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Research Article

Comparative Study of the Compaction Soil According of two Routes: Conventional Work and Permanent board

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Abstract

Soil compaction is a serious problem for vegetable crops. This compaction is caused by the passage of gear on the soil, especially under conditions of excess moisture. We studied the influence of the number of passage of the tractor, and the permanent plates on the degradation of the soil and the compaction. The experimental pieces that are based on the repeated passage of tractors under two different tillage conditions. The study of the resistance to penetration is carried out on two plots, one worked in a conventional way and the other worked in permanent boards (beds). This study showed an increased resistance to penetration by increasing the number of passage of the tractor on the ground. We have valued the density of the soil, and it has been found that there has been an observable increase in the density in the permanent boards. Statistical analysis showed that our experimental results are highly significant.

Keywords: *Conventional work, Permanent boards, Pass tractor, Penetration resistance, Bulk density.*

1. Introduction

Soil settlement is one of the major problems of vegetable crops. Soil compaction by wheeled agricultural vehicles has a negative impact on the structure of arable soils and in severe way, it will affect crop production in both the short term and long term (Soane, 1994). Thus, the practicability of a soil reflects its ability to accept the passage of gear and the action of tools (Billot et *al.*, 1993). The main causes of soil compaction are directly or indirectly related to the development of mechanization (Vitlox and Loyen, 2002). Over-use of machinery and inadequate soil management leads to compaction. In addition, the repeated passage of gears can vary the physical properties of the soil such as permeability, bulk density and resistance to penetration (Chehaibi and Hamza, 2006).

An experimental study (Elaoud and Chehaibi, 2011) of the soil compaction in the track of the wheels of the agricultural tractor used to conduct the cultivation operations showed that the pressure exerted by the wheel on the Surface of the soil, results in an extension of the pressure in depth resulting in a densification of the soil. The intensity of the soil compaction depends essentially on two major factors which arise mainly from the mechanical stresses applied by the machine and the mechanical resistance of the soil at the time of the passage of the latter. The mechanical strength of the soil depends on the texture and structure of the ground and its water status. The stresses applied to the soil depend on the weight of the craft, its forward speed, the contact pressure between the tires and the ground, the type of tire and the frequency of the passages (Larson et *al.*, 1994). This results in higher sensitivity to of soil compaction which is persistent and cumulative. Research on the simulation and experimental of agricultural soil compaction has been evaluated in Tunisia (Elaoud and Chehaibi, 2011; Elaoud et *al.*, 2014a; Elaoud et *al.*, 2014b). Experimentally, a minority of the study was performed in Tunisia, specifically in the area of Grombalia-Nabeul. Therefore, the objective of this work is to evaluate the soil's resistance to penetration and its Bulk density measured in conventional tillage, compared to that of the tillage in permanent boards.

2. Materials and Method

2.1 Experimental site and soil

The study was carried out at the High School of Agricultural Training in Citrus and Vines *Bouchrik-Grombalia* (Nabeul-Tunisia). The trials were conducted on a clay sand soil. With 21% clay, 6.9 loam and 71.8% sand. (Turki, 2016)

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2.2 Experimental plans and conditions

In this study, an assessment of the impact of the one worked in a conventional way and the other worked in permanent boards.

The technique of permanent boards implies that the tractor passages are always made in the same places in the fields and that the cultivation boards remain exactly the same places from year to year. Thus, the board generally corresponds to the width of land spanned by the tractor.

A first plot worked according to the conventional route of work on ground where the circulation of the wheels of the tractor is random, and a second plot worked in permanent boards 1 m in width, with wheels always evolving in the same place. The measurements were carried out initially to characterize the state of the soil, and just after one and two tractor passages. The passages are spaced 30 days apart. The experimental design was developed to evaluate the load settlement in the crop profile of agricultural soil. The evolution of the state of soil compaction was the subject of direct measurements after tillage and monitoring over time. The aim of the study is to analyze the behavior of the soil after passing the gear in the traditional tillage route on the one hand and in the working route of the soil in permanent boards.

