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Research Article

Effect of tillage of soil in compaction state

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Abstract

Tillage causes a problem on its condition through the passage of gear during plowing. Hence, we must study and optimize the parameters of this phenomenon to remedy and find solutions to reduce the damage.
This review examines the effect of repeated passages during tillage on agricultural land. The experiments were carried out with a Kubota L3430 tractor (34cv, 1200Kg) equipped with a three-disc plow with a diameter of 46 centimeters. After each tillage, soil compaction was characterized by measures of penetration resistance, density, soil permeability, and moisture. The results show that the number of passage of the agricultural machine during tillage leads to increase respectively the resistance to penetration, the density and illustrates the decrease in water infiltration. This implies that repeated passages on the same soil increase the rate of settlement. The effect of settlement is remarkable especially for the first 20 centimeters of depth

Keywords: *Tillage, compaction, engine, Resistance of penetration, Density.*

1. Introduction

The mechanization of agricultural operations is an indication of its modernization. On the other hand, this mechanization causes problems in the cultivated plots. This compression increases the stress at the tire/soil (A. Elaoud *et al.*, 2013) and reduced the physical fertility of the soil by reducing the storage and supply of water and nutrients.

Among the problems, the compaction of agricultural soils caused by the passage of heavy machinery, during the phytosanitary treatment or the plowing, is a big problem which contributes to losses of crop yields. Hence, we must study and optimize the parameters of this phenomenon to remedy and find solutions to reduce the damage. Also, the ability to accept the passage of vehicles, tractors and tools of action is established from the feasibility of the soil (Billot *et al.*, 1993).

The compaction of agricultural soils is mainly linked to the development of mechanization (Vitlox *et al.*, 2002).

A study of experimental aspect (A. Elaoud *et al.*, 2011; A. Elaoud *et al.*, 2015 ; A. Elaoud *et al.*, 2017 ; S. Chehaibi *et al.*, 2006; S. Chehaibi *et al*, 2013) soil compaction at the wheel track of the tractor and effect of the tillage tool used in Tunisia which shows the degree of compaction of agricultural soils based of mechanical and hydraulic parameters.

When passing an agricultural machine, we will apply it to the meeting point of the two pressures. After a second pass, the already packed area has been transformed into a compact block. The compressed zone increases and can go up to twenty centimeters. Below the area worked by the tools, the compaction clinging after several steps of creating a sincere crust basement. Only the basement that can touch this hard band.

In addition, compaction may decrease evaporative losses of the area around the plant will always be moistened. To this, we can add that this is a way to promote the proliferation of roots and the formation of secondary roots since they grow in a soil density of 1.2 g/cm^3.

Soil compaction is a phenomenon that is so complex that there are several factors involved and influence it. On the one hand, water content, texture, structure and organic matter levels are major factors influencing soil compaction and this is according to Nawaz *et al.* (2013). On the other hand, according to A. Elaoud (2015) there are other parameters acting on this phenomenon such as climate, the characteristics of the machines (weight, tire pressure, tire type ...) and other properties.

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2. Materials and methods

2.1 Site of experiences

The study plot is located in Tunisia with a silty-sandy soil (24% Clay, 50% Limon 36% Sand).

To carry out this experiment, we opted for the installation of a device (figure 2) with parcels divided into three blocks.

2.2 Engine and experimental device

The work was started by taking the initial situation of the soil by performing the measurement of the four parameters: resistance to penetration, density, humidity and permeability. Then, the same treatment was carried out three times per block which is defined by the passage of the tractor without tools and therefore the four parameters were measured in three different locations. Finally, the three different treatments were carried out in each block with a tractor mounted by a three-disc plow (Figure 1) followed by measuring the four parameters in three different locations. The treatments are defined as follows:

- T1: only one passage.
- T2: two successive passages.
- T3: three successive passages.

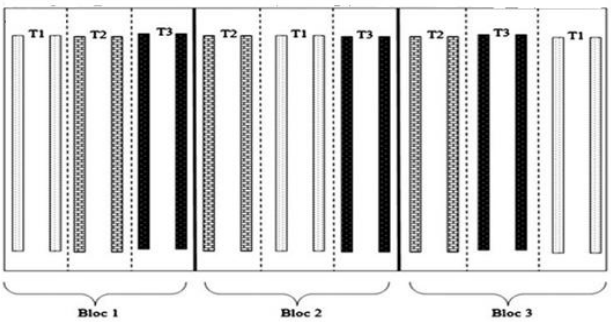

Fig.1 Experimental device

The work was carried out with a KUBOTA L3430 tractor weighing 1200 kg.

