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COMPARISON OF THE EFFECT OF THREE TILLAGE TECHNIQUES ON SOIL STRUCTURE AND CONSEQUENCES ON THE ROOT DEVELOPMENT OF DURUM WHEAT

S.Echcherki [1], M.A. Feddal[2], R. Labad[3] and Y.Bendib[4]

ABSTRACT

The objective of our study was to compare the effect of agricultural soil preparation on the physicomechanical properties of the soil and the consequences on the root system of wheat. To achieve these goals, three technical tillage chains (chain 1: deep tillage, chain 2: agronomic tillage, chain 3: no-tillage), were compared in the same pedoclimatic and historical situations. The experiment was carried out during year 2019/2020 on silty clay soil in the experimental station of the National Higher School of Agronomy (Algiers).

The results show that the technique affected the soil properties and the root system differently. The agronomic tillage has the best positive effect on soil humidity, porosity, and soil penetrometer resistance (p-value :0,0001). Concerning the roots, the density, the diameter, and length were better when the soil is deeply tilled, non-tilled, or agronomical tilled, respectively. Examining all the results of this study it is shown that how tillage is reflected in and contributes to the farmer's orientation towards the right choice to optimize and conserve soil and water at the same time. Thus, under this study's experimental conditions, the technical itinerary of tillage with agronomic ploughing appears to be an alternative to conventional ploughing. This method of tillage is easily feasible from a technical point of view. Besides, it can generate economic gains compared to ploughing. However, its impacts on the soil and crop yields need to be studied in the longer term.

(Key words: Soil moisture, porosity, penetrometric resistance, tillage, roots)

INTRODUCTION

North Africa is often considered a "climate change hotspot" that has been receiving increasing attention in recent years, particularly from natural and social scientists, especially agriculture (Schilling *et al*., 2020) . This problem is exacerbated by the failure of farming practices used by farmers, including tillage and the management of crop residue and weed. Besides, it would be interesting to recall that the establishment of field crops is very demanding in terms of energy needs. (Mebarki *et al*., 2020).

Tillage has been used for millennia to prepare the soil prior to sowing many of the annual grain crops. It involves applying power to break up and rearrange the entire tops oil structure. It has the primary aim of destroying weeds and pests but is also important for incorporating, redistributing or releasing nutrients and making the soil texture suitable for seed sowing, seed germination and for easy penetration of seedling roots (Anonymous, 2001). The first tool for burying and covering seeds appeared about 10,000 years ago in the Sumerian civilization. Then was gradually perfected over the centuries until the first "Roman plough" described by Virgil around the first year of humanity. The "modern plough" was designed in the United States by Thomas Jefferson in 1784 and patented by Charles Newfold in 1796. Its use then became widespread and quickly became one of the symbols of modern agriculture (Lal *et al*., 2007). Growth in ploughing and farming was promoted to feed a developing nation and the practice continued nearly unchecked through the early 20th century. By 1920, 955 million U.S. acres were in farmland. Over half was ploughed regularly. Intensive farming was the order of the day for much of the nation's breadbasket.

But then came the Dust Bowl and everything changed. Intensive farming helped to transform the United States into a powerful nation that was growing almost unchecked. But a disaster of natural and man-made origin

1. Ph.D. Student, Laboratory for the control of water in agriculture, National Higher School of Agronomy (ENSA), ES1603, Dept. of agricultural engineering, El Harrach, Algiers
2. Assoc. Professor, Laboratory for the control of water in agriculture, National Higher School of Agronomy (ENSA), ES1603, Dept. of agricultural engineering, El Harrach, Algiers.
3. Assoc. Professor, Laboratory for the control of water in agriculture, National Higher School of Agronomy (ENSA), ES1603,El Harrach, Algiers.
4. Assoc. Professor. National Higher School of Agronomy (ENSA), ES1603, El Harrach, Algiers

almost crippled the nation and changed how farmers thought about crop production. Since then, the results of numerous researches under different climatic zones in the world have revealed problems common to ploughed soils: compaction, decrease in soil organic matter content, erosion, limitation of water circulation (Köller, 2003; Lal *et al*., 2007; Baumhardt and Jones, 2002) and the energy and financial cost of this practice (Monnier, 1994). As a result, in the last few decades, the world shifted to various forms of soil tillage without turning the soil layers, up to direct seeding. In comparison, the conventional ploughing (ploughing with moldboard, turning the topsoil layer to a depth of 20-30 cm) is going less and less used. These techniques were grouped under simplified cultivation techniques, or conservation agriculture, when they leave more than 30% of the residues of the previous crop on the soil surface (Köller, 2003; Labreuche *et al*., 2007; Bhattacharyya, *et al*., 2006; Amanullah, 2017). The presence of mulch on the surface and the limitation of vertical soil disturbances protect the soil from wind and water erosion, limit MOS losses. Besides, mulch promotes soil biological activity and makes it possible to increase the working width of implements and thus reduce farmers' workload without reducing crop yields (Kern and Johnson, 1993; Köller, 2003; Arshad, *et al*., 1999; Dahai Guan, 2015; Hammel, 1989; and Kadu, *et al*., 2018).

