers

The machine consists of an 80 mm square pipe frame that is attached on the tie rods of the tractor's hydraulic lift.

The batteries with elastic fangs are attached to the rear cross member of the frame by means of three oscillating levers.

The elastic fangs are springs that have the active part of 145 mm, and the spiral part inserted in a “U” profile provided with channels for the passage of the active part. The channels are long enough to move back the elastic fangs in case of meeting the plants, also allowing a strong lateral vibration.

The angle of attack of the elastic fangs can be adjusted in the range of 5-90° by an indexing system with bolts (in 6 positions).

The machine transmission includes the flywheel shaft, the elastic coupling, the oscillating washer, the oscillating swingarm that imprints the oscillating movement of the batteries with elastic fangs.

In the working position, the angle of attack of the elastic fangs is adjusted according to the stage of vegetation of the plants and the degree of soil moisture.

Table 1 presents the conditions for conducting the experimental research.

Table 1. Conditions for conducting experimental research

Specifications	**Determinations in the corn sown plot**	**Determinations in the sun flower sown plot**
Previous crop	corn	corn
Soil type	brown-red forest soil	brown-red forest soil
Previous works	autumn ploughing, harrowing and sowing	autumn ploughing, harrowing and sowing
Degree of grinding	without clods larger than 50 mm	without clods larger than 50 mm
Soil moisture between 0 – 10 mm	20.5 %	16 %
Terrain slope	max. 3.5 %	max. 4.2 %

The experiments were performed using an aggregate consisting of an 80 HP tractor and a harrow with elastic fangs for the maintenance of corn and sunflower crops.

3 Results and discussion

The determination of the qualitative working indices of the harrow with elastic fangs required the following steps:

3.1 Determining the degree of soil grinding

The experimental researches were conducted in repetitions, on a 0.5 x 0.5 m^2, with a maximum angle of attack of the elastic fangs. The results are presented in Table 2.

Table 2. Determining the degree of soil grinding

Crop	**Repetition**	**Degree of grinding [%]**	
		between 0 – 10 mm	**between 10 – 50 mm**
Corn	R1	89.6	10.4
	R2	78.3	21.7
	R3	83.2	16.8
	Average	83.7	16.3
Sun flower	R1	88.1	11.9
	R2	81.2	18.8
	R3	92.7	7.3
	Average	87.3	12.7

From the analysis of Table 2 it results that the harrow with elastic fangs achieves, in appropriate moisture conditions, a good grinding of the soil.

Also, it was noticed that it achieves a good breaking of the crust formed after a torrential rain, if it is put to work about four days after the rain.

3.2 Determining the degree of plant damage

The experimental researches were conducted in three repetitions and at two working speeds (4 and 6 km/h).

The results are presented in Table 3.

Table 3. Determining the degree of plant damage

Crop	Repetition	Degree of damage [%]	
		4 [km/h]	6 [km/h]
Corn	R1	1.1	1.3
	R2	0.8	1.5
	R3	0.4	1.2
	Average	0.7	1.3
Sun flower	R1	0.6	0.9
	R2	0.3	1.0
	R3	0.7	1.1
	Average	0.5	1.0

The results in Table 3 show that the degree of plant damage has values according to agrotechnical norms.

It should be noted that some of the plants recover in time if they are not uprooted.

3.3 Determining the degree of weed destruction

The experimental researches were conducted in three repetitions and at two working speeds. The results are presented in Table 4.

Table 4. Determining the degree of weed destruction

Crop	Repetition	Degree of weed destruction [%]	
		4 [km/h]	6 [km/h]
Corn	R1	43.5	61.5
	R2	58.9	66.6
	R3	51.7	57.3
	Average	51.4	61.9
Sun flower	R1	48.1	56.6
	R2	37.9	50.1
	R3	55.8	59.3
	Average	47.3	55.3

The results presented in Table 4 show that the degree of weed destruction is relatively low, as the destruction of weeds that are at a high stage of development would increase the degree of plant damage.

It would be advisable to use the machine when the weeds are in an early stage and to repeat the work whenever necessary, but this has negative effects on fuel consumption, as well as on the degree of soil compaction.

3.4 Determination of the degree of levelling and the degree of loosening

The experimental researches were conducted (in two repetitions) in order to determine the influence of the work performed by the harrow with elastic fangs.

The determination surface has the dimensions of 20 x 20 m.

