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STUDIES ON MINIMUM WHEAT TILLING

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Abstract

The development of alternative soil tillage technologies, which ensure the conservation and maintenance of its productive capacity as well as the reduction of energy consumption per unit of processed area, is today a necessity in developing a sustainable agriculture. The study presented in this paper was carried out in the area of Oravița, Caraș-Severin County, Romania, and refers to the minimum tillage technology in wheat culture. The study points to the unfavourable effect of intensive soil works – classic (conventional) system – on soil erosion. This has led to the development of some research oriented towards new technologies of soil working in the conservation system. The purpose of this paper is to promote the introduction of alternative technologies in agricultural works, by dealing with the main technical, economic and environmental aspects that compete for the achievement of efficient agriculture. From an economic point of view, this method is less expensive because fuel consumption and machine working time are reduced. The use of modern mechanization technologies has a great economic efficiency due to the following aspects.

Key words: *economic efficiency, soil, minimum tillage, production capacity*

INTRODUCTION

The concept of soil conservation includes a set of activities, measures and technologies that compete to maintain its state of fertility over an unlimited period [2], [3].This concept will develop in the future because soil is the most important means of human existence that ensures agri-food products, raw materials for industry, renewable energy sources; therefore, maintaining its biological capacity is a necessity imposed by the very existence of social life [14], [15]. Soil working technology represents an important way of ensuring the requirements for preserving the productive potential of the land and the evolution of their development has been dominated, at the beginning, by certain practical needs, especially of an economic nature – low energy consumption, short execution time of the works; it then forcefully met the requirements related to the concept of soil conservation [22], [24]. Soil works occupy a main place in mechanization technologies both from the point of view of its effects (loosening and aerating the soil, storing and preserving the soil, storing and preserving water in the soil, mobilizing the nutrients necessary for plants, destroying weeds, fighting diseases and pests, incorporating vegetal residues, etc.) as well as from the point of view of specific energy consumption [1], [5]. Sustainable agriculture implies that it should not only ensure an uninterrupted supply of food, but also have an accepted and recognized socio-economic impact on the environment and on human health [6], [21]. Equipping a modern and sustainable agriculture according to the experience of leading countries in this field is done with a wide range of machines and equipment, of which the machines that represent the energy basis are of great importance and economic efficiency [10]. The development of alternative soil tillage technologies, which ensure the conservation and maintenance of soil productive capacity as well as the reduction of energy consumption per unit of processed area, is today a necessity in order to develop a sustainable agriculture [11], [18]. The conventional system is characterized by vigorous annual loosening of the soil by turning the furrow, which is then followed by other works. In relation to the intensity and frequency of soil work, three major categories of methods are distinguished within this system, namely: loosening by ploughing with furrow turning, loosening by discus and reduced loosening [12]. This system of loosening the soil also defines the type of conventional agriculture [13]. The problems that arise in order to find optimal formulas for the relationship between high productivity and a healthy environment are particularly numerous in the field of agriculture; nowadays, it is unanimously recognized that socio-economic development should change its conception in order to be less destructive from an ecological point of view; it should rely on a new concept – the global concept of sustainable development – as an imperative for continuous progress in the development of human society [9], [20]. Currently, unconventional soil tillage defines extremely varied processes – from direct sowing in uncultivated soil to deep loosening without turning the furrow [19]. Between these two extremes, there are variants such as: reduced works (classical rationalized), minimal works (with coverage under 30%), minimal works with vegetable mulch (with coverage over 30%), sowing on earth lifts, partial works or works per strips, etc. This terminology highlights the specific character that defines this procedure applied at a given time, in a certain area, and in accordance with local specifics [4], [23].

MATERIALS AND METHODS

The study presented in this paper was carried out in the area of Oravița, Caraș-Severin County, Romania. The studies relate to the mechanization technology of minimal tillage in wheat. The mechanized works were carried out by S.C. DJ&B AGRO COMERȚ S.R.L. from Oravița. The following mechanized works were carried out: scarification, preparation of the germination bed and wheat sowing:

-The scarification work was carried out with the agricultural aggregate Challenger MT-765B tractor + Horsch Tiger 8AS scarifier.

-The germination bed preparation work was carried out with the agricultural aggregate Challenger MT-765B tractor + Swifter ST 17000 combine.

-The sowing work was carried out with the agricultural aggregate Fendt-820 Vario tractor + Horsch Pronto 6AS seeder.