2.3 Characterization and measurement modalities

2.3.1 Measurement of penetration resistance

Soil penetration resistance is an important mechanical property that can be used as an indicator of soil compaction and it is important in determining the least limiting water range. In this study, the penetrometer was used, to measure soil mechanical resistance in the field (Vitlox, 1998). Soil resistance to penetration of a point is an indicator of the state of compaction and its evolution over time. It is a complex function of parameters characterizing the state of a ground such as cohesion, angle of internal friction and friction metal underground. Measures the state of soil compaction using the penetrometer must be accompanied by measures of its water content near the points of measurement (Billot et *al.* 1993). Different types of penetrometer have been developed to measure soil penetrability (Bengough et *al.*, 2001; Lowery et *al.*, 2002) that operate on static or dynamic principles. The static penetrometer is pushed into the soil at a constant rate, while the dynamic penetrometer is driven into the soil by repeated hammer-blows (used mainly in civil engineering), (Herrick et *al.*, 2002) described a dynamic penetrometer for use in soil science, enabling cheap, repeatable soil strength assessments in the field. The penetrometer model that we used for measurements of soil resistance to penetration in the different treatments is dynamic penetrometer (penetrologger). This is penetrologger has been especially developed to measure the resistance to penetration of the soil and to save the measuring results to digitally process them on a computer. The penetrologger is available as a complete set suitable for measurements up to a depth of 80 cm. The set consists of the penetrologger, cones, cone check, probing rod, a depth reference plate, a set of tools, a battery charger, a cable, software and a test report. The penetrometer used is of the electronic type, also called penetrologger (Fig 2).

The application of equal pressure on both handles pushes the cone vertically into the soil. A mechanism of integrated measuring allows recording the penetration resistance encountered during the phase of insertion of the cone (Abrougui et *al.*, 2012).

2.3.2 Measurement of Bulk Density

Soil Bulk density was measured by a soil cylindrical core (diameter = 5 cm, height = 5 cm) taken with a cylinder densimeter, the sample was collected every 10 cm, at a depth of 30 cm. We then obtained the dry mass of the sample after drying in a stove at a temperature of 105°C for 24h. Bulk density (g/cm^3) is a parameter that makes it possible to distinguish the physical state of a soil. The dry soil density is measured on a cylindrical core of soil (diameter D = 5 cm, height h = 5 cm) taken with a cylinder densimeter, samples are taken every 5 cm. This method involves pressing a cylinder into the ground in three different depths (10, 20 and 30 cm) and sampling at each depth for the two working modes (conventional and permanent). The sample is placed in an oven at 105 ° C for 24 hours until a constant weight corresponding to the dry weight is obtained (Yoro and Godo, 1990).

The density of the soil Mv is determined according to the expression: Mv= Ms / V

With Ms: dry mass (g); V: cylinder volume (cm); Mv: density (g / cm). The volume of the cylinder is:

$V = 5 \times \pi \times r\ 2$

With r = 2.5 cm, where V = 98.17 cm.

2.4 Statistical Analysis and Modeling

From the experimental results, a model was chosen considering the soil penetration resistance as a function of the soil bulk density, depth and number of passes. The soil penetration resistance data were submitted to an analysis of variance at a 5% significance level. The effects of the variables were studied by regression analysis. All statistical analyses were performed using the Excel specific program (Statistical). The model was chosen based on the coefficient of determination, the significance of regression coefficients.

Modeling based of relation between the dependent variable and number of independent variables are in the form

$$Y_i = a_0 + a_1X_1 + a_2X_2 + a_3X_3 + \dots + a_kX_k$$

Where, for a set of "i" successive observations, the predicted variable Y is a linear combination of an offset "a_0", a set of "k" predictor variables "X" with matching "a" coefficients, and a residual error ε. The "a" values are commonly derived via the procedure of ordinary least squares.

The significance of coefficients was estimated by student's t-test and p-values.

The higher the level of the t-value and the lower the p-value, the more significant is the coefficient (Khuri et *al.*, 1987). The sign of each coefficient suggests the direction of the relationship. The elimination of insignificant variables gives more accurate forecasts according to Sonmez and Rowings (Sonmez et *al.*, 1998). The R^2 have been widely used for model evaluation, these statistics are oversensitive to high extreme values and insensitive to additive and proportional differences between model predictions and measured data (Legates et *al.*, 1999).

Two models will be established in our case: the first describes a compaction model when Conventional Work and the second for Permanent board.

3. Results and discussion

The objective of this study is to evaluate soil compaction in both conventional and permanent soil working methods and to find a statistical model while taking into account the two physical parameters of the soil such as resistance to penetration and the density.