The tractor has access to the field with a speed of 2000 turns / minutes. The four wheels front / rear (7 - 16 / 12.4 - 24) of the tractor are inflated in two kilograms of air pressure

Fig.2 Tractor in work

2.3 Soil characterization parameters

Density

The density of the soil is one of the most important parameters for determining the tillage effect. Among the methods for determining this parameter, the method of the cylinder densimeter was used in our test. This sampler densimeter is introduced into the ground through a cylinder guide and hammer (Figure 2).

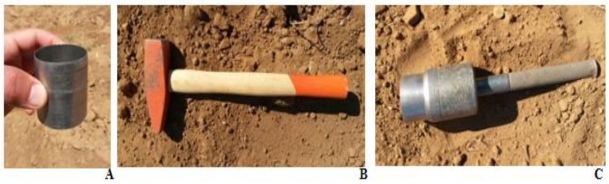

Fig.3 Material used in density measurement and water content - A: cylinder; B: hammer; C: cylinder holder

This method consists in driving a cylinder into the ground in three different depths (10, 20 and 30 cm) and taking samples at each depth for the three tillage techniques.

Hymidity

The sample is placed in an oven at 105ºC for 24 hours (Figure 25) until a constant weight is obtained which corresponds to the dry weight.

Fig.4 Dry soil samples in the oven

The density of the soil is determined according to the expression:

$$Mv = Ms / V$$

With

Ms: dry mass (g);
V: volume of the cylinder (cm^3);
Mv: density (g / cm^3);

The volume of the cylinder is:

$$V = 5 * \pi * r^2$$

With r = 2.5 cm where V = 98.17 cm^3

Water content

The soil moisture content is determined as follows:
-Weigh the sample in the fresh state and determine its wet weight;
-Place the sample in the oven at 105ºC for 24 hours;
-Weigh the sample and determine its dry weight.
The water content will be determined by the expression:
$W = ((Mh - Ms) / Ms) * 100$
With Mh: wet mass of the soil sample;
Ms: dry mass of the soil sample;
W: water content (%).

Resistance to penetration

Resistance to penetration is a physical parameter that allows knowing the state of a soil. It is measured in situ using a penetrometer (Figure 6) whose handling is the depression into the ground of the device that records every centimeter runs a force value.

To take action, you first need to establish a work plan. This plan includes the definition of plots of land, the number of measurements per plot and the parameters of penetrologger. It is possible to create the plan program on the penetrologger directly or using a computer.

The main features of the penetrologger are:

• The measurement results can be displayed both graphically and numerically.
• Automatic calculation of mean values and standard deviations. It is possible, optionally, to store the data in the device for later analysis on computer since its storage capacity is important (500 measurements)
• The graphical software allows you to directly read the data on graphs or in digital form, or to print them.
• Programmable project planning.

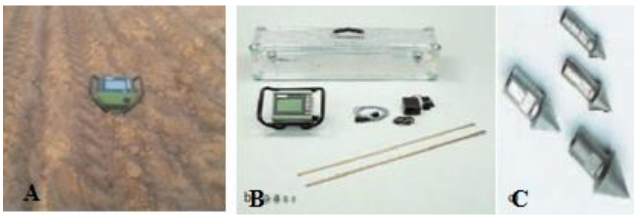

Fig.5 Penetrometer

A: Measuring device, B: Accessories, C: Tapered tips

Permeability

Soil permeability is one of the physical properties of the soil. It is defined as the speed of the flow of water in the soil or the ability of the soil to let the water through.

A soil is considered impervious when the coefficient K is less than 10^{-6} m / s. Conversely, above 5 10^{-5} m / s, the soil is considered very permeable and therefore, its ability to infiltrate is excellent. Table 1 presents the different classes of permeability expressed in m/s while briefly describing the general characteristics associated with the soil.

