THE EFFECT OF WHEELS OR TRACKS ON SOIL

D. Knežević, L. Šumanovac, T. Jurić, P. Lukač, A. Atanasov

Abstract: *The paper presents the influence of wheels or tracks on the soil in relation with soil deformation due to their action. Soil compaction causes pore volume to decrease, and that impairs internal air-water condition and consequently plant growth and development. This is especially the case with the soil containing a higher amount of clay particles. The paper produces a number of the possibilities to decrease soil compaction such as the following: a proper choice of pneumatic tyres and their inflation pressure; the appropirate moment of soil tillage in relation to soil moisture; reduction of field machine traffic, etc.*

Key words: *wheels, tracks, soil compaction, agricultural soil.*

INTRODUCTION

Wheels or tracks of agricultural machines directly affect the soil by normal vertical and tangential load, which inflicts compaction and shear. Soil consistency is an

important physical characteristic, which affects the way how the weels of a field machine influence the soil. This implies the soil resistance to mechanical stresses due to the wheel action of a machine or other machine parts. As a result of the wheel or track action some deformation can occur and they depend on the following:

- granulometric soil composition and present condition
- soil moisture
- tangential load of drive wheels
- the size of the contact area between the wheel and soil
- pressure arrangement within the contact area

In today's agricultural production high drawing forces directly cause soil disturbance, which is especially true for large farms where wide-swath machines are applied.

MATERIAL AND METHODS

The paper cites the results produced by the researchers who analyzed wheel action upon soil. It is necessary to pay attention to soil moisture in order to limit soil compaction; further, the machine traffic should be limited, and appropriate tyres should be used, in relation with their inflation pressure and size because it determines the contact area between the wheels and the soil. Continuous tracks, especially the rubber ones diminish soil compaction. A larger contact area between the tracks and soil has a favourable effect on soil compaction, compared to the wheel and soil contact area.

RESULTS AND DISCUSSION OBTAINED BY LITERATURE ANALYSIS

When you want to choose the wheels which would cause less soil compaction compared to the compaction caused by a standard wheel, you can opt for dual tyers, broad tyres, or terra tyres (Filipović, D. et al.; 1998). Large loads are transferred across a larger area and this in turn reduces the tyre pressure upon the surface (arable land) with the aim of soil compaction reduction. Figure 1 shows the contact areas between the wheels and surface in case of use of different tyres.

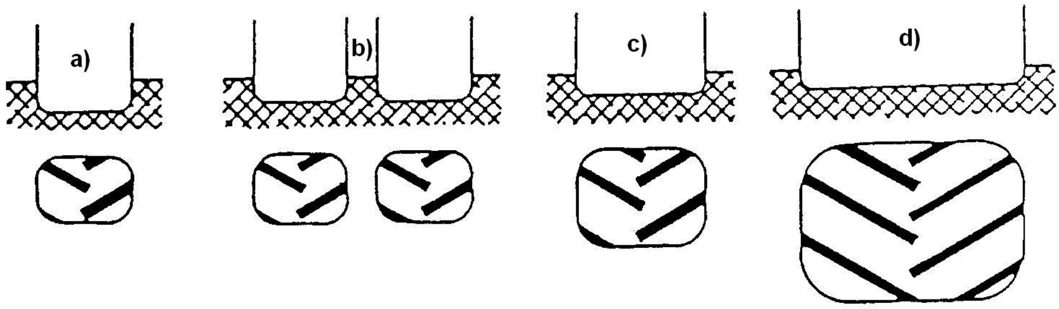

Figure 1. Contact area between different tractor tyres and soil
a) standard tyre 18.4 R 38, b) dual tyres 18.4 R 38, c) broad tyre 650/60-38, d) terra tyre 66x43.00-25

Soil compaction can be reduced by the use of tracks, as already mentioned before. This is especially favourable with rubber belt tracks. The disadvantages of metal track tractors are the aggrevated ergonomics in relation to the tractor driver, the impossibility of taking part in public traffic, reduced speed, etc. All these problems can be solved in the case when rubber tracks are used (Filipović, D. et al.; 1998). Tracks effect the soil in the similar way as wheels. They act both in the vertical and horizontal direction causing vertical and horizontal surface stresses. Soil deformation increases from the front towards the back track part. Shear resistance values depend on the soil type and its conditions. The shear is also influenced by the rib size and height. A bigger deformation is caused by the tracks with segments shifted apart.

The higher tractor engine power, the higher tractor mass. Each wheel of the back axle is subjected to up to 5 t of load in cas of a 175 kW tractor. One of the main tyre parameters is their inflation pressure. Inflation pressure should be lower for field traffic at the same wheel loads, than for hard surface traffic (asphalt roads, etc.). In this way you can avoid a possible tyre damage due to improper inflation pressure. Certain difficulties happen due to the lack of inflation pressure gauge, which regulates the pressure for field or road traffic due to which field traffic operates at the same inflation rates as the road traffic. New tyres of 900 mm of width are able to fulfill both field and road traffic requirements. Nowadays there are three different sizes: 900/50R42, 900/55R32 i 900/60R32. They can replace the standard size tyres used so far (Table 1).

