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The Effect of Compaction on the Physical and Hydrodynamic Properties of Soil and on the Growth and Productivity of Soybean Crop

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The research was conducted at the Scientific and Agricultural Research Center in Latakia (Sitkheris Center)in the year of 2022 using Randomized Complete Block Design at which four different levels of pressure were applied to a silty clay soil (0- 163- 216- 297 kpa)at the plastic limit (the optimal tillage limit of the soil). Results showed that soil compaction in the surface layer (5-20

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cm) caused an increase in the bulk density by 0.21 g/cm^3 at the pressure 163 kpa ,an increase by 0.25 g/cm^3 at the pressure 216 kpa and an increase by 0.33 g/cm^3 at the pressure 297 kpa. This effect diminished as depth increased, and the total prose size significantly decreased at all levels of the applied pressure compared to the control treatment. A significant decrease, was also noticed in the leaf surface area of the soybean (flowering stage) along with the decrease in the pressure, where the decrease ranged from 4329.93 cm^2/plant, in the treatment without pressure, to 1746.22 cm^2/plant at the pressure 297 kpa. The results also showed a decline in the soybean productivity and the percentage of both protein and oil in the dry seeds along with the increase in the pressure, where the productivity recorded a decline by 214.22 kg/dunum at the pressure 297 kpa compared to the control treatment.

Keywords: Soil compaction; bulk density; porosity system distribution; soil hydraulic constants. soybean.

1. INTRODUCTION

In light of the advanced agricultural progress, agricultural machinery entered the agricultural fields on a large scale starting from basic tillage then preparing the seedbeds and ending with harvesting and transporting the crop. The above-mentioned processes led to the soil being exposed to different pressures that ranged (100-450 kpa) [1]. Soil compaction is considered a source of concern in the modern agriculture due to the increased size and weight of the machinery routinely used in the agricultural activities. These pressures are not limited to the surface layer, but exceed it to reach the depth of (40-80) cm, where the surface and subsurface layers have been affected over the past decades because of the increased load of agricultural machinery [2]. In general, soil compaction is considered one of the main threats to sustainable crops due to the deterioration of the physical properties of soil [3,4]. Soil compaction distorts the soil structure, increases bulk density, and reduces total porosity [5]. It was found that at the pressure 174.18 kpa and moisture by 67.5% of the field capacity on clay soil, the size of the air prose decreased which exceeded the limit value 12% at depth (0-20) cm and (20-40) cm to reach 7.57% at the depth (20-40) cm [6].

The soil compaction at the depth of 30 cm led to an increase in the soil resistance to the penetration by 1.5 times, and a decrease that equal or greater than 27% in the big pores, in addition to an increase by 6% in the soil density, also a decrease equivalent to 66-fold in the saturated hydraulic conductivity coefficient [7]. Pressure also has a negative effects on the water movement in the soil, root growth and availability of nutrients [8,9]. Thus, it reduces both growth and productivity of the crops. According to [10], when the soil was exposed to pressure by 310 kpa productivity decreased by 30.51%. Also, [11] indicated that the yield of both corn and soybean decreased by 25% and 20% respectively, due to the compaction.

According to Skef [12], leaf surface area of the soybean decreased with increasing pressure, in which reduction was from 814.1 cm^2/plant in the treatment without pressure to 5842.18 cm^2/plant in the treatment with the pressure 307.4 kpa.

Kadro [13] found that the average production of the yellow corn, in the treatment without pressure, was (1075.55) kg/dunum and declined at the pressures 199 kpa and 330 kpa to (818.40) kg/dunum and (439.08) kg/dunum, respectively.

A decline was recorded in the rate of both oil and protein in the dry soybean seeds when the soil was exposed to a pressure by 307.4 kpa, to which the oil declined by 2.81% and the protein by 8%, compared to the control treatment without pressure [12].

Soybean is considered one of the important strategic crop as it is relied upon as food for humans in addition to benefit from it as animal feed in various ways such as green fodder or silage, in addition to the high rate of protein content [14]. Soybean also, has a deep root system that sensitive to the physical environment during its different growth stages.

