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THE IMPORTANCE OF SOIL IN CHOOSING THE USE OF TRACTORS FOR CARRYING OUT AGRICULTURAL WORKS THAT CONSUME HIGH ENERGY

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Abstract. *The purpose of this work (analysis of the importance of soil in the choice of tractors for energy-intensive agricultural work) is to highlight the crucial relationship between the physical properties of the soil and the energy efficiency of agricultural mechanization. Close knowledge of soils involves researching unitary complexes of morphological characters - aspects of color, constitution and structure of the soil profile. The importance of soil in the choice and use of tractors for energy-intensive agricultural work is fundamental and translates directly into energy efficiency, equipment performance, and environmental protection. To link soil to crop production, it is necessary to know the ecological characteristics of the soil type, its natural fertility and recommendations for its use, i.e.: the assortment of crops; soil work; fertilizers; improvement works. These are the minimum data necessary to be known for the judicious use of soil. All agricultural work that is performed mechanized is carried out depending on the physical and mechanical properties of the soil. The characteristics of the work are also determined depending on the genetic horizons of the soil profiles. The resistance of the soil to work is the greatest factor influencing fuel consumption. On heavy (clayey) or compacted soils, the tractor has to exert a much greater tractive effort to pull the implement (e.g. plough), resulting in a considerably higher specific fuel consumption per hectare. Wet or poorly structured soils increase the wheel slip coefficient. Excessive slip means energy (fuel) is wasted instead of being transferred as traction force. Choosing the correct tyre pressure and running system for the type of soil is crucial to keeping slip at an optimal level (usually between 8% and 15%).*

Keywords*: soil, tractor, agricultural work, soil strength*

INTRODUCTION

The importance of soil in the choice and use of tractors, especially for energy-intensive agricultural work, is essential and manifests itself in three critical aspects: the required power, energy efficiency (fuel consumption) and sustainability of the work. (OKROS, ADALBERT, 2025; OKROS, ADALBERT, 2015).

Improper use of tractors, ignoring the condition of the soil, leads to its degradation. (DAVID-FEIER S., ET.AL. 2020).

Heavy tractors, especially on soils worked at optimum or excessive moisture, exert high pressure, leading to compaction. Compaction increases energy consumption in subsequent work; affects soil drainage and aeration; hinders root development and ultimately reduces production**.** (DUMA COPCEA, A., 2022, NICOLETA MATEOC-SÎRB, 2025).

Knowledge of the soil allows the adoption of conservative tillage technologies (minimum tillage or no-tillage), which reduce the number and intensity of tractor passes, save fuel and protect the soil structure. (CÂMPIAN, O., ET.AL. 2002, CÂMPIAN, O., ET.AL 1989).

The type of soil (clay, sandy, loamy, etc.), humidity and degree of compaction determine: clayey or heavily compacted soils offer a much higher specific resistance to advance (ka) during plowing or other processing work, requiring tractors with increased power and high tractive force; heavy, wet or unstable soils may require the choice of tracked tractors that ensure uniform weight distribution, increased traction and minimize soil compaction; light (sandy) or loamy soils, in good conditions, allow the efficient use of wheeled tractors.(Anișoara DUMA COPCEA, ET.AL. 2024; Ţărău, D., ET.AL. 2020).

The soil structure dictates the depth and type of work required (for example, deep scarification is often necessary on heavy, compacted soils, requiring specific machinery and powerful tractors). (NITA, L., 2019 ; NIȚĂ, S., 2022).

Taking into account the physical characteristics of the soil (texture, structure, moisture, resistance to penetration) is not just a recommendation, but an engineering and agronomic necessity, ensuring that engine power is efficient and the soil structure is maintained fertile. (LUCIAN DUMITRU NIȚĂ, 2023).

Optimizing traction and specific pressure (footprint) - is the element where concern for soil health is most directly manifested. (Anișoara DUMA COPCEA, ET.AL. 2024, GRAD, I., ET.AL. 2014).

On clay soils, crawler or semi-tracked tractors are preferred. Tracks reduce the specific pressure (weight per unit area) by 40-70% compared to wheels, preventing deep compaction and providing superior traction on slippery soils. (CĂPRUCIU, F., ET.AL.1990)

Medium or coarse textured soils that do not retain excessive water and are not extremely prone to severe compaction use wheeled (4x4) tractors, which offer better speed and maneuverability. (CASIANA, MIHUȚ, ET.AL.2018)

Choosing wide, radial tires (with high air volume) and maintaining as low a pressure as possible (adjusted according to load and speed) is vital. (ANDREESCU, C. 2010).