In Algeria, the results of research carried out over ten years, notably by Amara *et al*. (2008), Bekkouche (2012), Hamani (2013), Amara *et al*. (2015), and Ferrah (2014) have shown that the direct seeding system presents many problems. The development of direct seeding has increased the use of herbicides necessary to control the growth of weeds which is no longer ensured partially by ploughing. These systems are therefore, efficient but at high chemical input costs, thus, increasing their potential to pollute surface water. Field surveys show that the few farmers using direct seeding are questioning the effect of these techniques on the development of weeds and the adaptation of their equipment stock.

Another observation to be credited to Algerian farmers is the ignorance of the application of techniques adapted to local conditions and lack of knowledge of the use of agricultural equipment, where we noticed significant differences in the yield of crops grown under identical environmental conditions. Moreover, the variation in yield is due, among other things, to the different physicochemical characteristics of the soil, which leads to questioning the choice of tillage equipment. Consequently, shows the lack of information of the decision-maker (the farmer) as to the precise action of the different tools on the state of the land, in various types of soil and variable climatic conditions. Hence, the interest in characterizing the effect of implements on the soil and being able to predict the quality of work that will be obtained under given soil conditions by a chosen sequence of tools and according to a known operation method.

Many technical and scientific references on the impact of tillage methods on soil quality are available; but, these researches highlight the comparison between conventional tillage, minimum tillage, and direct seeding. Otherwise, our work introduces the tool chain comprising conventional tillage, agronomic tillage and comprising no-tillage with an offset disk.

The question we asked ourselves before starting this study is what will be the best way to improve the structural state of the soil, with the tools that the majority of Algerian farmers have at their disposal. As well, we know that almost all farmers have an offset disk, disc, or share plow on their farms and sometimes a harrow, a smooth, or croskill roller.

Therefore, the objective of this study was to compare the impact of chains farming tools on the physicomechanical properties of the soil and the possible consequences on wheat rooting.

To achieve these objectives, we compared three technical tillage chains in the same pedoclimatic and historical situations. The treatments were chosen to represent a gradient of tillage intensification. Each system maintains a minimum level of mechanization to control weed development and to prepare the seedbed. These tillage practices are being studied in the context of cereal production.

MATERIALS AND METHODS

Presentation of the conditions of the experiment

Two experiments were carried out:

The first experiment was conducted during year 2019/2020 on a field located at the experimental station of the National Higher School of Agronomy (ENSA), which is situated at Belfort in el Harrach Algiers state. The soil of the field has clay loam texture, according to the USDA classification, with the content of 39.5% clay, 20.2% fine silt, and 3.96% coarse silt, in addition to 20% and 13.6% of fine and coarse sand, respectively.

The second study was conducted at the experimental station of the Technical Institute of Large Crops (ITGC) of Setif located in eastern Algeria, at the place called R'MADA in the commune of MEZLOUG, daira of Ain Arnat, at an altitude of 1080 m, at latitude 36° 9' N and longitude 5° 21' E; whose soil is characterized by a slight slope (3%) and has pebbles on the surface. The soil at the experimental site belongs to the alluvial soil class. The soil profile shows that the soil is slightly deep (40-70 cm) in the presence of a limestone slab very close to the surface

We chose to crop the Vitron wheat variety. This variety spies the first third of April in the coastal areas and at the end of April in the high plains. Moreover, the Vitron variety has an average tillering and slightly higher fertility than Waha (it has an average of 50 to 60 grains spike^{-1}). Also, it has a high PMG (thousand-grain weight).

The seeding rate was 120 kg ha^{-1}, corresponding to an average grain of 300 square^{-1} meter, which is the rate recommended by the ITGC (Technical Institute for Field Crops) for the study area.

The average temperature registered during the experimentation period was 14.5°C, with a rainfall average of about 266 mm, which is exceptional compared to the regional average of 749 mm. The highest rainfall was recorded during January with 77.10 mm and 345.9 mm in total. While, the wet period lasts only 5 months from mid-October to November, and decreases in December-January and mid-February, on the other hand, the months of March, May and June are dry.

Equipment used

Taking into account the geometry and topography of the plots and considering the objectives of our experiment, we used the block device. The experimental field at the first site measure 0.54 ha in size, while the trial blocks were 500 m (50 m long and 10 m wide) separated by 1 m wide grassed strips, giving nine blocks, three for each tool chain level (CH). The three combined tool chains of soil tillage referred to as levels of work are described in Table 1.

For the experimental device adopted at the second site is identical to that of the first site, but we added a fourth chain is that of direct seeding.

For all the experiment, AGRIC PSM 30 seed drill coupled to a JOHN DEERE 5605 tractor was used for sowing operation.

Level	Name	Chain
Level 1 (CH1)	Conventional work	Plough with shares (30 cm deep) - offset disk -vibrocultivator – roller.
Level 2 (CH1)	agronomic plowing	Plough with shares (15 cm deep) - offset disk - vibrocultivator – roller.
Level 3 (CH3)	minimum work	Offset disk - vibrocultivator – roller
Level 4 (CH4)	direct seeding	No tillage

Soil bulk density measurement

Coring method was used to collect soil, which is the most commonly used method. Briefly, a cylinder of known volume (400 cm³) with a sharpened end is mechanically driven in the ground and then cleared by digging around it. To determine the bulk density samples were taken from three broad horizons (0, 10, 30 cm), then drying it in the oven (at 105°C for 24 hours). In the end, the samples were weighed, and the bulk density was calculated using the dry weight and the volume of the soil sample

$$\rho_{as} = \frac{P}{V}$$

With:

ρ_{as} : Bulk density; P: weight of the dry sample; and V: volume of the soil sample.