2. MATERIALS AND METHODS

Research was conducted in the Scientific and Agricultural Research Center (Sitkheres Center) in the year of 2022 on a slity clay soil (uT). The soil was exposed to four different levels of pressure at the plastic limit (moisture is suitable to agricultural activities) with three replicates for each level.

The pressure was carried out using a tractor (Newholand) and a water trailer. The weight can be controlled on the axle of the rear wheels of the trailer at which three different loads were used. And the tractor and the trailer were weighed together, then the front, the middle and the rear axle were weighed using the electronic weighbridge. The weight on the rear axle was the greatest, so it was adopted for its greatest compressive force, then the corresponding pressure for each load was calculated in order to determine the wheel pressure according to the following (Table 1).

The contact surface area was calculated as an ellipse on a solid ground [15] by the following law:

$$F = a*b*3.14 / 4$$

(a): ellipse width cm
(b): ellipse length cm

That was carried out by placing a cardboard under the wheel, and placing a carbon sheet on it, then drawing the contact surface resulted from the pressure of the wheel on the cardboard. The contact surface was at the pressure P1= 376.8 cm^2, the pressure P2=436.6 cm^2 and the pressure P3=482.8 cm^2.

Pressure was calculated as follows:

P1= (wheel load (kg)/contact surface)* 100
= (615/376.8) *100
= 163 kpa
P2= (wheel load (kg)/contact surface)* 100
= (940/435.6) *100
= 216 kpa
P3 = (wheel load (kg)/contact surface)* 100
= (1435/482.8) *100
= 297 kpa

The soil was exposed to the above-mentioned pressures, starting from the treatment of the highest pressure (297) kpa, then the treatments of the lower pressure. The process was conducted by emptying an amount of water from the trailer estimated by liter to reach the minimum weight equivalent to the studied loads, and subsequently weighing them again using electronic weighbridge. After that 70 kg p2o5/h of phosphate fertilizers and 60kg k2o/h of Potash fertilizers were added. Then loosening the soil and cultivating it to the depth of (0-5) cm, and the soil were left compacted at the two depths (5-20) cm and (20-40) cm. And, after that the first application of nitrogen fertilizer (urea) was added before planting as follows:

Table 1. Pressure levels to which the soil was exposed

Pressure levels	Wheel load (kg)	Wheel contact surface with soil (cm2)	Pressure (kg/cm2)	Pressure (kpa)
P0	0	0	0	0
P1	615	376.8	1.63	163
P2	940	345.6	2.157	216
P3	1435	382.8	2.972	297

Fig. 1. illustrates the mechanism of calculating the area of the wheel contact surface

Table 2. Some physical and chemical properties of the studied soil

Analysis	Depth	
	2-5 cm	20-40 cm
Clay	45.89%	47.36%777774
Silt	50.51%	47.35%
Sand	3.6%	5.29%
Plastic limit (weight)	24.19%	24.78%
Shrinkage limit	17.2 % (size)	19.32% (size)
Soil type	uTSilty clay	uT Silty clay
Percentage of the organic matter	0.82%	0.65%
Total calcium carbonate	43.2%	43.8%
Active calcium carbonate	24%	26%
Cation exchange capacity	33.7 mm/100 g soil	33.7 mm/100 g soil
Field capacity % (size)	38.0%	37.1%
Permanent wilting point % (size)	20.71%	23.21%
Particle density	2.36 g/cm^3	2.64 g/cm^3
Bulk density	1.09 g/cm^3	1.19 g/cm^3
pH	7.53	8.1

The first application was before planting 30 kg/h, and the second one 100 kg/h was after the separation, while the third one was at the beginning of flowering stage 100 kg/h. Rows were prepared for planting at which a space of 50 cm was left between them and 25 cm between one plant and the other. Soybean crop (cultivar sb 44) was planted in April, 2022, then the post-planting operations began which included separation, weeding and irrigation.