Two types of tractors were used for mechanized soil works in wheat:

-the Fendt-820 Vario tractor;

-the Challenger MT-765B tractor.

The Fendt-820 Vario tractor is equipped with two gearboxes (Turboshift hydrostatic gearbox with reverse + 6-speed mechanical gearbox) and can achieve a number of 44 forward and reverse speeds (24 fast speeds + 20 slow down speeds).

Operating parameters of the tractor are as follows:

-Nominal power N_p = 190 HP = 140 kW

-Nominal engine speed n_e = 1,900 rpm (ω_m = 200 rad/s)

-Nominal motor torque M_e = 90 daNm

-Hourly fuel consumption G_h = 27.3 kg/h

-Specific fuel consumption g_s = 195 g/kWh

-Weight W = 7,700 daN.

This shows that, with the increase of the load, the tractor can stop for the following reasons:

1.The tractor engine tends to stop, which means that the sum of the resistance forces exceeds the value of the tangential force, and the adhesion force with the ground has a value greater than the tangential force, i.e.:

$$F_{max} > F_{tg} < F_r + F_t \pm F_p$$

2.The tractor wheels are completely skidding so that the tractor stands still, which means that the adhesion force with the ground is less than the sum of the resistance forces of the aggregate and, at the same time, less than the tangential force, i.e.:

$$F_{tg} > F_{max} < F_r + F_t \pm F_p$$

The points of intersection between the lines of variation of the tangential force and the maximum force of adhesion with the ground represents the limit at which:

$F_{max} = F_{tg} = F_r + F_t \pm F_p$.

This shows that the aggregate moves only when the adhesion condition is satisfied, i.e.:

$F_{max} > F_{tg}$

When the adhesion condition is not satisfied, i.e., when the tangential force is greater than the maximum adhesion force, in the operating calculations regarding the formation of aggregates, it will be considered that:

$F_{tg} = F_{max}$

It is observed that the adhesion force is satisfied for gears I, II, III and unsatisfied for gears IV, V and VI.

The traction forces of the Fendt-820 Vario tractor, when moving on land prepared for sowing, in forward gears are:

$$F_{t\,I;II;III} = F_{\max} - F_r = 3{,}850 - 770 = 3{,}080 \text{ daN}$$

$$F_{t\,IV} = F_{tg\,IV} - F_r = 2{,}903 - 770 = 2{,}133 \text{ daN}$$

$$F_{tV} = F_{tgV} - F_r = 1{,}910 - 770 = 1{,}140 \text{ daN}$$

$$F_{tVI} = F_{tgVI} - F_r = 1{,}375 - 770 = 605 \text{ daN}$$

The Challenger MT-765B tractor equipped with Challenger Powershift transmission achieves 16 forward speeds and 4 reverse speeds.

The operational parameters of the Challenger MT-765B tractor are:

-Nominal power N_p = 320 HP = 238 kW

-Nominal engine speed n_e = 2,100 rpm (ω_m = 220 rad/s)

-Nominal motor torque Me = 108 daNm

-Hourly fuel consumption Gh = 46.4 kg/h = 54 l/ha

-Specific fuel consumption gs = 195 g/kWh

-Weight W = 11,800 daN

-Drive wheel radius r = 0.762 m

-The adhesion condition is satisfied for gears I-VI and unsatisfied for gears VII-XVI.

Traction forces of the Challenger MT-765B tractor, when moving on stubble, in forward gears are:

$$F_{t1-6} = F_{\max} - F_r = 10{,}620 - 600 = 10{,}020 \text{ daN}$$

$$F_{t7} = F_{tg7} - F_r = 9{,}344 - 600 = 8{,}744 \text{ daN}$$

$$F_{t8} = F_{tg8} - F_r = 8{,}320 - 600 = 7{,}720 \text{ daN}$$

$$F_{t9} = F_{tg9} - F_r = 7{,}296 - 600 = 6{,}696 \text{ daN}$$

$$F_{t10} = F_{tg10} - F_r = 6{,}656 - 600 = 6{,}056 \text{ daN}$$

$$F_{t11} = F_{tg11} - F_r = 5{,}760 - 600 = 5{,}160 \text{ daN}$$

$$F_{t12} = F_{tg12} - F_r = 5{,}248 - 600 = 4{,}648 \text{ daN}$$

$$F_{t13} = F_{tg13} - F_r = 4{,}352 - 600 = 3{,}752 \text{ daN}$$

$$F_{t14} = F_{tg14} - F_r = 3{,}456 - 600 = 2{,}856 \text{ daN}$$

$$F_{t15} = F_{tg15} - F_r = 2{,}688 - 600 = 2{,}088 \text{ daN}$$

$$F_{t16} = F_{tg16} - F_r = 1{,}920 - 600 = 1{,}320 \text{ daN}$$

Design of the technological scarification process

The Horsch Tiger 8 AS scarifier is intended for loosening the soil up to a depth of 35 cm. It works in aggregate with the Challenger MT-765B crawler tractor.