Table 1.

Comparing 900 tyres with previous equipment (wheel load 4,5 t, v = 50 km/h)

	Air pressure, bar	Compared values	Air pressure, bar	Load bearing capacity
900/55R42	1.2	650/65R42 710/70R38	1,6[1)] 1,4	+ 23% + 6%
900/65R32	0,8	650/65R42 710/70R38	1,6[1)] 1,4	+ 60% + 40%

Source: Weiβbach, M.; 2001.

Dual tyres are more convenient compared to terra tyres because they can be used in a more universal way on a tractor. Load bearing capacity of 900 mm tyres is higher than the bearing capacity of the tyres used so far. This is especially obvious in tyres such as 900/65R32, that have a higher air volume. Increased loads are present in self-propelled harvesting machines, where increased loads occur in cycles and they are transferred to the soil (empty tank – full tank) - the fact that distinguishes tractors from such machines. Tyre load bearing capacity increases when the tyre is broader and the air volume is increased as well. This enables driving under very heavy loads and at lower tyre air pressure. When you reduce the tyre width the necessary load bearing air pressure rises. If the tyre air pressure is too high, the tyre pressure on the soil increases. Diagrams 1 and 2 show the dependence of soil wheel pressure and the wheel penetration depth (tractor wheel, diagram 1, harvesting machine wheel, diagram 2).

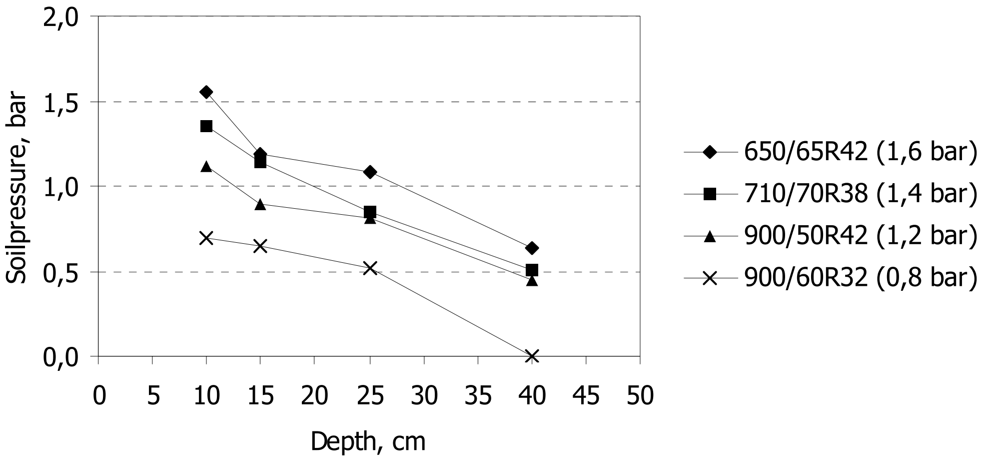

Diagram 1. Soil load under wide tyres with same bearing capacity of 4,8 t

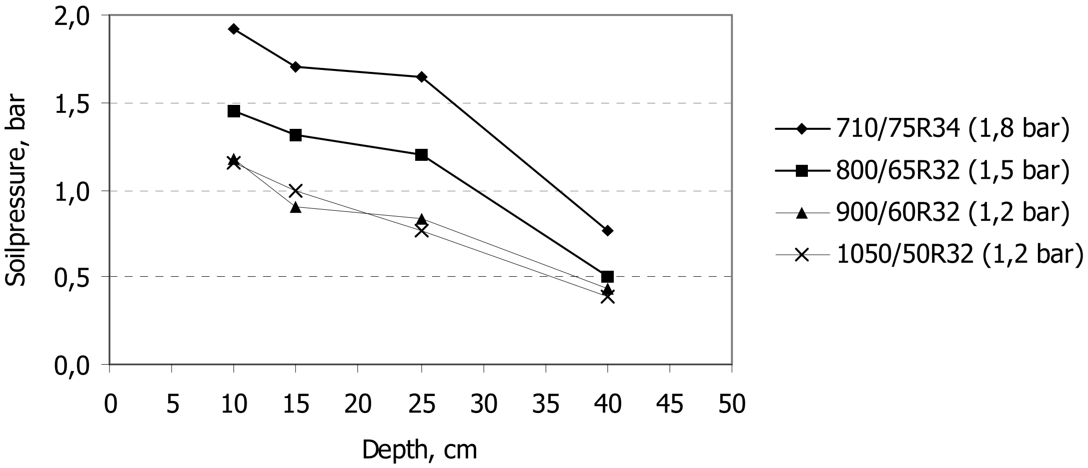

Diagram 2. Soil load under different harvester tyres (wheel load 8,3 t)

Based on diagrams 1 and 2 it is obvious that wheel pressure on the soil is lesser at higher depths. A conclusion can be made based on the diagrams that the wheel pressure is not the decisive factor acting along the soil depth, but the pressure on the soil surface (Weiβbach, M.; 2001.).