Samples of the treatments were taken from the depths (5-20, 20-40cm) using a metal cylinders at a rate of (6) cylinders per depth to determine the physical properties of the non- structurally damaged soil. Samples of a__structurally damaged soil were also taken from these depths, to determine the physical properties of the studied soil. Results were as shown in (Table 2).

It was shown, through (Table 2), that the studied soil was a silty clay soil at the two depths (0-20 cm) and (20-40 cm). Moreover, it was noticed that the clay percentage increased along with depth, which ranged between (45.89% and 47.36%) at the two depths (0-20 cm) and (20-40 cm), respectively. In addition, the silt percentage was high which recorded (50.51%- 47.35%) at the two mentioned depths.

The bulk density was determined using a metal cylinder with a capacity of 100 cm^3. Total porosity and the distribution of porous system were calculated using the membrane pressure device that contains pressure-resistant ceramic plates, to determine the size of the prosperity groups according the law:

Ibrahim and Barakat [16]: pm= $\frac{4\sigma W}{d}$

Pm: Pressure (pka), σW: Surface tension of water (newton/meter), d: pore diameter.

Then, the size of each porosity group was determine as follows:

PV%>50µm=PV%-Wvol.pF1.8
PV%>10µm=PV%-Wvol.pF2.5
PV%(10-50) µm=Wvol.pF1.8-Wvol.pF2.5
PV%(0.2-10) µm=Wvol.pF2.5-Wvol.pF4.2
PV%<0.2 µm=Wvol.pF4.2

WvolPF1.8 is the volumetric moisture at the end of the pressure that equivalent to pF1.8, pv% : Total porosity size of soil which determined as follows:

$$PV\% = (1 - \frac{\rho d}{\rho s}) * 100$$

ρd : The bulk density.
ρs : The particles density of soil (g/cm^3)

Moisture tensile curves were determined by the membrane pressure device, so the equation was of the form: $\Psi = a \, . \, \theta^b$ according to (Gardner *et al.,* 1982).

3. RESULTS AND DISCUSSION

3.1 Bulk Density

The bulk density was studied since it is a complex physical property through which many other physical properties can be identified. It indicates the structural state of the soil, and involves in other physical calculations as well as helps in converting the gravimetric moisture into volumetric moisture. Therefore, it was necessary to study this physical property and its changes during the compaction process.

In (Fig. 2) the bulk density was (1.09) g/cm^3 at depth (5-20) cm in the treatment without pressure (control treatment). And it singniflctly increased at all levels of applied pressure which increased by 0.21 g/cm^3 at the pressure 163 kpa and 0.25 g/cm^3 with increasing the pressure to 216 kpa, while it increased by 0.33 g/cm^3 when the pressure was 297 kpa Results showed that soil compaction clearly affected the bulk density of soil.

In (Fig. 3), it is clear that the bulk density at depth (20-40) cm was significant with increasing the pressure. The density reached 1.19 g/cm^3 in the treatment without pressure (the control). It increased by 0.07 g/cm^3 at the pressure 136 kpa, and increased by 0.12 g/cm^3 with increasing the pressure to 216 kpa, and increased by 0.18 g/cm^3 at the pressure 297 kpa.

It is also clear that density decreases with depth which indicates that the pressure diminishes with depth, and this is similar to what was found by [17].