3.1 Soil resistance to penetration

Examination of the results of the penetration resistance of the control and of the plot grown in permanent plates shows that soil resistance follows the same pattern. It grows from the surface of the soil to the depth considered. Indeed, at the upper horizons (0-5 cm), the resistance to penetration of the soil is in the vicinity of 1 daN/cm², on the other hand, at 25 cm depth for example, it reaches 2 daN/cm², or even more. It has been observed that rainfall is an important agent (moisture) thus contributing to the accentuation of the settlement considering that the resistance to penetration measured in the initial state is significant for both plots (conventional work and work in planks (Figure 1).

However, it should be noted that conventional tillage has provided the highest penetration resistance values. This can be explained by the fact that the wheels of the tractor by advancing on the ground, affect more surface and induce more settlement.

On the other hand, when working the floor in permanent boards, the wheels always run in the same place and the surface worked is not disturbed by the pressure of the wheels.

Furthermore, after the tractor has passed, there is a clear difference between the values of the ground resistance compared to the initial state. Indistinctly (Verhallen, 2011) states that 80% of compaction comes from the first pass. Thus, our results almost coincide with those of these researchers, noting that the phenomenon is not proportional. Indeed, it is noted that the resistance to penetration of the first passage is greater than that of the initial state at the level of the two routes. Following the second passage, an increase in the resistance of the soil with respect to the initial state is also recorded. However, the soil worked in conventional mode is marked by high values. Indeed, at 20 cm depth for example, the resistance of the soil measures 2.5 and 1.9 daN/cm² respectively in conventional soil work and in permanent boards. (Figure 2 and figure 3).

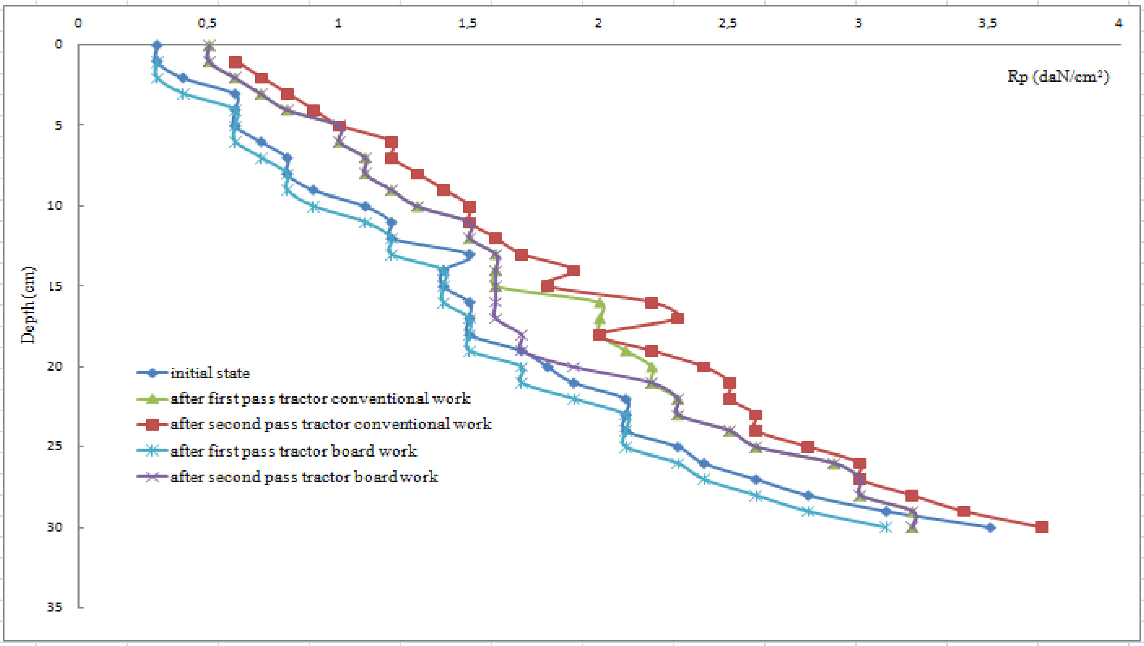

Fig.1 Measure of soil resistance to penetration function of number pass tractor and working conditions