Table 1 Infiltration classes according to the coefficient of permeability

Permeability (m/s)	Soil Typology	Nature of the soil	Ability to infiltrate
$K < 10^{-6}$	Very little permeable soil	Clay	Nothing
$10^{-6} < K < 3.10^{-6}$	Low permeability soil	Clay soil	Bad
$3.10^{-6} < K < 10^{-5}$	Soil poor permeability	Loamy soil	Low
$10^{-5} < K < 2.10^{-5}$	Soil enough permeable	Very fine sand	Good
$2.10^{-5} < K < 5.10^{-5}$	Permeable Soil	Fine sand	
$K > 5.10^{-5}$	Very permeable soil	Medium sand	Very good

This parameter is determined by the Muntz method (Figure 6) which is based on the principle of constant load infiltration. This is to install a cylinder depressed 5 cm deep in the soil in which we poured a blade of water of 3 cm which will remain constant throughout the test. Once the blade of water is launched, a vase of Mariotte of capacity 3 liter filled with water is installed reversed on the cylinder. In this time, a timer has been triggered for the measurement of time. Then, we recorded the evolution of infiltrated volume as a function of time. The reading of the volume of water was made from a graph paper lying on the vase.

Fig.6 Permeability measurement

3. Results and discussion

3.1 Evaluation of the moisture content during the work done

Figure 7 shows the comparison of moisture along the experiment on the first twenty centimeters of soil. It is found that the moisture values increase well after tractor entry with the plow and this is due to the heavy continuous rain that fell before 3 days of the test.

The value of moisture decreases with depth for the 3 treatments and this explains the effect of superficial layer packed on the inner layers.

Likewise, the value of humidity also decreases from one treatment to the next because of successive passages on the same trace.

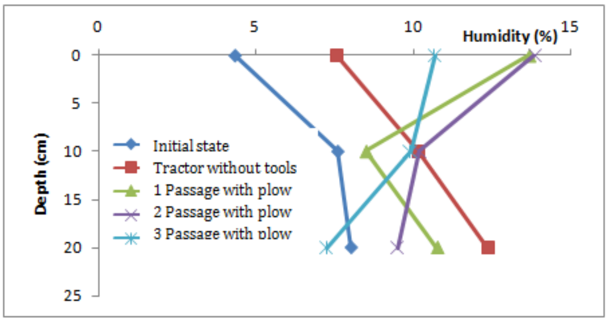

Fig.7 Moisture of the soil

3.2 Density study

For the initial state, the value of the density (Figure 8) increases while going towards the deepest layers. This increase may be due to the increase in the intensity of settlement caused by tillage that probably preceded our work.

The density values at the depth (ten centimeters) for the two treatments concerning the entry of the tractor without tools and the passage of the tractor once with the plow seem a little wrong.

The increase in the density value from one step to the next shows the effect of the repeated passage on the ground, thus increasing the phenomenon of soil compaction.

The decrease in density while going to the deeper layers is remarkable. In fact, this decrease is not strong. This may reflect that the settlement is more remarkable in the upper layers than in the lower layers.

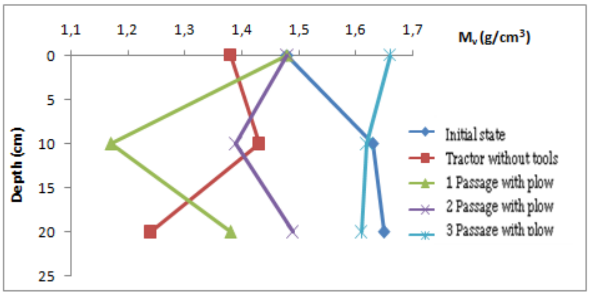

Fig.8 Density of the soil

3.3 Permeability study at the site

Permeability indicates the rate at which water enters the soil surface. The soil of the site has a silty-sandy texture.

After performing the field permeability measurement three times per treatment, a whole calculation procedure must be followed in order to have the value of permeability.

Plotting of the evolutionary curve of cumulative infiltration as a function of time log ((Icum) = f (log (t)) in the figure 9.