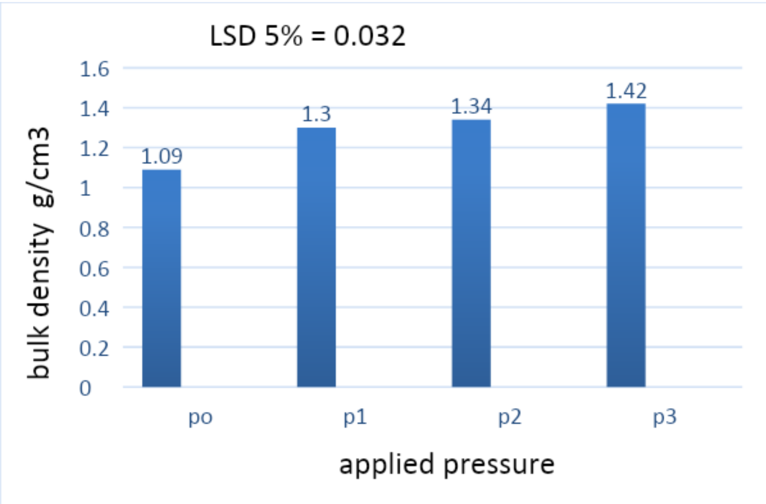

Fig. 2. The change in the bulk density as the applied pressure changes at the depth (5-20) cm
p1= 163 kpa, p2= 216 kpa, p3= 297 kpa

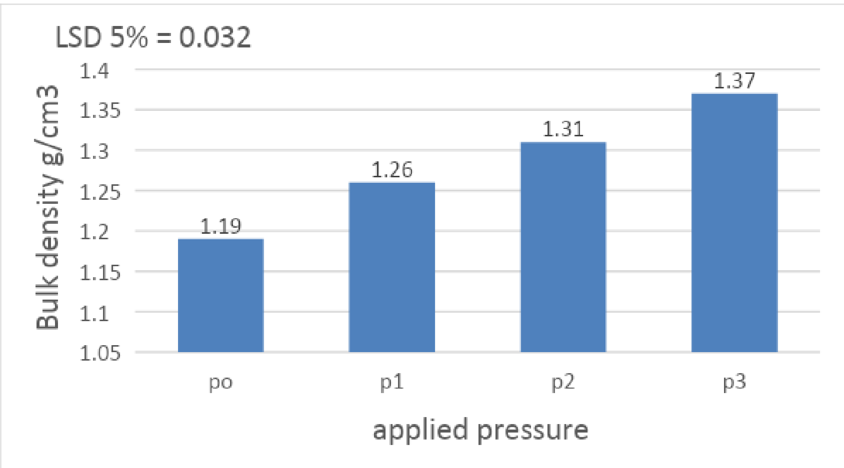

Fig. 3. The change in the bulk density as the applied pressure changes at the depth (20-40) cm.
p1= 163 kpa, p2= 216 kpa, p3= 297 kpa

Table 3. Changes of the porous system of soil at different levels of pressure at the depth (5-20) cm

Pressure (kpa)	Pv%	Pv >50 µm	Pv >10 µm	Pv 0.2-10 µm	Pv <0.2 µm
0	58.55a	12.45a	20.39a	17.45A	20.71g
163	50.19c	9.36bc	11.19bc	15.11Bc	24.89e
216	48.66d	9.56bc	10.16bcd	12.85Cde	25.65d
297	45.62f	5.02d	6.02e	12.43E	27.17b
LSD5%	1.22	1.67	2.10	1.89	0.47

Pv% (total porosity), pv>50 (pores are bigger than 50 µm), pv>10 (pores are bigger than 10 µm), pv= 0.2-10 (pores range from 0.2 to 10 µm), pv<0.2 (pores are less than 0.2 µm).
The similar characters means there is no significant difference

Table 4. Changes of the pore system of the soil at different levels of pressure at the depth (20-40) cm

Pressure(kpa)	Pv%	Pv >50 µm	Pv >10 µm	Pv 0.2-10 µm	Pv <0.2 µm
0	54.92a	15.99a	17.8a	13.85A	23.21f
163	53.40ab	13.89bc	16.3a	13.61A	23.79ef
216	50.00de	10.4bc	11.6bc	12.66ab	25.74bc
297	47.72f	7.12de	7.76d	13.05ab	26.91b
LSD5%	1.16	2.65	1.93	2.23	0.77

Pv% (total porosity), pv>50(pores are bigger than 50 µm), pv>10 (pores are bigger than 10 µm), pv 0.2-10 (pores are between 0.2 and 10 µm), pv<0.2 (pores are less than 0.2 µm)
Similar character means there is no significant difference

3.2 Porous System Distribution

Total pore size in the soil plays an important role in the processes of transporting and storage within the soil sector. As the porous system distribution has the most prominent role in all these processes, therefore the pore size determination was of the pore groups with a diameter bigger than 50 microns and the pore groups with a diameter of (0.2-10 µm) as well as the pores of a diameter less than 0.2 µm. So, the results were as shown in (Table 3).

