Determination of qualitative working indices of harrows with elastic fangs

Dan Cujbescu¹, Gheorghe Matei³, Dimitar Kehayov⁴*, and Atanas Atanasov⁵

¹National Institute of Research – Development for Machines and Installations Designed to Agriculture and Food Industry – INMA Bucharest, Ion Ionescu de la Brad nr. 6, sector 1, Romania
²University Politehnica of Bucharest, Department of Biotechnical Systems, Splaiul Independentei nr. 313, sector 6, Romania
³University of Craiova, Fac. of Agronomy, Alexandru Ioan Cuza st., No 13, Craiova, Romania
⁴Agricultural University-Plovdiv, Department of Agricultural Mechanization, 4000 Plovdiv, Bulgaria
⁵University of Ruse, Agricultural Machinery Department, 7012, Ruse, Bulgaria

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].

* Corresponding author: dkechajov@mail.bg
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.

![Diagram of the harrow with elastic fangs](image)

**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.

| 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 m², with a maximum angle of attack of the elastic fangs. The results are presented in Table 2.

| 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.

| Crop            | Repetition | 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.

| Crop            | Repetition | Degree of weed destruction [%] |
|-----------------|------------|-------------------------------|
|                 |            | 4 [km/h] | 6 [km/h] | 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

| Crop     | Angle of attack | Working depth [mm] | Average |
|----------|-----------------|--------------------|---------|
| Corn     | 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    |
| Sunflower| minimum         | 12  19  22  23  17  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     | km/h | 3.78 | 6.15 | 8.57 |
| Hourly fuel consumption l/h      | 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 6 is 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 values, 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 sunflower at the speed of 4 km/h and of 1.3 % for corn and 1.0% for sunflower 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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