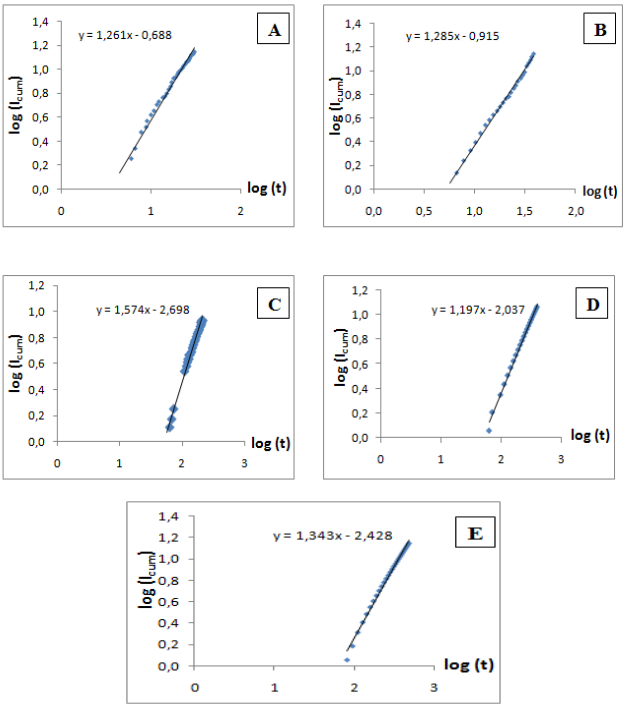

Fig.9 Cumulated infiltration as a function of time

A: Initial state, B: Passage of the tractor without tools, C: Single pass of the tractor with plow, D: Two successive passes of the tractor with the plow, E: Three successive passages of the tractor with the plow.

The determination of the cumulative infiltration as a function of time from the curve then the base time and finally the rate of infiltration are illustrated in the table 2.

Table 2 Infiltration rate

	I_{cum}	T_{base} (min)	I_{base} (m/s)
Initial state	$0.205 . t^{1.2617}$	2.617	$5.5 . 10^{-5}$
Tractor without tools	$0.121 . t^{1.2854}$	2.854	$3.5 . 10^{-5}$
1 passage with plow	$0.002 . t^{1.5745}$	5.745	$1.4 . 10^{-6}$
2 passages with plow	$0.009 . t^{1.1971}$	1.971	$2.1 . 10^{-6}$
3 passages with plow	$0.003 . t^{1.3431}$	3.431	$1.3 . 10^{-6}$

We observe the high significance of results of infiltration test with a regression R^2 (0.99)

It is remarkable sharp decrease in value of permeability during carrying out work going from a value of 5.5 10^{-5} m/s to a value of 1.3 10^{-6} m/s. Indeed, according to (Table 13), the soil from the initial state was a very permeable soil of "medium sand" nature and which has a very good infiltration ability. After the work has been completed, the soil has become poorly permeable with poor infiltration ability and behaves like clay soil.

This shows that the phenomenon of settlement is present in the layers following the tillage with repeated passages of the machine equipped by a plow with three disks.

3.4 Study of resistance to penetration

Figure 10 shows that the curves are the same for all passages. Indeed, for the first 10 centimeters, each passage contributes to increasing the value of the resistance to penetration. In fact, this shows that the phenomenon of settlement is accentuated in the superficial layers than in the lower layers.

The permeability values already measured give us good information about the state of the soil, which has been very permeable and has become bad in terms of infiltration rate. The permeability results decrease well after the tractor has moved with the plow. This strong decrease cannot be due only to the effect of the passages and the weight of the machine with the tool but the rainfall because the saturation of the soil in water and it contributed to the more of settlement which explains the rise in compaction rates especially in the first ten centimeters.

The part of 10 to 15 centimeters deep appears a part of meeting between the curves of the different stages of work until they meet with the values of the treatment of the initial state at the level of 15 centimeters of depth. This is explained by the general appearance of the resistance to penetration, which generally increases in the beginning and then decreases.

The passage of the tractor without tool caused a clear settlement compared to the initial state which is high and which spreads on the first twenty centimeters. Whereas after the entry of the tractor with the plow, the settlement is clear just for the first ten centimeters. This decrease in the endangered area can be explained at the time interval between the different stages that has left the ground at rest momentarily.

Penetration resistance values increase with depth. This continuous increase explains the effect of superficial layers already packed on the inner layers.

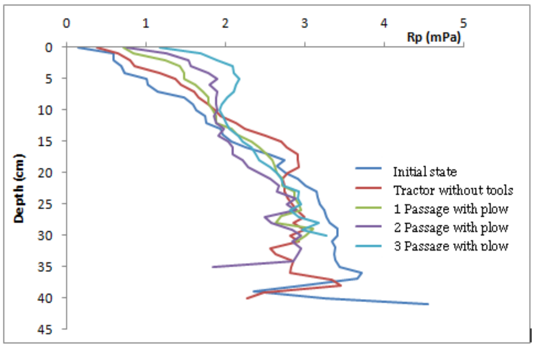

Fig.10 Penetrometric profile of treatments

Conclusions

Soil compaction becomes one of the problems contributing to losses in the plant and soil. This work is in addition to the studies already carried out to better characterize this phenomenon. Measurement parameters (density and resistance to penetration) increase with increasing number of passes during tillage. On the other hand, permeability decreases with increasing compaction. As a solution to this phenomenon, access to the plot with farm machinery is required at the appropriate time for the soil.

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