Soil water content (H%) measurement

To determination of soil humidity, weight moisture method was used. The samples were taken from five points and three horizons (0-10, 10-20, and 20-30 cm), giving a total of 15 samples in each plot.

The soil water content was calculated directly by weighing the soil before and after drying ((105°C 24h^{-1}). The immediate weight corresponds to the total mass (Mt), and the mass after drying represents to the solid mass (Ms). The water content (W) was equal to:

$$W = \left(\frac{Mw}{Ms}\right) \times 100 = \left[\frac{(Mt - Ms)}{Ms}\right] \times 100$$

With:

W: humidity level (%)

Mw: mass of water (g)

Ms: mass of the solid (g)

Mt: total soil mass (g)

Measurement of total soil porosity (P) expressed in %

Soil porosity was determined as the ratio of bulk density and the actual density. It was calculated using the following equation:

$$n\% = 100 \times (1 - \rho_{as} / \rho_{s})$$

Where:

n%: soil porosity (%)

ρ_{as} : Bulk density

ρ_{s} : is the density of soil, estimated at 2.43 g/cm³ (Feddal, 2015) ;

Penetrometer resistance measurement

The penetrometer resistance was measured using a manual penetrometer. The penetrometer measures the maximum resistance during the penetration at several depths. This device supports a maximum pressure of 08 MPa.

Root density measurement

Soil samples were taken from the plots using coring techniques with a metal cube of known volume (18000 cm³), 30 cm long, 30 cm wide and 20 cm high. The cube was mechanically driven into the soil (0-20 cm) by its sharp end, then freed by digging around it. The roots were extracted from the soil samples using the water floating technique. After that, the roots were separated from the organic debris, and their weight was measured. The root density was calculated by dividing the weight (gr) by the volume of the cube (18000 cm³).

Statistical analysis methods

To process the results, we used the XLSTAT software.

RESULTS AND DISCUSSION

Impact of the succession of farming tools on soil moisture (H%)

To dive our findings, statistical analysis, and histograms (Figure 2 and 3) were carried out using a chain-by-chain analysis on the three horizons (A, B, C):

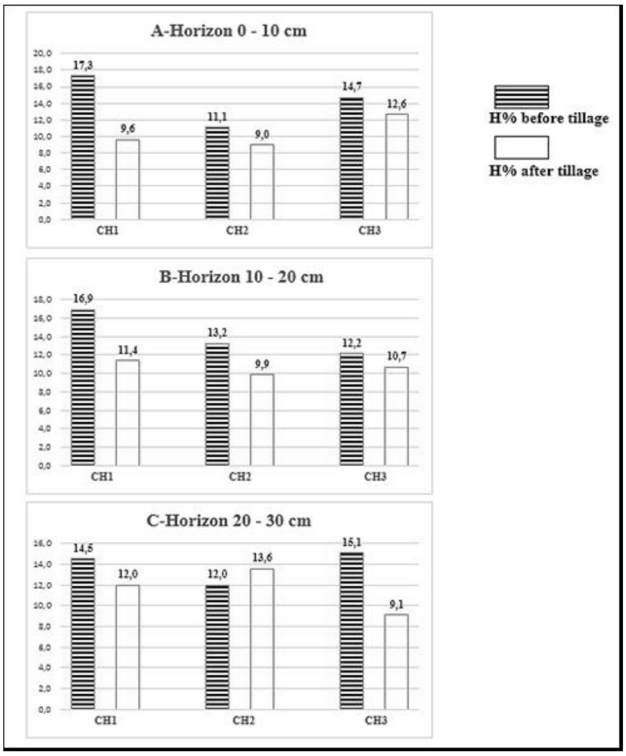


Figure 1. The variation of H% before and after tillage for the three tool chains for the three horizons A, B, C for the first site.

Table 1. Statistical analysis of the effect of cultivation techniques on soil moisture

	CH1	CH2	CH3
Horizon 1	p-value : **0,004** alpha 0,05 **THS**	p-value :0,242 alpha 0,05 **NS**	p-value :0,892 alpha 0,05 **NS**
Horizon 2	p-value :**0,006** alpha 0,05 **THS**	p-value :**0,003** alpha 0,05 **THS**	p-value :**0,027** alpha 0,05 **HS**
Horizon 3	p-value :0,38 alpha 0,05 **NS**	p-value :0,24 alpha 0,05 **NS**	p-value :**0,0001** alpha 0,05 **THS**

In a general way, it can be concluded that the farming tools, whatever their application and passage, decreased soil moisture on the first two horizons. Soil dryness can be explained by high evaporation resulting from the disturbance of the soil by the working parts of the tillage tools on the first 15 centimeters. On the other hand, on the third horizon, first 15 centimeters. On the other hand, on the third horizon, no moisture loss was registered for chains 2 and 3, where tillage affected only the first 15 cm. In contrast, the decrease in moisture was recorded at the level of plots plowed to 30 cm.