A low-pressure tire has a larger footprint on the ground, distributing the weight over a larger area and achieving a compromise between grip (needed for traction) and protection of the soil structure (needed for fertility). (S. IORDACHE, ET.AL.2011; UNTARU, M., ET.AL. 1981).

MATERIAL AND METHODS

The classification of soils relevant for the study on the choice of tractors and energy consumption is done according to texture and structure/degree of compaction, since these parameters determine the specific resistance to traction (the force required to work the soil).

Soils requiring high energy effort - these soils offer the greatest resistance to processing, requiring the use of high-power tractors with high traction force and rolling systems that reduce compaction (tracks or dual wheels).

Soils with compacted clay texture - have a high clay content, massive structure, high apparent density, poor drainage, specific resistance to maximum traction. Highest fuel consumption. Work must be performed in short intervals of optimal humidity.

Soils with loamy-clay texture - have a balance between clay and clay, but with a tendency to compact at depth (plough sole); increased resistance, especially during deep ploughing. Requires high power to break the dense structure.

Chernozem, although rich in humus, compaction caused by repeated traffic increases its density. It presents increased resistance especially to deep plowing. It requires great power to break the dense structure.

RESULTS AND DISCUSSIONS

Track mechanism adhesion to the ground

Tracked tractors, like wheeled tractors, can function normally only under conditions of good adhesion to the ground. It is considered that the adhesion of tracked tractors is achieved due to the friction of the tracks with the ground and due to the reactions of the ground that occur as a result of its pressing, in the opposite direction to the tractor's movement, by the track spurs.

Thus, the tangential traction force F_m is $F_m = \mu G + \sigma n_p A_v$

where μ is the coefficient of friction between the track and the soil;

G - operating weight of the tracked tractor;

σ - average unit effort at tangential compression of the soil;

n_p - number of spurs sunk into the soil;

Av - the projection on a vertical plane of the support surface of the spur that takes up the tangential force, which depends on its dimensions (length and width).

The distribution of horizontal reactions between different spurs of the caterpillar depends on numerous constructive and operational factors. Studies show that the distribution of tangential reactions between different spurs of the support surface depends on the traction force at the hook. When the tractor is idling and at low values of the traction force (when slipping usually occurs) the tangential reactions of the soil are created, in particular, by the first spurs of the support surface, and the maximum value of this reaction is around the first support roller. At the other spurs, sunk in the soil, the tangential reactions are small, reaching zero or even becoming negative. With increasing traction force, the distribution of tangential reactions becomes uniform. At high traction forces, tangential reactions are concentrated in the rear part of the support surface (the rolling process is accompanied by slipping of the running system).

Tracked tractor slipping. Based on the relationship $\eta_s = \frac{F_m v}{F_m v_t} = \frac{v}{v_t} = \frac{r}{r_m}$ spin of the tracked tractor is $\delta = 1 - \eta_\delta = 1 - \frac{v}{v_t} = \frac{v_t - v}{v_t}$

where: is the theoretical speed of the tractor, which can be expressed by the ratio between L- Δl the length L of the track support surface and the contact time t of each spur with the ground t $\left(v = \frac{L - \Delta l}{t} \right)$

- the tangential deformation of the soil produced by each spur from the moment of contact with the soil until its exit from the soil.

Substituting vt and v in the above relationship, we obtain: $\delta = \left(\frac{L}{t} - \frac{L - \Delta l}{t} \right) \frac{t}{L} = \frac{\Delta l}{L}$

The maximum tangential unit stress of the soil can be determined based on the average unit stress.

Using the relationship $\eta_s = \frac{F_m v}{F_m v_t} = \frac{v}{v_t} = \frac{r}{r_m}$ is obtained

$$\sigma_{\max} = \chi \sigma = \chi \frac{F_m - \mu G}{n_p A_v}$$

On the other hand, the united effort σ_{max} can be expressed in terms of soil deformation according to the relationship, i.e. $\sigma_{max} = c\Delta l$

Therefore: $\delta = \frac{\Delta l}{L} = \frac{\sigma_{\max}}{cL} = \chi \frac{F_m - \mu G}{cLn_p A_v}$

Where: χ is a coefficient that considers the distribution of the reaction between the track spurs.