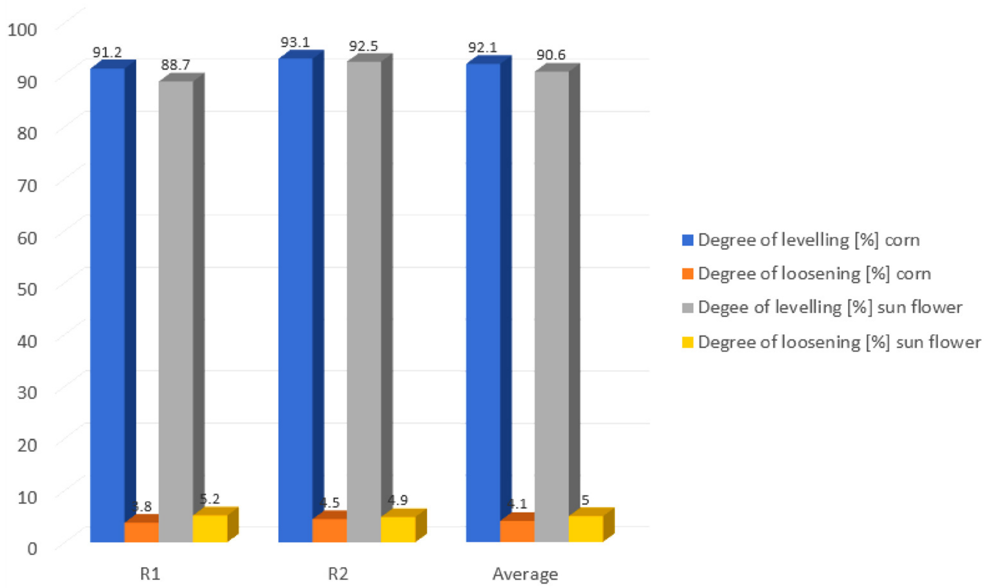

Fig. 2. Determination of the degree of levelling and the degree of loosening

From the analysis of the data presented in Figure 2 it results that the harrow with elastic fangs achieves a degree of soil levelling between 90.6 - 92.1%, being considered appropriate and a degree of loosening between 4.1 - 5.0%.

3.5 Determining the working depth of the machine

The working depth was set at 10 points along the entire working width of the machine, in two positions of attack of the elastic fangs: maximum and minimum.

The results are presented in Table 5

Table 5. Determining the working depth of the machine

Crop	Angle of attack	Working depth [mm]										Average
Crop	minimum	25	28	32	40	21	29	37	30	35	31	30.8
	maximum	47	50	42	45	51	42	46	38	55	41	45.7
Sun flower	minimum	12	19	22	23	17	18	18	20	22	27	19.8
	maximum	34	37	30	30	42	47	45	38	32	45	38.0

From the results obtained in Table 5 it results that the working depth has minimum values between 19.8 - 30.8 mm, the maximum values being between 38 - 45.7 mm.

3.6 Determination of energetic indices

Energetic indices were determined on a flat terrain, sown with corn in the state of the second node.

Experiments were conducted at three speed gears, in three repetitions, the result being presented in table 6.

Table 6. Determining the energetic indices

Indices name	M.U.	Values for gears		
		I	II	III
Effective working speed	km/h	3.78	6.15	8.57
Hourly fuel consumption	l/h	5.49	6.23	7.7
Skidding	%	3.35	3.47	3.67
Tensile strength of the machine	daN	231	212.5	224
Power required to operate the unit	CP	3.23	4.84	7.11
Engine power utilization coefficient	%	14.7	14.9	16.5

From the data presented in Table 6is observed that the values of hourly fuel consumption are situated between 5.49 l/h (1st gear) and 7.7 l/h(3rd gear).

Skidding has low values, situated around the value of 3.47%.

The tensile strength of the machine also has small vales, between 212.5 and 231 daN.

The maximum power necessary for driving the aggregate is 7.11 HP.

The coefficient of using the engine's power is very small (maximum 16.5%), leading to the idea of using the harrow in aggregate with small power tractors (<65 HP).

4 Conclusions

The experimental field researches of the harrow with elastic fangs were performed in order to determine the qualitative work indices:

- Degree of soil grinding,
- Degree of plant damage,
- Degree of weed destruction,
- Degree of levelling,
- Working depth,
- Energetic indices.

From the analysis of the data, it resulted that:

- the degree of soil grinding had values between 83.7 and 87.3% for the 0-10 mm fraction and between 12.7 and 16.3 for the 10-50 mm fraction;
- the degree of plant damage has a value of 0.76% for corn and 0.5% for sun flower at the speed of 4 km/h and of 1.3 % for corn and 1.0% for sun flower at the speed of 6 km/h;
- the degree of weed destruction has value between 47.3 – 51.4% at the speed of 4 km/h and between 55 – 61.9 % at the speed of 6 km/h;
- the degree of soil levelling has values between 90.6 – 92.1 %, and the degree of loosening between 4.1 - 5.2 %
- the working depth was between 19.8 – 30.8 mm at the minimum angle of attack of the elastic fangs and of 38 – 45.7 mm at the maximum attack angle of the elastic fangs;
- the hourly fuel consumption had the value of 7.71 l/h (3rd gear);

- the coefficient of using the engine's power was 14.9 % for the 2nd gear and 16.5 % for the 3rd gear.

Through the mechanical control of weeds, the machine leads to the decrease of the quantity of herbicides introduced in the soil.

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