Results indicated that pv% was (58.55%) at the depth (5-20) cm and the pressure (0), and it significantly decreased at the pressure 163 kpa to 50.19%, that is, by 9.89% ,while it significantly decreased at the pressure (297 kpa) to 45.62% that is, by 12.93%. Therefore, it is concluded that the total porous size decreases with increasing the pressure. And according to [18], soil compaction occurs when the soil granules are compressed, which reduces the pore area and changes the pore size and the distribution as well.

It was noticed that the pores of diameters bigger than 10 µm (the air pores) which shouldn`t be less than 12% in the clay soils, according to [19], were sufficient for the gas exchange in the treatment without pressure. And it sharply decreased at the pressure 163 kpa, which recorded 11.19% and recorded 10.16% at the pressure 216 kpa, in which exceeded the limit value at the pressure 297 kpa:

As for the pores of diameters (0.2-10 µm), their size decreased with increasing the pressure from 17.45% without pressure to 15.11% at the pressure 216 kpa, and to 12.43% at the pressure 279 kpa.

It is worth noting that those pores of the diameter (0.2-10 µm) were the pores that contained water available to plants, and their size must fall within the normal range of the average pores, that is, according to [20], within the range (7-20)% for that type of soils.

While the pores of diameters less than 0.2 µm, that contained water not available to the plant and their normal range according to [20] must fall within the range (5-20)%, their percentage increased with increasing pressure. They recorded 20.71% at the pressure (0) and became 24.89% when the pressure was 163 kpa that is, they significantly increased by 4.18% at the pressure 163 kpa, and increased to 25.65% at the pressure 216 kpa that is, by 4.94%, and when the pressure was 297 kpa they increased to 27.17%, that is, by 6.46%.

The total pore size and the porous system distribution were determined in the substratum soil. The results were as shown in (Table 4): pv was 54.92% at the depth (20-40)cm and the pressure (0) while it significantly decreased to 53.40% at the pressure 163 kpa by 1.52%, and significantly decreased to 50.00% at the pressure 216 kpa that is by 4.92%, and significantly decreased to 47.72% by 7.2% at the pressure 297 kpa. It was found that the total pore size decreases with increasing pressure and this is similar to was found by [5].

As for the pores that their diameters are bigger than 10 µm (air pores) which should not be less than 12% in the clay soils according to [19], it was found that they were sufficient for gas exchange in the treatment without pressure. They insignificantly decreased at the pressure 163 kpa which reached 16.38% and to 11.6% when significantly decreased at the pressure 216 kpa as well as they significantly decrease to 7.76% at the pressure 298 kpa. Thus, They exceeded the limit value at the two pressures (216) and (297) kpa.

It was also found that the Pores with diameters (0.2-10 µm), which are the pores that contain water available for plant, didn`t significantly changed at the levels of the studied pressure at this depth.

As for the pores with diameters less than 0.2 µm, their percentage increased with the increased pressure. The pores percentage was at the pressure (0) 23.21% and 23.79% at the pressure 163 kpa that is, it insignificantly increased by 0.58%, whereas it significantly increased by 2.35% to 25.74% at the pressure 297 kpa. and by an increase of 3.7% when it significantly increased to 26.91% at the pressure 297 kpa.