The results shows that the cumulative moisture was more or less the same in the period of sowing with a slight advantage of CH_2 and CH_4 that was what it showed the statistical test, on the other hand in the stage of emergence we noticed a great value of H% at the level of chain 1 equal to 37.48% compared to the chain 2, 4 and 3 that is equal to 26.4%, 20.7% and 18.19% respectively; this noticed a great value of H% at the level of chain 1 equal to 37.48% compared to the chain 2, 4 and 3 that is equal to 26.4%, 20.7% and 18.19% respectively; this might be due to the succession of the tools that favor the moisture content. Then at the level of tillering stage the moisture content was higher in direct seeding (CH3) 40.1%, with %, followed by the simplified cultivation technique (33.6%) and conventional work (30.1%) and tine seeding (19.52%). This is in agreement with many authors who have amply reported that conservation techniques, notably no-till and simplified tillage, increase soil moisture content compared to conventional techniques. Indeed, no-till techniques were characterized by an absence of soil disturbance (Mrabet, 1993). The water content undergoes a regular fall in all the tool chains at the level of the heading stage, due to evaporation and soil heating. At the end of the cycle the H% content was almost the same with a small advantage to CH4 and CH3, which showed the importance of the no-till technique in the storage of water at the end of the cycle.

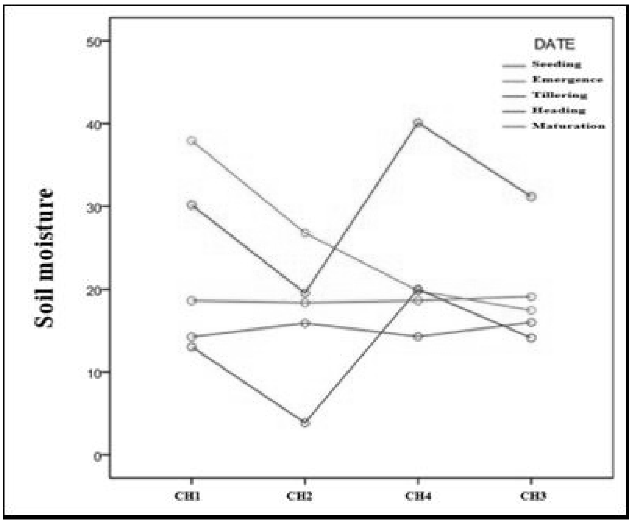


Figure 2. Variation of soil moisture in relation to depth and vegetative stage for the second site

Table 2. Statistical analysis of the effect of cultivation techniques on soil moisture

Stages		HUMIDITY		
		A	B	C
seeding	CH1	a	a	a
	CH2	a	b	a
	CH3	a	ab	a
	CH4	a	ab	a
Emergence	CH1	a	a	a
	CH2	ab	b	b
	CH3	b	b	c
	CH4	b	b	bc
Tillering	CH1	bc	b	ab
	CH2	c	c	b
	CH3	b	a	a
	CH4	a	a	a
Heading	CH1	b	b	c
	CH2	c	c	d
	CH4	b	ab	b
	CH3	a	a	a
Maturation	CH1	a	a	a
	CH2	a	a	a
	CH3	a	a	a
	CH4	a	a	A

Impact of the succession of tillage tools on the total porosity of the soil (n %)

Porosity is a physical characteristic that reflects the structural state of the soil; a soil whose aggregates are distributed in such a way that it resists the aggressions related to the cycle of wetting/drying or freezing/thawing is a soil said to have a stable structure and therefore maintains its pore space at a fixed level.The analysis of the effect of the cultivation technique on the pest porosity shown in Figure 3 and 4.

Table 3. Statistical analysis of the effect of cultivation techniques on soil porosity

	CH1	CH2	CH3
Horizon 1	p-value : 0,493 alpha 0,05 **NS**	p-value :0,876 alpha 0,05 **NS**	p-value :**0,0001** alpha 0,05 **THS**
Horizon 2	p-value :0,416 alpha 0,05 **NS**	p-value :0,725 alpha 0,05 **NS**	p-value :**0,05** alpha 0,05 **S**
Horizon 3	p-value :0,869 alpha 0,05 **NS**	p-value :0,389 alpha 0,05 **NS**	p-value :**0,008** alpha 0,05 **HS**

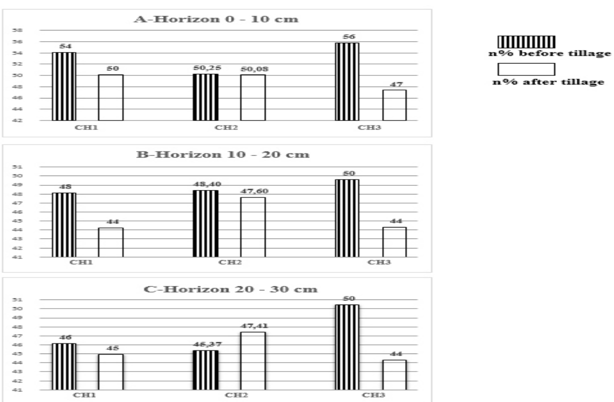


Figure 3. Variation of n% before and after tillage for the three tool chains for the three horizons A, B, C for the 1st site

The results in the first horizon showed that the passage successive of the offset disk and the vibrant shank cultivator reduced the porosity by 9%. In contrast, in deep conventional work, we registered only a reduction of 4%. On the other hand, CH2 with agronomic ploughing seems to have the best porosity since it remained stable on this horizon with 50%. In line with the first horizon, the second horizon seems to be more stable with the CH2 compared to CH1 and CH3, where we registered a decrease in porosity by 4 and 6%, respectively.