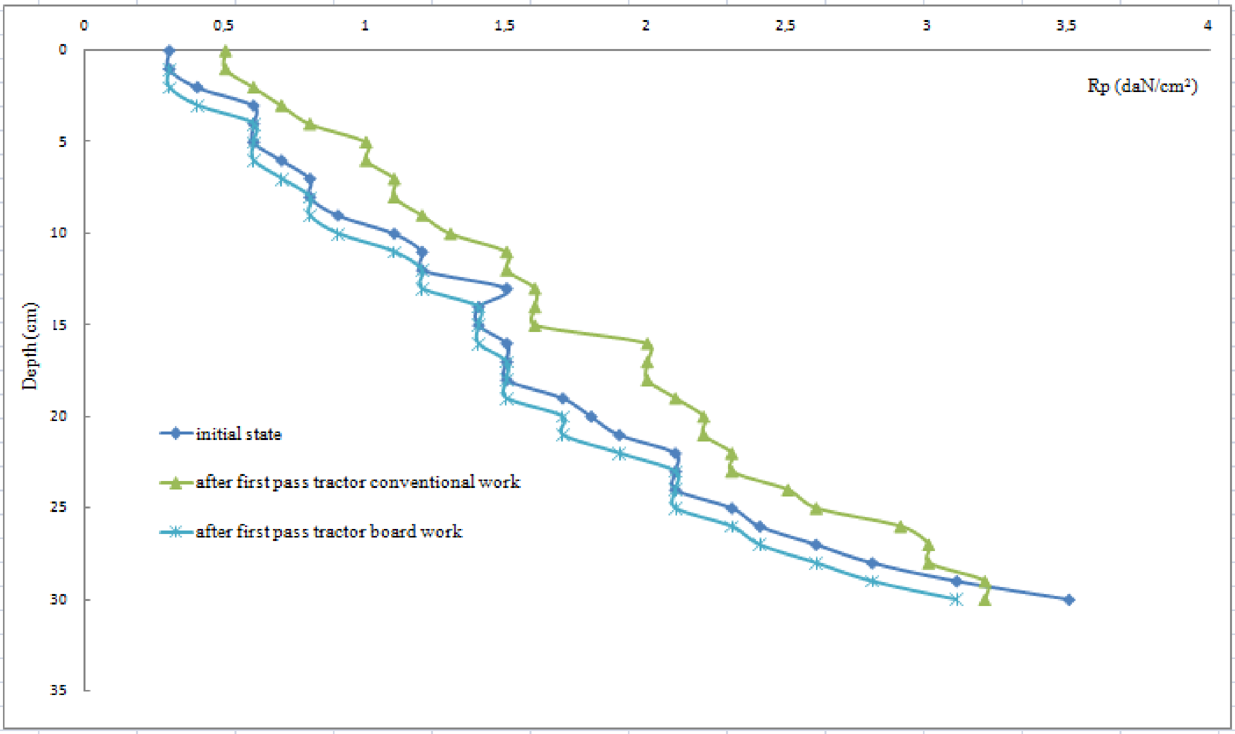

Fig. 2 Measure of soil resistance to penetration after first pass tractor

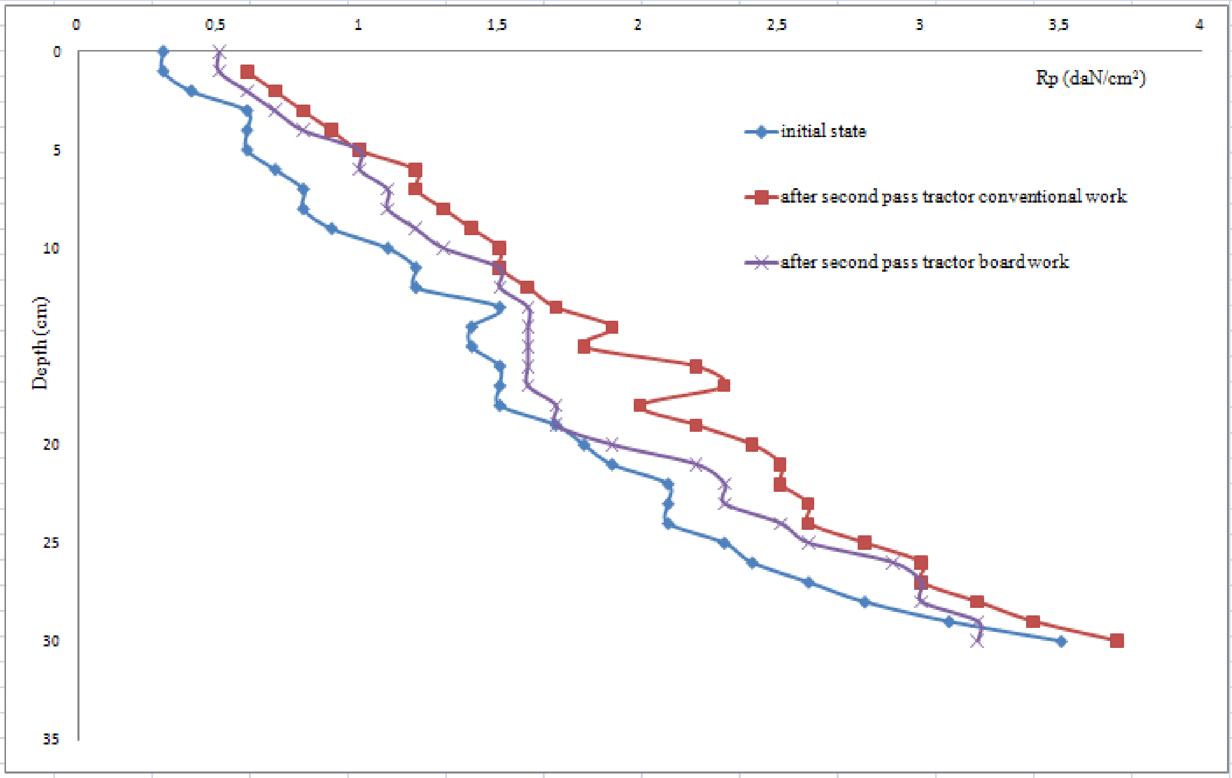

Fig. 3 Measure of soil resistance to penetration after second pass tractor

3.2 Bulk Density

The increase in density is a function of the number of tractors passing through the two plots, the one worked in conventional mode and that worked in permanent boards (Figure 4).The Bulk Density measured in the permanent plots over the depth of 20 cm range from 1.432 to 1.398 g / cm³ (Fig 4).