Figure 2 shows a measuring device set on a wheel and used for testing the motive power transmission by the tyre. Based on that a mathematical model for soil pressure measuring was designed (Sommer, C. et al.; 2001.).

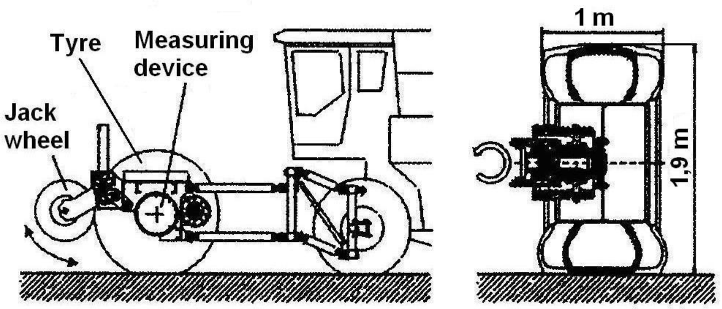

Figure 2. Single wheel testing device with wheel loads < 6 t

These models are not capable of taking into account a constant change of moisture, which has a significant influence on soil compaction. Therefore, the driver should be provided with further in-situ help related to the present soil conditions. The Jaklinski model was used to determine the pressure arrangement in wheel-soil contact as well as the pressure arrangement along soil depth. Figure 3 shows the mathematical model parametres.

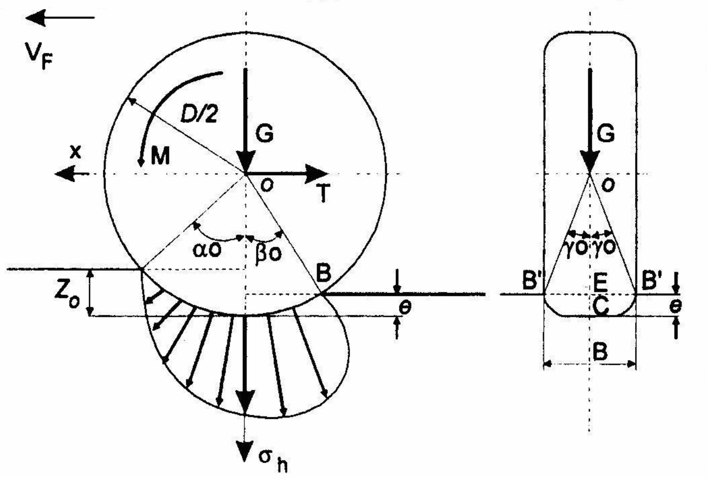

Figure 3. Schematic view of the parameters in the Jaklinski model
and the depth function of soil pressure σ_h

The paramaters shown are as follows: wheel load **G**, motive power **T,** contact area **F**, track depth $\mathbf{Z_0}$, tyre diameter **D**, tyre flatness **e.** Normal tension $\boldsymbol{\sigma}$ and transversal tension $\boldsymbol{\tau}$ on the contact area were computed by a mathematical model. Angles $\boldsymbol{\alpha_o}$, $\boldsymbol{\beta_o}$, and $\boldsymbol{\gamma_o}$ describe the form of the tyre-soil contact area. A k_4 coefficient was used to describe the tyre deformation in combination with soil characteristics. The transfer of vertical pressure in the soil along the depth can be computed using the following formula:

$$\sigma(h) = \frac{G}{T}\left(\frac{D}{B}-1\right)\exp\left(\frac{Z_0\, h}{e\sqrt{k_4}}\right)$$

The research (Sommer, C. et al.; 2001) included four different tyre types which had different mean values of motive power in case of 15% of tyre slippage. The following tyre types were subjected to investigation and the following coefficient values of traction drive k: narrow tyres k = 0,22; standard tyres k = 0.46; wide tyres k = 0.52; terra tyres k = 0.58. Due to the reduction of internal pressure from 2.24 bar to 1.08 bar more favourable values were achieved during the reasearch on a ploughed soil. It was also determined that in case of use of the tyres with a load increase from 3.9 to 5.9 , the soil pressure increased at the depth of 20 cm for 55% (computed) and for 36.4% (measured).

CONCLUSIONS AND FUTURE WORK

Soil compaction due to field machine wheel or track action causes undesirable soil changes. Soil compaction can be reduced by the use of tyres which can operate at a larger contact area between the tyres and the soil, which reduces the tyre pressure on the soil. It can be achieved by wide tyres, terra tyres, and dual tyres. The same can be achieved if you use lighter tractors and implements, as well as if you reduce the tyre inflation pressure. The reduction of soil compaction is also possible if you use caterpillar tracks, especially rubber belt tracks. Wide swath agircultural machinery and the reduction of machine passes are benifical to the soil. Soil compaction is influenced by the parameters described in the paper, but also by soil moisture, which is not influenceable. Due to this tillage should be done at the proper moisture level.

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