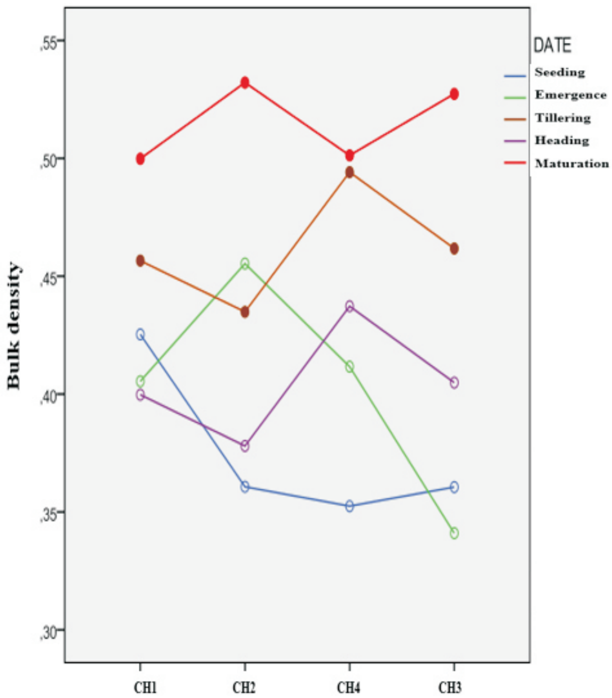


Figure 4. Variation of n% in relation to depth and vegetative stage for the second site.

At the third horizon, the porosity was stabile with CH1 (1% decrease), compared to CH3 with 6% of decreased. On the other hand, CH2 increased porosity by 2%. Statistical analysis showed a significant effect on total soil porosity only with CH3 on the first and second horizons.

Table 4. Statistical analysis of the effect of cultivation techniques on soil porosity for the 2nd site

		Bulk density		
Stages		A	B	C
Seeding	CH1	a	a	A
	CH2	a	b	A
	CH3	a	b	A
	CH4	a	b	A
Emergence	CH1	a	a	A
	CH2	b	ab	A
	CH3	abc	b	A
	CH4	ac	b	A
Tillering	CH1	a	ab	ab
	CH2	a	a	B
	CH3	a	b	ab
	CH4	a	ab	A

Heading	CH1	a	ab	ab
	CH2	a	a	A
	CH4	a	b	ab
	CH3	a	ab	B
Maturation	CH1	a	a	A
	CH2	a	a	A
	CH3	a	a	A
	CH4	a	a	A

The results showed that the porosity obtained at the sowing stage is a function of the soil disturbance level. The porosity decreased from the conventional technique CH1 to the no-till technique CH4 passing by an average for the simplified cultivation technique CH3. Then we notice at the level of tillering and heading stage the porosity increases in an exponential way at the level of the no-till plots. Thus, the no-till improves the physical and chemical properties of the soil compared to the conventional (Mrabet *et al*., 2001). Tebrugge and During (1999) showed that the difference in porosity between tilled and no-tilled soil was maximal after ploughing; the difference decreased during the cropping season. Statistical analysis shows that there was no significant effect of technique on horizon A.

Impact of the succession of farming tools on the mechanical resistance of the soil

The penetrometer resistance (**Rp**) is one of the indicators frequently used to provide insight into the state of soil compaction and the stress the soil places on root progression. We analyzed the evolution of the soil penetrometer resistance concerning the depth of the three toolchains studied.

a. Horizon A (0 – 10 cm) :

The figure below shows the effect of the passage of the different tillage tools of the three chains on the soil's penetrometer resistance in the first horizon. We noticed that CH2 allowed the lowest Rp with a decrease of 0.6 MPa, followed by CH1 with 0.5 MPa and finally CH3 with 0.4 MPa.

b. Horizon B (10 – 20 cm) :

At the level of the second horizon, the observation was quite the same as the first. The tools had a reducing effect on Rp; we have to mention that the deeper we go, the more Rp increases.

c. Horizon C (20 – 30 cm):

The three tillage chains allows a reduction of Rp on the third horizon. The largest reduction was recorded with CH2 with a difference of 0.8 MPa, followed by CH3 and CH1 with 0.67 MPa and 0.33 MPa.

The student test confirms that there was a highly significant effect of the three toolchains on Rp over the 20 - 30 cm horizon. However, it should be noted that CH2 had a greater effect on Rp than CH1 and CH3.