This shows that there is a natural decompaction even if there is a passage of the machine. The value of the bulk density increases in the parcel worked in permanent boards. This increase may be due to the higher settlement intensity caused by tillage which preceded our work before the construction of the boards (Figure 5 and 6).

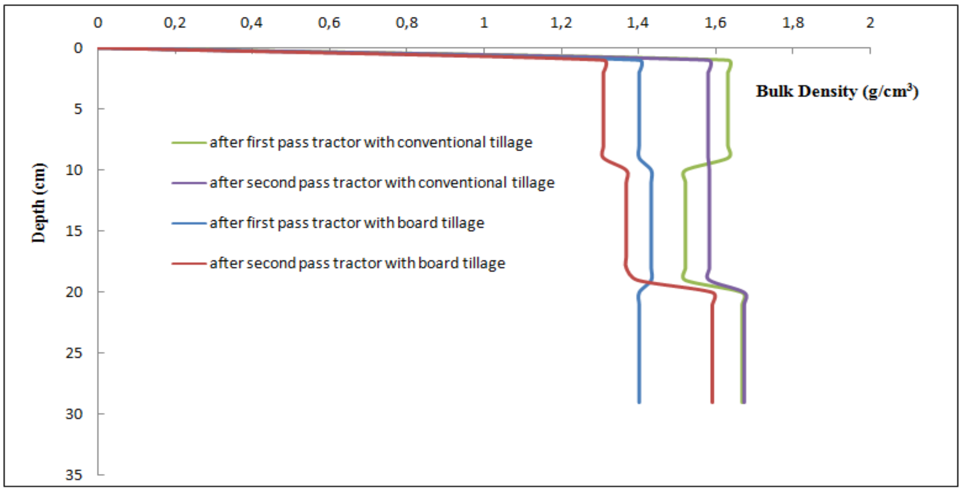

Figure 4. Measure of soil density function of number pass tractor and working conditions