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In the case of tractor operation in a stabilized mode on horizontal terrain F_m-$\mu G \approx F_t$,where Ft is the traction force at the hook.

Thus, the skidding of the tracked tractor is: $\delta \approx \frac{F_t}{cLn_p A_v}$

So, the losses during the skidding of the tracked tractor, in the case of operation in a stabilized mode on a horizontal terrain (road), are directly proportional to the traction force. These losses also depend on the mechanical properties of the soil and the constructive parameters of the track mechanism.

By testing tracked tractors in field conditions, it was possible to establish a certain dependence of the skidding on the height h of the spurs and the traction force Ft. Figure 1, a shows the results of tests on stubble, and Figure 1, b — on the field for different spur heights.

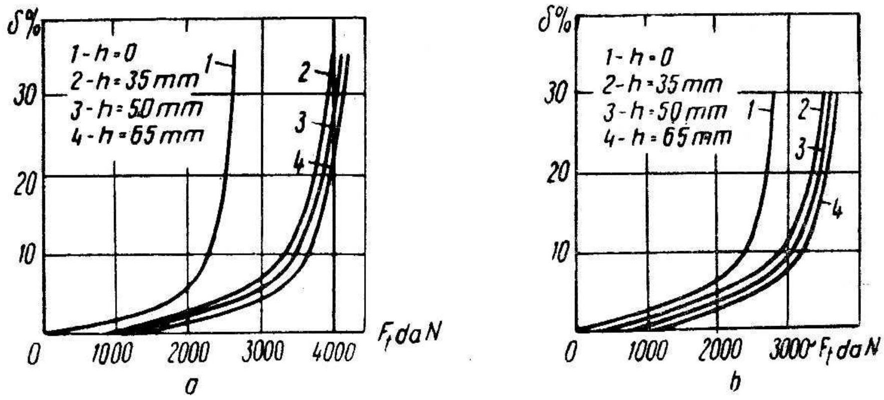

Figure 1. Slippage as a function of traction force Ft and spur height h

The best traction qualities were obtained for h=35mm. If the spurs have h>40…45 mm, the grip improves to a very small extent; on the other hand, the rolling resistance force increases.

Skidding is also represented in terms of the coefficient of use of the adhering weight.

$\varphi_m = \frac{F_m}{G}$ or the coefficient of adhesion utilization $\varphi_t = \frac{F_t}{G}$

If δ represented (figure 2) as a function of, φ_t the respective curves can also be used as nomograms for calculations.

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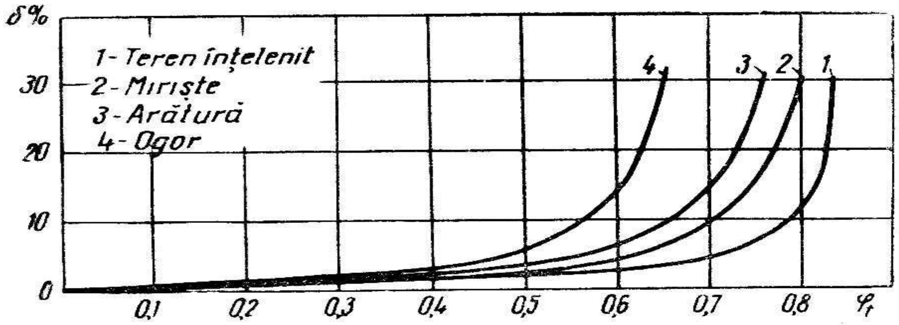

Figure 2. Skating δ according to φ_t

As in the case of wheeled tractors, the slippage of tracked tractors cannot be determined accurately analytically. In most of the literature, the same experimental method and the relationship are recommended $\delta = \frac{n_1 - n_2}{n_1} \cdot 100[\%]$ for determining skidding for both wheeled and tracked tractors.