3.3 Saturated Hydraulic Conductivity Coefficient

Saturated hydraulic conductivity coefficient is one of the most prominent hydraulic properties of soil and it represents the ratio of flow to hydraulic potential gradient. It is used to determine the field`s need for both drainage and mechanical loosening. And it is one of the most important physical properties of soil for assessing its structural condition when conducting mechanical loosening on cohesive soils [21]. It is also considered as an indicator for detecting compacted sites in the cohesive subsurface soil layers, and when it is less than 0.1 m/day, it indicates that the soil needs mechanical loosening. This coefficient is greatly affected by the size of total porosity, especially the pores with diameters bigger than 10 microns and the degree of stability of these pores [22], in addition to being affected by the carbon content of the soil [23]. This coefficient is also considered one of the hydraulic indicators which are greatly affected by the soil compaction, especially at the plastic limit where the size of the pores bigger than 10 microns and the pores stability decreases. Consequently, they negatively affect the movement of both water and air within the soil sector and the distribution of the root system where the vital space of the root distribution decreases. Moreover, it is very hard to determine this coefficient due to the complexity of the soil`s porosity system, which the amount of the water flowing throw the soil section is proportional to the fourth exponent of the pore radius according to the following Hagen-Poiselle law**:**

$$q = \pi . r^4 . \left(\frac{\Delta p}{8 . \mu . L} \right)$$

q: the amount of flowing water**.**
Δp: hydraulic height
r: radius
: viscosityµ
L: tube length

The importance of determining the pore radii that take part in the transmission processes, comes from the fact that any increase, no matter how small is, in the pore diameter is accompanied by an exponential increase in the amount of the flowing water. It is also important to avoid the effects resulting from existence of the pores of big diameters, which could be caused by an earthworm or a root. Saturated hydraulic conductivity coefficient is calculated on the basis of the geometric mean, and it is determined in the laboratory by metal cylinders at the depths (5-20) cm and (20-40)cm.

$$Kf = \frac{V}{F . t} . \frac{l}{h}$$

I: Length of the sample cm.
h: hydraulic height cm.
This method depends on Darcy`s Law, as follows:

$$Kf = \frac{q}{grad\varphi_H}$$

q: the amount of water flowing through the soil sector.
: hydraulic gradient grad φ_H

Measurements of all samples were taken at a single hydraulic gradient and in the situation of stable flow according to (Schonberg ,1965). Samples were taken after pressing the soil and saturating it with water for 24 hours. Then, they were put in the measuring device of saturated hydraulic conductivity.

Results are shown in (Table 5) as follows:

Hydraulic conductivity coefficient of saturated soils at the depth (5-20)cm recorded 4.53 m/day in the treatment without pressure, and it significantly decreased to 1.05 m/day at the pressure 163 kpa as well as decreased to 0.71 m/day at pressure 216 kpa. Then it continued to decrease until it reached 0.09 m/day at the pressure 297 kpa.

The coefficient recorded at the depth (20-40)cm 3.29 m/day in the treatment without pressure, while it significantly decreased to 2.1 m/day at the pressure 163 kpa, and decreased to 1.01 m/day at the pressure 216 kpa, and it continued to decrease which it recorded 0.21 m/day at the pressure 297 kpa.

It was also noticed from the Table 5 that the hydraulic conductivity coefficient in the treatment without pressure decreased as the depth increased, while in the treatment that exposed to pressure the conductivity coefficient increased as the depth increased.

The aforementioned results are similar to those indicated by [10].

3.4 Hydrodynamic Constants

After determining the moisture content and its laboratory equivalent the moisture tension by the membrane pressure device at different levels of the pressure applied on the soil samples taken from the studied treatments using a metal cylinder with a capacity of 100 cm^3, the correlations between the moisture tension and the moisture content of the soil (moisture tension curves) was determined. The equations were of the form $\Psi = a\,.\,\theta^b$, which a and b were experimental constants as it is indicated in (Table 6).