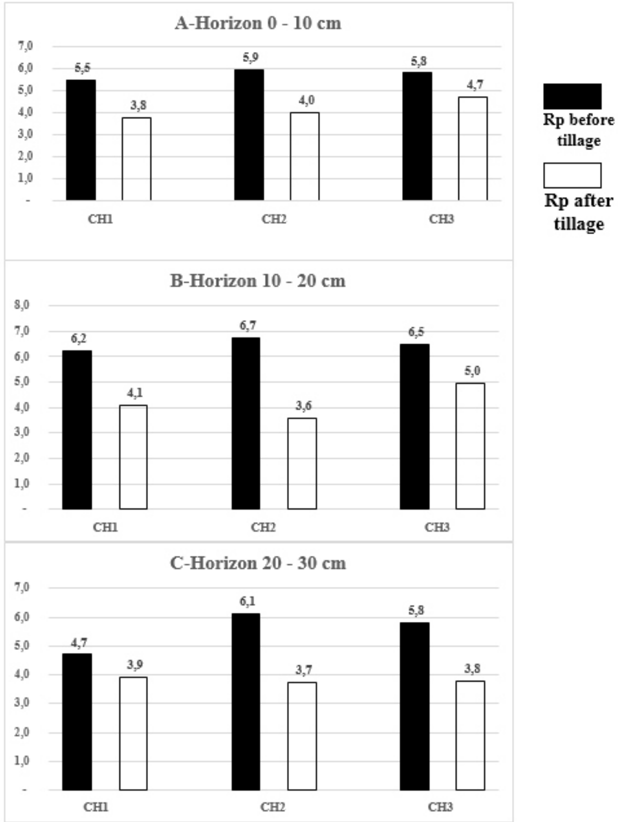


Figure 5. The variation of Rp (MPa) before and after tillage for the three tool chains for the three horizons A, B, C.

Table 5. Student test (Rp, horizon1, tool chain).

	CH1	CH2	CH3
p-value	**0,028**	**0,001**	**0,022**
Alpha	0,05	0,05	0,05
Interprétation	**S**	**HS**	**S**

Generally, the three chains of soil tillage implement, despite their differences, have a diminishing effect on soil Rp; chain 2 with agronomic ploughing allows the greatest reduction in Rp over the entire soil horizon.

It must be pointed out that Rp reaches its maximum values for the three chains at a depth of 20 cm, which can be linked to the history of the plot which has been ploughed for several years at the same depth, which induced a ploughing sole, the values of Rp then decreased at the horizon 20 - 30 cm.

Multiple regression analysis between the dependent variable Rp and the independent variables H%, n% yielded the following model equation:

Rp CH1 = -3, 19 - 0, 15 *H% (CH1) + 0, 12 * n% (CH1)
R^2=0, 71 P<0.05

The equation illustrates the relationship between Rp, n and H, where 71% of the variability in Rp ($R^2 = 0.71$) could be explained by the moisture (H %) and porosity (n %). We notice that H% correlated negatively to Rp, contrary to n% where there was a significant positive correlation (especially if the soil is dry). Further, H% had slightly more effect than n% on Rp, with the coefficients 0.15 and 0.12, respectively.

The work of Isabelle Breune in 1997 can explain the increase of Rp in the function of n%. The author reported that for a matrix potential of 33 kPa, which corresponds approximately to the field capacity in sandy soil, the relationship between porosity and Rp is almost linear.

Furthermore, since the porosity is a volume measurement and the Rp is a precise measurement, the information provided by one or the other was sometimes quite different. Besides, sometimes it is possible to observe an increase in Rp with depth without noticing a remarkable difference in bulk density. This phenomenon generally explained by the increase in friction along the stem with depth (Soane, 1973). Thus, occasionally the Rp values wrongly define the presence of a compact zone. Therefore, it is recommended to measure Rp together with other parameters such as H (%) and n (%).

For CH2 and CH3, the established regressions were not significant.

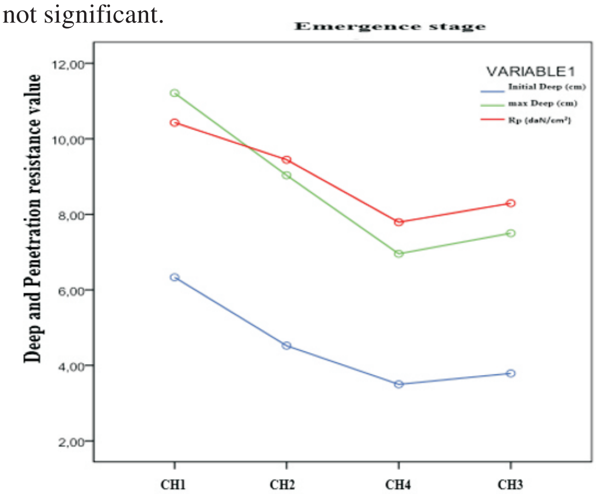


Figure 6 . Effect of tool chains on RP(MPa) at emergence stage for 2nd site.