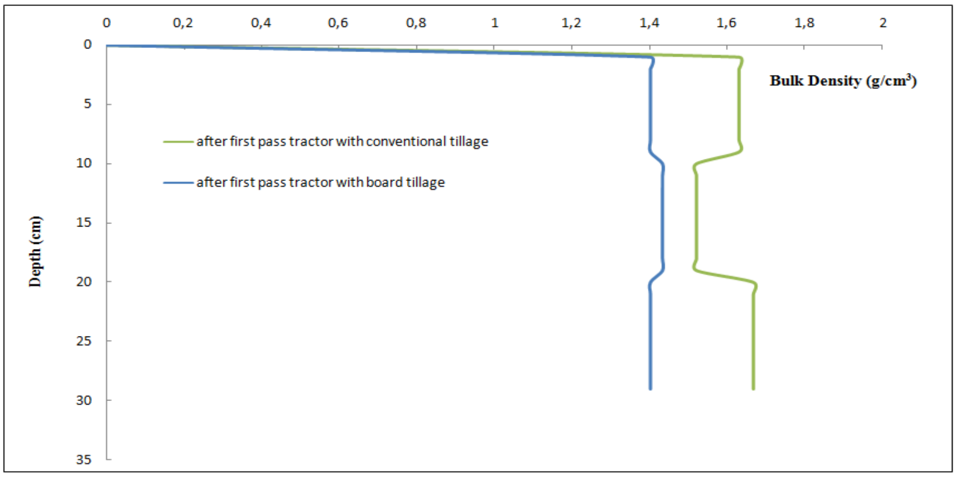

Fig. 5 Measure of soil density after first pass tractor

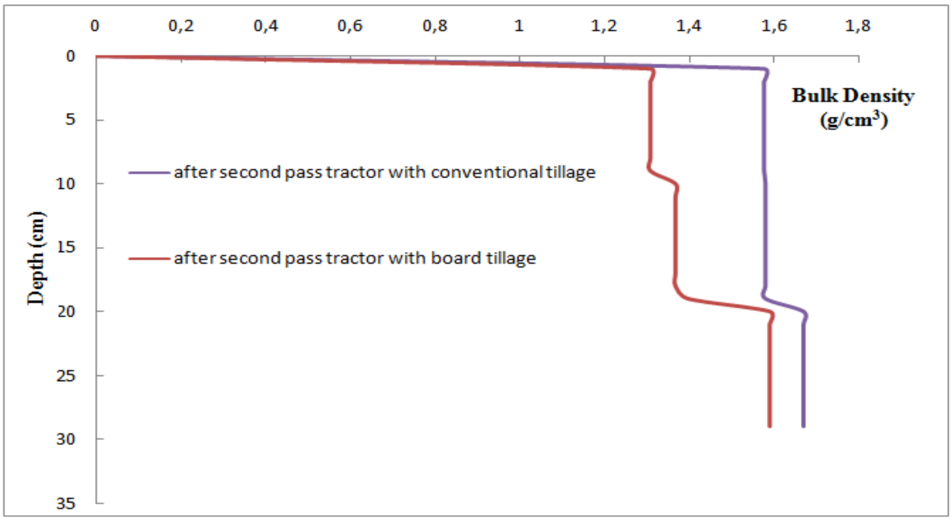

Fig. 6 Measure of soil density after second pass tractor

3.3 Statistical analysis and Modeling

3.3.1 Statistical analysis for Permanent Board

The regression statistics of model for permanent board are presented in Table 1. As can be seen the multiple R coefficient indicated that the correlation between the different variables and Rp was moderate (The multiple R = 0.98). According to R square statistic, 97 % for the total variance for the estimation of Rp was explained by model. The descriptors and the regression coefficient of model ‘permanent board’ presented in Table 2 and 3 demonstrated that except the bulk density variable (P-value= 0.34), all the soil mechanical properties measures were statistically significant in estimating Rp (P-value < 0.05). In terms of the relative importance of the estimation of a dependent variable, it can squabble that the depth and number of passes made the largest contribution across the model (P-values = 2.9606E-42 ; 1.2539E-07 respectively). The choice of the input of the tractor (passage number) played an important role in increasing soil compaction. Indeed, the model proposed for estimation of Rp, obtained from the experimental data of the soil penetration resistance determined from the cone index while considering the different levels of Depth (D), Bulk Density (BD) and Number of passes (N), is given by the following equation:

Rp=0.2239-0.0924D+0.2204 N– 0.0434 BD

This equation represents the proposed model from the regression analyses for permanent board. The model was chosen considering the determination coefficient (R^2), the significance of regression coefficients and the lack of adjustment of the model. To test the significance of the analysis of variance (F-test) is performed according to the standard procedure (Montgomery et al., 2003). This test follows an F-distribution with degree of freedom (d.o.f) ν_1=3 and ν_2=56 for Rp. Since, the calculated F-value (F=695.485276) is greater than the critical F-value (2.88379E-44), so the significance is strong. Therefore, it is concluded that the model is valid for permanent board.

Residual plot is applied to detect potential outlier observations (Figure 7). The residues show a self-correlation between the different observations. The residual values are close and located between [-0.6, 0.6].