Considering that the dynamic radius *rm* of the tracked tractor is constant, it is determined by the relationship $r_m = \frac{t_s z}{2\pi}$ and that when idling, most of the time, there is slipping (negative slippage), the slippage can be determined more precisely. When establishing the experimental method, the starting point is the relationship $\eta_s = \frac{F_m v}{F_m v_t} = \frac{v}{v_t} = \frac{r}{r_m}$ If the actual number nr of rotations of the drive wheels is measured on a section of land of length S (usually, the rotations of both wheels are measured and the average value is considered), the value of the rolling radius *r* when running under load is established from zero to the maximum value, i.e. $r = \frac{S}{2\pi n_r}$

For the same distance traveled *S*, assuming that the tractor does not skid (δ =0), i.e. *r=rm*, the theoretical number of rotations nt is calculated, i.e $n_t = \frac{S}{2\pi r_m}$ substituting the above relation and rm , we obtain $\delta = 1 - \eta_\delta = \frac{n_r - n_t}{n_r}$ or: $\delta = \frac{n_r - n_t}{n_r} \cdot 100[\%]$

The experimental results obtained by this method and the above relationship as a function of Ft or φ_t also highlight the phenomenon of slipping of the running system when idling or with small loads. One of the causes of slipping of the crawler running system is that the tangential action of the soil being greater than the traction force, the soil is pressed forward. Up to a certain value *Ft*, which depends on the construction of the tractor and the mechanical properties of the soil, the movement is accompanied by the phenomenon called slipping (negative slippage). The explanation of the sudden increase in the coefficient at high traction forces is the same as for wheeled tractors.

The coefficient of adhesion of the tracks to the ground. In the case of crawler tractors, the entire weight being adherent, the adhesion coefficient is defined by the ratio: $\varphi = \frac{F_{m\max}}{G}$

Using relationships $\delta = \frac{\Delta l}{L} = \frac{\sigma_{\max}}{cL} = \chi \frac{F_m - \mu G}{cLn_p A_v}$ and $\varphi = \frac{F_{m\max}}{G}$ is obtained $\varphi = \mu + \frac{\delta_{ad} \cdot cLn_p A_v}{\chi G}$ where δ_{ad} is the permissible skidding of the tracks with the ground.

From the above relationship it follows that theoretically the adhesion coefficient depends on the admissible losses during slipping, the mechanical properties of the soil, the parameters that characterize the construction of the tracks and the friction coefficient. μ .

The maximum tangential traction force $F_{m\ max}$, allowed by the adhesion to the ground, is understood as the maximum value of this force with which the tractor can work for a long time in the respective ground conditions and with admissible losses due to slipping.

Table 1 shows the values of the adhesion coefficient φ for different roads and soils, in the case of tracked tractors.

Table 1

Rolling resistance coefficients f and adhesion φ for tracked tractors

Type of road or soil	f	φ
Asphalt	0,06	
Dry, clayey, trodden road	0,06	1
Dry, sandy, trodden road	0,06	1,1
Dry, chernozem, trodden road	0,07	0.9
Wet, mowed hayfield	0,08	1,2
Wet, unmowed hayfield	0.07	0,6
Wet stubble	0,08	0.9
Ploughed land	0,08	0.7
Freshly ploughed land	0,10—0,12	0,6
Wet sand	0,10	0,5
Dry sand	0,15	0.4
Swamp	0.10—0,12	0,3
Trampled snow road	0,06	0,6

CONCLUSIONS

Therefore, detailed knowledge of the soil (agrochemical and physical analyses) is the starting point in choosing the right working tactics and tractor, having a direct impact on the energy efficiency and sustainability of the entire agricultural activity.

Based on theoretical and experimental research, it was concluded that for tracked tractors, with operating speeds lower than 18 km/h, so in the case of agricultural tractors, it is convenient to place the drive wheels at the rear, and for high-speed tracked vehicles (over 18 km/h) it is better to place the drive wheels at the front.

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Rubber tracked tractors allow an increase in traction compared to rubber wheeled tractors, by improving adhesion to the ground, in the distribution of forces along the length of the track, in the axle load.

Greater stability and maneuverability, effective turning in place.

Reduction of fuel consumption per unit area.

Constructive solutions for wheeled tractors to increase grip by doubling the drive wheels or achieving lower air pressure in the tire are not effective.

The reliability of the track is greater than that of a rubber tire, at least 2.8 times.

The use of the tractor throughout the entire agricultural year, through the constructive technical equipment incorporated into these tractors.

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