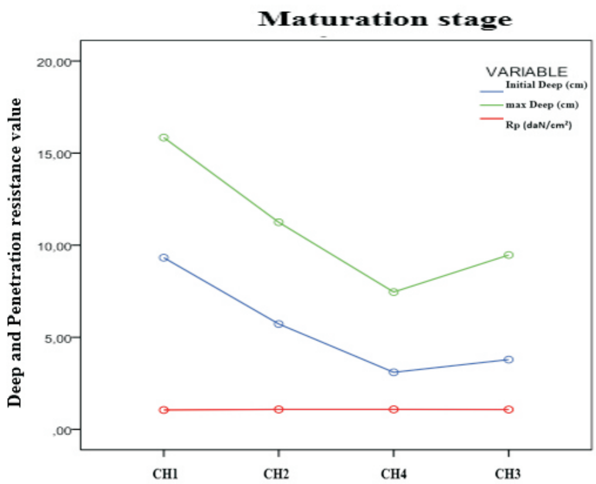


Figure 7. effect of tool chains on RP(MPa) at maturation stage for 2nd site

Table 6. Statistical analysis of the effect of cultivation techniques on Rp for the 2nd site

Stage	Technique	debit RP(cm)	max RP(cm)	RP
Emergence	CH1	a	a	a
	CH2	b	b	ab
	CH3	b	c	b
	CH4	b	c	ab
Maturation	CH1	a	a	a
	CH2	b	b	a
	CH3	a	d	C
	CH4	c	c	A

Figures 6 and 7 clearly showed the effect of the passage of the different tillage tools on the penetrometer resistance of the soil. We notice that from a depth of 11.5 cm, the penetrometer resistance becomes more important after the passage of the ploughing tools, then the results showed that there was a contradictory relation of the Rp and the degree of mechanization, that is to say that the Rp increases if one passes from the CH1 conventional technique to the CH3 direct seeding; and also the resistance to penetration is in depth at the level of the conventional technique and as one passes towards the no-till technique it becomes superficial. The statistical analysis shows that there was no significant effect of the technique on Rp at the level of chain 1.

Analysis of the effect of cultivation techniques on root development and consequences on the yield of durum wheat

Effect of tillage on durum wheat root development

Root Density

Figure 8 shows the variation in root density for the three chains over the last physiological stages (head emerging, Flowering, and Maturity).

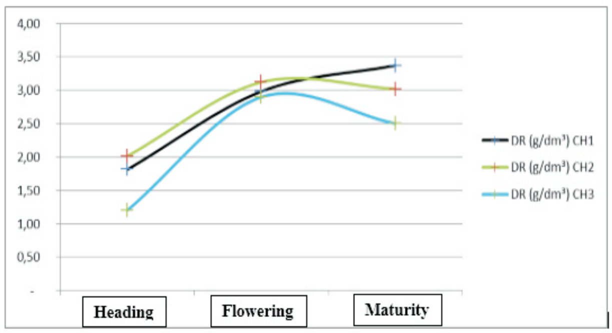


Figure 8 . Variation in root density for the three chains during the last three stages of durum wheat development

The results showed that the average root density was variable across both factors (physiological stage and toolchain), and the values vary from 1.2 g/dm³ and 3.37 g/dm³.

The root density increased from head emergence to flowering using all the three toolchains. The CH2 showed the highest root density during both the stages. However, while the CH1 kept increasing the root density until maturation to reach 3.37 g/dm³, the root density decreased slightly after flowering to achieve 3.02 g/dm³ and 2.5 g/dm³ with CH2 and CH3.

Root diameter

Figure 9 shows the variation in root diameter for the three chains over the last three stages of durum wheat development

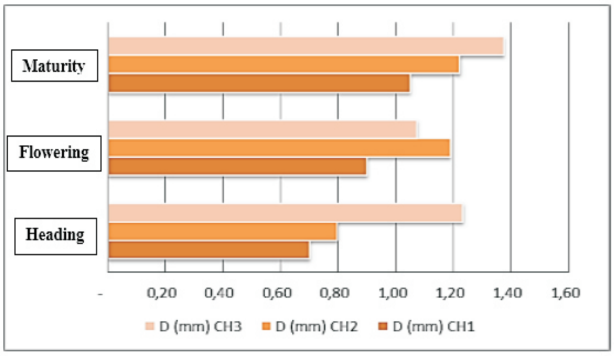


Figure 9. Variation in root diameter for the three chains during the last three stages of development of durum wheat

The root diameter measured during the last three growth stages of wheat was significantly higher in plots worked without the share plow (CH3). The mean root diameter in CH3 was 1.38 mm, compared to 1.22 mm and 1.08 mm for CH2 and CH1.

Reduced tillage such as CH3 does not favour proper root development at depth due to the superficial intervention of the tools. This finding confirms the results of Rp, where deep compaction was recorded, which may have caused a horizontal root development and not vertical.

Root elongation

Figure 10 shows the variation in root elongation for the three chains over the last three stages of durum wheat development.

The results shows that the root length rate was faster with CH3, increasing from 5.9 cm at heading stage to 10.46 cm at flowering. However, the elongating stagnate in this value was observed until the end of wheat development. The rapid root elongation using CH3 may be explained by the structure created at the surface layers that favors growth initiation. In contrast, at depth, the soil is not tilled, or the soil Rp is high, forcing the elongation to stops.

The deep plowing and agronomic plowing tillage with the share plough, increased root length until maturity stage. The root length reached the highest value of 12.23 cm with CH2 compared to 11.81 cm using CH1.