3.3.2 Statistical analysis for Conventional Tillage

The regression statistics of model for conventional work are presented in Table 4. As can be seen the multiple R coefficient indicated that the correlation between the different variables and Rp was moderate (The multiple R = 0.97). According to R square statistic, 95 % for the total variance for the estimation of Rp was explained by model. The descriptors and the regression coefficient of model ‘permanent board’ presented in Table 5 and 6 demonstrated that except the bulk density variable (P-value= 0.16), all the soil mechanical properties measures were statistically significant in estimating Rp (P-value < 0.05). In terms of the relative importance of the estimation of a dependent variable, it can squabble that the depth and number of passes made the largest contribution across the model (P-values = 4.7034E-38 ; 5.8314E-05 respectively).

The model proposed for estimation of Rp, obtained from the experimental data of the soil penetration resistance determined from the cone index while considering the different levels of Depth (D), Bulk Density (BD) and Number of passes (N), is given by the following equation:

Rp=0.0498-0.0933 D+0.2122 N– 0.1068 BD

This equation represents the proposed model for ‘conventional work’.

To test the significance of the regression analysis of variance (F-test) is performed according to the standard procedure. If the calculated F value is greater than the F critical value, there is a real relation between dependent and independent variables. This test follows an F-distribution with degree of freedom (d.o.f) ν_1=3 and ν_2=56 for Rp, so that the critical region will consist of a value exceeding 1.10157E-37. Since the calculated F-value (F=396.83402) is greater than the critical F-value (1.10157E-37), so the significance is strong. Therefore, it is concluded that the model is valid for ‘conventional work’.

Residual plot is applied to detect potential outlier observations (Figure 8). The residues show a self-correlation between the different observations. The residual values are close and located between [-0.5, 0.5].

Table 1 Regression statistics for permanent board (bed)

Statistical regression	
Coefficient of multiple determination	0.98684435
Coefficient of determination R^2	0.973861771
Error-type	0.141071433
Observations	60

Table 2 Analysis of variance for testing significance of regression for permanent board (bed)

	Degree of freedom	Sum of squares	Average square	F	Critical Value F
Regression	3	41.52286897	13.84095632	695.485276	2.88379E-44
Residuals	56	1.114464362	0.019901149		
Total	59	42.63733333			

Table 3 Analyses of regression considering different parameters for permanent board

	Coefficients	Error-type	t-value	P-value
Constant (a_0)	0.22391332	0.104422092	2.144309841	0.03636273
Variable X 1 (a_1)	0.09426138	0.002419836	38.95363003	2.9606E-42
Variable X 2(a_2)	0.22043555	0.036427374	6.051370827	1.2539E-07
Variable X 3 (a_3)	-0.043410312	0.045707284	-0.94974604	0.34632228