The technical characteristics of the Horsch Tiger 8 AS scarifier are:

-length: 7.95 m;

-maximum working depth: 35 cm;

-mass: 7,800 kg;

-number of loosening coulters: 33 pcs.;

-working width of a coulter: 23 cm;

-number of furrow rows: 4 rows;

-distance between furrow rows: 23 cm;

-distance between coulters per row: 91 cm;

-roller tire sizes: 7.50-16;

-tire air pressure: 2.8 bar;

-pendulum traction bar;

-axle load: 5,100 kg

-drive power: 275-385 HP.

The scarified area of 100 ha has the following dimensions:

-length 1,000 m;

-width 1,000 m.

The scarifying work will be carried out by moving the aggregate according to the shuttle method. The minimum lot size should ensure work on at least one shift.

Calculation of economic indices

Economic indices assume both the knowledge of the consumption per area unit and of the expenses per ha, by elements of expenses [8].

Production costs for carrying out a mechanized agricultural work are composed of indirect costs and direct costs [7].

Indirect costs are costs incurred by the performance of several mechanized works or in the general interest of the enterprise. Indirect costs are recorded separately and then, according to certain criteria, a share is allocated for each mechanized work [17].

Direct costs are costs that are directly determined and included in the cost of each mechanized work. In assessing the economic efficiency of an agricultural aggregate, only the indicator of direct expenses is used because it expresses the reduction of labour and material expenses by using the respective agricultural aggregate. Direct expenses are expressed in RON/ha.

Design of the technological process for the preparation of the germination bed

The Swifter ST 17000 combinator is intended for the preparation of the germination bed. It works in aggregate with the Challenger MT-765B tractor. The technical characteristics of the Swifter ST 17000 combiner are:

-working width: 17 m;
-transport width: 3 m;
-working depth: 5-15 cm;
-mass: 9,100 kg;
-number of loosening coulters: 166 pcs.;
-number of furrow rows: 4 rows;
-distance between furrow rows: 23 cm.

The working organs of the Swifter ST 17000 combine are: front levelling bar, four rows of active chisel-type organs, double rear roller and rear levelling bar. The active chisel-type organs for loosening can be replaced with arrow-coulter-type organs for weeding. The combiner is ideal for the preparation of the germination bed, being able to work after ploughing or after scarification, in a single pass, leaving the land ready for sowing [16].

Design of the technological process for sowing

The Horsch Pronto 6AS seeder is intended for row sowing of straw cereals at a distance of 15 cm between rows. It works in aggregate with the Fendt-820 Vario tractor.

The technical characteristics of the Horsch Pronto 6AS seeder are:

-working width: 6 m;
-length: 9 m;
-mass: 7,850 kg;
-number of coulters: 40 pcs.;
-type of coulters: with discs;
-distance between rows: 15 cm;
-volume of the seed box: 3,500 l

RESULTS AND DISCUSSIONS

Costs of mechanized works

Exploitation and economic indices of the mechanized works of scarification, land preparation and sowing in wheat are:

1. Calculation and formation of the aggregate to be scarified

Machine's resistance to scarification is:

$R_m = K_0 \cdot a \cdot b \cdot n = 5 \cdot 10^3 \cdot 0.2 \cdot 0.23 \cdot 33 = 8{,}250$ daN,

where:

K_0 – soil resistance to scarification (for medium soil, $K_0 = 5 \cdot 10^3\ daN/m^2$)

a – working depth ($a = 0.2\ m$)

b – working width of a coulter ($b = 23\ cm$)

n – number of scarifier coulters (n=33 buc)

Working speed

By comparing the aggregate's resistance to scarification with the traction force that the Challenger MT-765B tractor can develop, speed gear VII is chosen with which the scarification work will be carried out. The working speed will be:

$v_l = v_t(1-\delta) = 2.3(1-0.1) = 2.07\ m/s = 7.4\ km/h$

The working capacity of the scarification aggregate

The actual hourly working capacity is calculated with the relationship:

$W_h^r = 0.1 \cdot B_l \cdot v_l \cdot K_s = 0.1 \cdot 7.5 \cdot 7.4 \cdot 0.8 = 4.44\ ha/h$

where:

B_l – working width ($B_l = 7.5\ m$)

v_l – working speed ($v_l = 7.4\ km/h$)

K_s – coefficient of use of working time ($K_s = 0.8$)

The actual working capacity per shift is calculated with the relationship:

$W_{sch}^r = W_h^r \cdot T_s = 4.44 \cdot 8 = 35.5\ ha/sch$

The *number of scarification aggregates* is calculated with the relationship:

$$n_a = \frac{S}{W_{sch}^r \cdot n_z \cdot n_s} = \frac{100}{35.5 \cdot 1 \cdot 3} = 0.94$$

A scarified aggregate will be used to perform the work in three days.

2. Calculation and formation of the germination bed preparation aggregate

The tensile strength of the combiner is:

$R_M = K \cdot B_l = 350 \cdot 17 = 5{,}950\ daN$

where:

K – specific strength in daN/m;

B_l– working width of the combiner, in m

Working speed

By comparing the aggregate's resistance to the prepared ground with the traction force that the Challenger MT-765B tractor can develop, speed gear X is chosen with which the work will be carried out. The working speed will be:

$v_l = v_t(1-\delta) = 3.2 \cdot (1-0.1) = 2.9\ m/s = 10.4\ km/h$

The working capacity of the land preparation aggregate

The actual hourly working capacity is calculated with the relationship:

$W_h^r = 0.1 \cdot B_l \cdot v_l \cdot K_s = 0.1 \cdot 17 \cdot 10.4 \cdot 0.8 = 15\ ha/h$

The actual working capacity per shift is calculated with the relationship:

$W_{sch}^r = W_h^r \cdot T_s = 15 \cdot 8 = 120\ ha/sch$

A ground preparation aggregate will be used to perform the work in one day. The method of movement in work will be the method of movement following circular routes with 90o turns.

Calculation and formation of sowing aggregates

The tensile strength of the seed drill is:

$R_M = K \cdot n = 50 \cdot 40 = 2{,}000\ daN$

where:

K – specific strength on the coulter in daN/m;

n – number of disc coulters.

Working speed

By comparing the traction resistance of the seeder with the traction force that the Fendt-820 Vario tractor can develop, the fast speed gear II is chosen with which the work will be carried out. The working speed will be:

$v_l = v_t(1-\delta) = 2.7 \cdot (1-0.15) = 2.3\ m/s = 8.3\ km/h$

Actual working capacity of the sowing aggregate

The actual hourly working capacity is calculated with the relationship:

$W_h^r = 0.1 \cdot B_l \cdot v_l \cdot K_s = 0.1 \cdot 6 \cdot 8.3 \cdot 0.7 = 3.5\ ha/h$

The actual working capacity per shift is calculated with the relationship:

$W_{sch}^r = W_h^r \cdot T_s = 3.5 \cdot 8 = 28\ ha/sch$

A sowing aggregate will be used to carry out the work in four days. The method of movement in the work will be the shuttle method.

CONCLUSIONS

Following the studies carried out, the following conclusions can be drawn and the following recommendations can be made: Total expenses for the minimum soil tillage in wheat, under the conditions of Oravița, were 209 RON/ha. Direct expenses in the amount of 175 RON/ha represent 80% of total expenses. Fuel expenses (117 RON/ha) represent 56% of total expenses, respectively 67% of direct expenses of the minimum tillage works. Optimal mechanization technology consists in the judicious correlation of works and agricultural aggregates during the entire technological process in order to produce with the lowest labour costs and energy consumption.

The use of modern mechanization technologies has great economic efficiency due to the following aspects:

-the works are carried out in a short period, so that optimal time for carrying out the technological work is observed;

-the number of required aggregates is reduced;

-the number of passes in the field is reduced;

-soil subsidence degree is reduced;

-fuel expenses are reduced;

-expenses with remunerations are reduced;

-significant savings per ha are obtained.

Apart from choosing the most economical option in mechanization technology, there are other important methods of reducing energy consumption: performing daily maintenance; adjusting the aggregates properly; choosing the optimal speed according to the work and terrain.

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