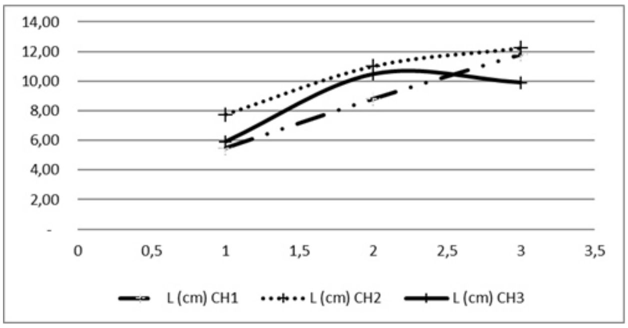
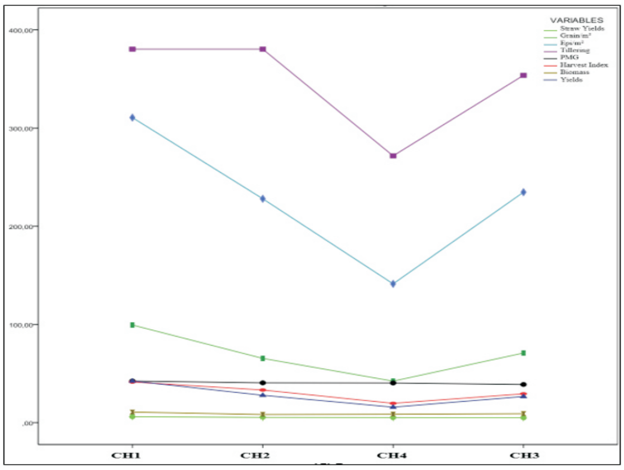


Figure 10. Variation in root elongation for the three chains over the last three stages of durum wheat development.

Effect of tillage on the agronomic characteristic of durum wheat

In this last part, we are presenting and discussing all the performance results obtained



.**Figure 11.** the variation of agronomic characteristics of durum wheat according to cultivation techniques

Table 7. Statistical analysis of the effect of cultivation techniques on agronomic characteristics of durum wheat for the 2nd site

Anova one-way *p<0,05								
chains	Tillering	grain/m²	Epi/m²	Staw yields t ha^{-1}	pmg	Harverst Index	biomass t ha^{-1}	yield qx ha^{-1}
CH1	a	a	a	a	a	a	a	a
CH2	a	c	b	a	a	ab	a	b
CH3	a	c	b	a	a	ab	a	bc
CH4	b	b	c	a	a	b	a	c

These results showed that conventional tillage favored biomass production as a result of several plant characteristics such as the number of spikes produced unit^{-1} area and the PMG. In direct seeding, the increase in biomass production is a function of the soil cover rate. Several authors have reported improved water comfort of the crop planted under the ground cover. Compared to bare soil, increased residue facilitates infiltration, reduces wind speed and runoff. It limits evaporation and capillary rise of water from deep in the soil, maintaining additional moisture in the soil that is used by the crop (Mrabet, 2002; Findeling *et al*., 2003; Khaledian *et al*., 2006). Cereal growth rate was higher in CT than in SD. In SD, the growth rate of the crop increased as a function of the residue quantum (Fellahi, *et al*., 2013).

This shows that the interest of adopting a good technical itinerary and especially some operations that have beneficial effects on the production in a general way (in grains and straw), especially fertilization in combination with irrigation.

The passage of tillage tools had a decreasing effect on soil moisture, porosity, and penetrometer resistance on the three horizons (10-20-30 cm), using both CH1 and CH3. At the same time, CH2 allowed conservation of water content in the third horizon (20 -30 cm), due to the undisturbed soil at depth and homogeneity of soil porosity over almost the entire profile. This result is encouraging insofar as there is currently high rainfall variability in northern Algeria, agronomic ploughing may offer a solution to soil drying.

The porosity results are directly related to the bulk density, which does not show a remarkable change during this experiment. However, interpreting results must be with caution as they may be misled by other mechanisms, including wetting, desiccation, and settling. The soil porosity is generally reduced in conservation tillage systems due to Non-ploughing, which decreases macroporosity formed by soil tilling. But, like direct seeding systems, they favor the formation of macropores of biological origin. These changes occur gradually, and differences between systems can be observed after several years of application.

Soil preparation with tillage promotes root development better than other techniques due to the creation of an excellent structure. Agronomic ploughing seems to offer a framework allowing good root elongation, whereas deep ploughing provides a better root density. The minimum work appears to provide the best root diameter, but a low root elongation, which calls into question simplified cultivation techniques.

In the appreciation of all our results of the second site, we believe that the simplified cultivation techniques (SD and TM) have responded favorably to the edaphic and cultural parameters in semi-arid zones and essentially to the preservation of the soil by the increase of the organic matter, the stability of the soil and that in spite of the monoculture practiced on three consecutive years.

Today, in my opinion, an economic study is needed to decide which technique to use for durum wheat. In experimental conditions, the technical route of ploughing with agronomic ploughing can be an alternative to conventional ploughing, but with subsoiling every four years to destroy the plough sole. The practice of this method will allow, among other things, to avoid polluting the water table and even the soil. This tillage method is easily feasible from a technical point of view and can generate economic gains compared to ploughing, but its effects on the soil and crop yields need to be studied in the longer term.

For the future, we recommend focusing on other parameters, such as the weight distribution of the aggregates. The aggregation weight distribution is the best way to assess and characterize the action of tools on the soil structure by giving more details on the size of the clods formed after the passage of the devices, and their proportion concerning the volume of soil stirred.

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