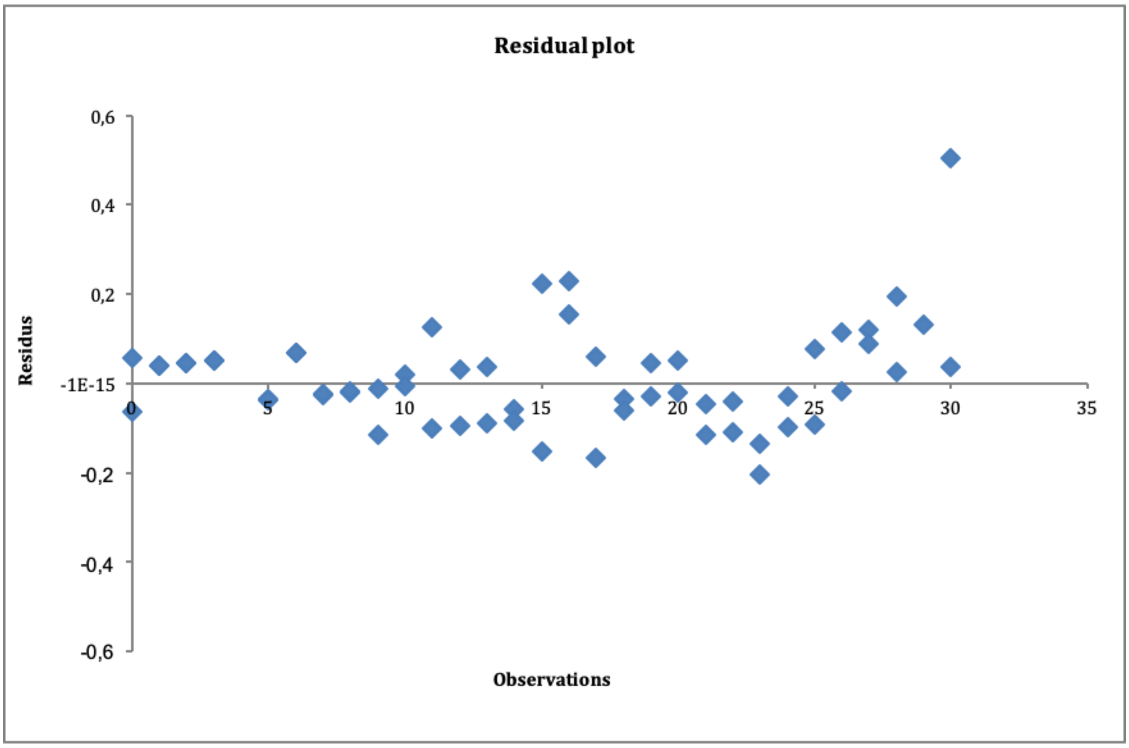

Fig. 7 Residual plot versus the observations

Table 4 Regression statistics for conventional work

Statistical regression	
Coefficient of multiple determination	0.97727902
Coefficient of determination R^2	0.955074282
Error-type	0.184766697
Observations	60

Table 5 Analysis of variance for testing significance of regression for conventional work

	Degree of freedom	Sum of squares	Average square	F	Critical Value F
Regression	3	40.642231	13.5474103	396.83402	1.10157E-37
Residuals	56	1.911769	0.03413873		
Total	59	42.554			

Table 6 Analyses of regression considering different parameters for conventional work

	Coefficients	Error-type	t-value	P-value
Constant (a_0)	0.049888197	0.16119853	0.30948296	0.75810283
Variable X 1 (a_1)	0.093330269	0.00286923	32.5280103	4.7034E-38
Variable X 2(a_2)	0.212215104	0.04879157	4.34942182	5.8314E-05
Variable X 3 (a_3)	-0.106837573	0.07564594	-1.41233711	0.16338406

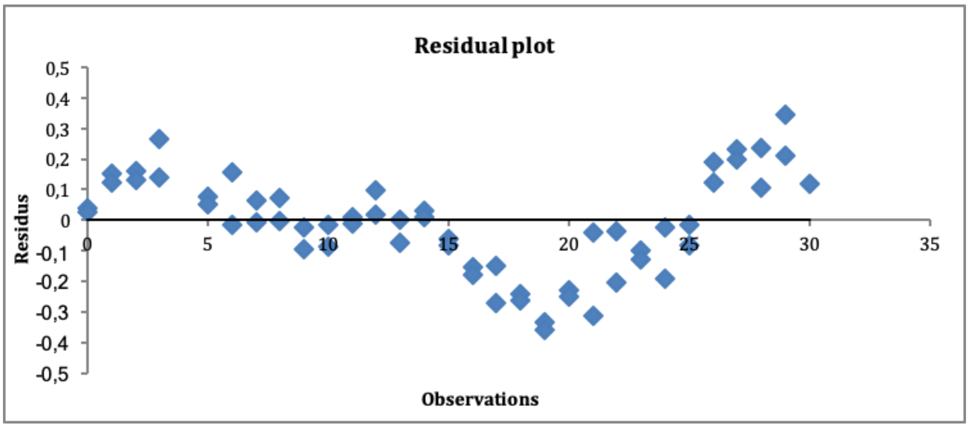

Fig. 8 Residual plot versus the observations (conventional work)

Conclusion

We conducted an experimental study on the effect of the number of passage of the tractor under two conditions of the tillage one or the plot has undergone a conventional tillage and the other has undergone a work of the soil in permanent boards (beds) where the wheels of the tractor do not run over the worked belt, showed the influence of the number of tractor passes on the degree of compaction of the soil. Indeed, the increase in the number of passage of the tractor on the ground transmits a higher pressure which leads to a higher compaction. Therefore, in order to minimize soil compaction is to use light tractors, or to use tractors equip large tires to distribute the weight force, or to minimize the ground wheel contact surface by the use of boards Permanent staff. The average penetrometer profiles are closely related to the number of passes that the proof that the first pass is most important to the impact of the regulation, therefore it is necessary to choose the best condition in the first passage (Elaoud et *al.*, 2011). The time parameter is measured in this work and shows that the soil decomposes by time (a few days after compaction) by natural effect (air absorption).

The two methods 'permanent board and conventional work' are very similar. For 'permanent board' have to be able to declare that it is slightly more important.

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