From the Table 6, It can be noticed that the experimental constant (a), at the depth (5-20) cm, ranged from 0.145 in the treatment without pressure to 0.00127 in the treatment at the pressure 297 kpa. This also applied to the experimental constant (b), where it was -7.619 in the treatment without pressure and decreased to 12.454 in the treatment at the pressure 297 kpa. This led to a result that when the pressure increased the experimental constants decreased, so when the experimental constants decreases the moisture tension increases at the same moisture content available for the plant. Therefore, absorbing this water becomes more difficult and requires additional energy from the plant, which would be at the expense of the growth and productivity of the plant. This explains the decrease in the plant height and its leaf area, and this is similar to what indicated by [13].

3.5 Leaf Area in the Flowering Stage

Leaf area expresses the plant efficiency in covering a particular area of earth and the crop`s ability to control the weeds [24]. It is also responsible for intercepting solar radiation, photosynthesis and metabolism efficiency, biomass accumulation in the plant and the processes of evaporation and transpiration [25,26]. Therefore, it is considered as an indicator of the quality of the growth of the root system and the nutrients absorption within the plant in order to achieve the highest yield from the plant.

Table 5. The effect of different levels of pressure on the saturated hydraulic conductivity coefficient of soil at the two depths (5-20)cm and (20-40)cm

Pressure P(Kpa)	**Kf (m/day)**	
	(5-20)cm	**(20-40)cm**
0	4.53A	3.29a
163	1.05B	2.1b
216	0.71C	1.04c
297	0.09D	0.21d
LSD5%	0.26	0.21

Similar character means there is no significant difference

Table 6. The effect of different levels of pressure on the soil`s hydrodynamic constants at the depth (5-20cm)

pressure	Equation	Coefficient of determination	Experimental constants	
			a	b
0	$\varphi = 0.1455\,.\,\theta^{-7.619}$	$r^2 = 0.98$	0.1455	-7.619
163	$\varphi = 0.019\,.\,\theta^{-9.643}$	$r^2 = 0.99$	0.019	-9.643
216	$\varphi = 0.00105\,.\,\theta^{-12.256}$	$r^2 = 0.97$	0.00105	-12.256
297	$\varphi = 0.00127\,.\,\theta^{-12.454}$	$r^2 = 0.96$	0.00127	-12.454

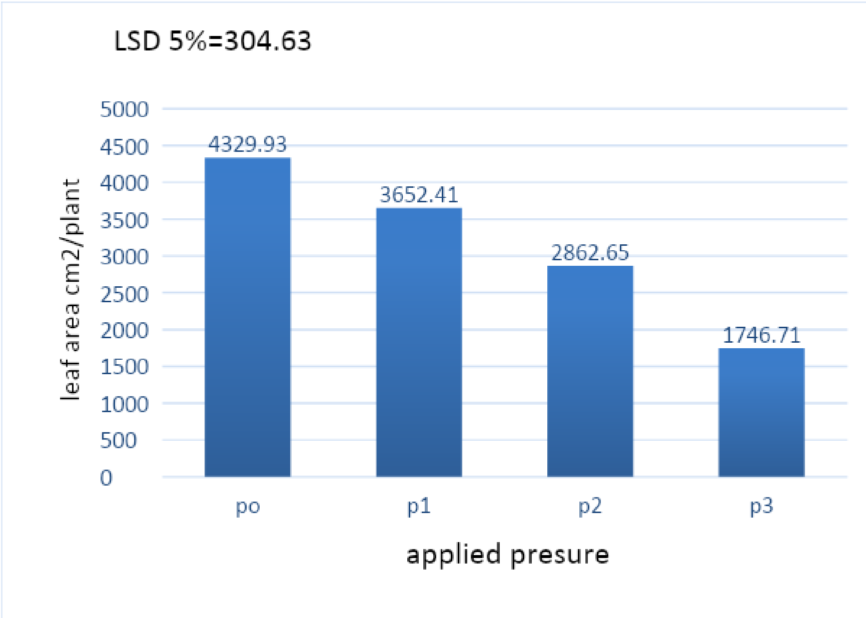

Fig. 4. The change in the leaf area (cm^2/plant) along with the change in the applied pressure.
P1= 163 kpa, p2= 216 kpa, p3= 297 kpa

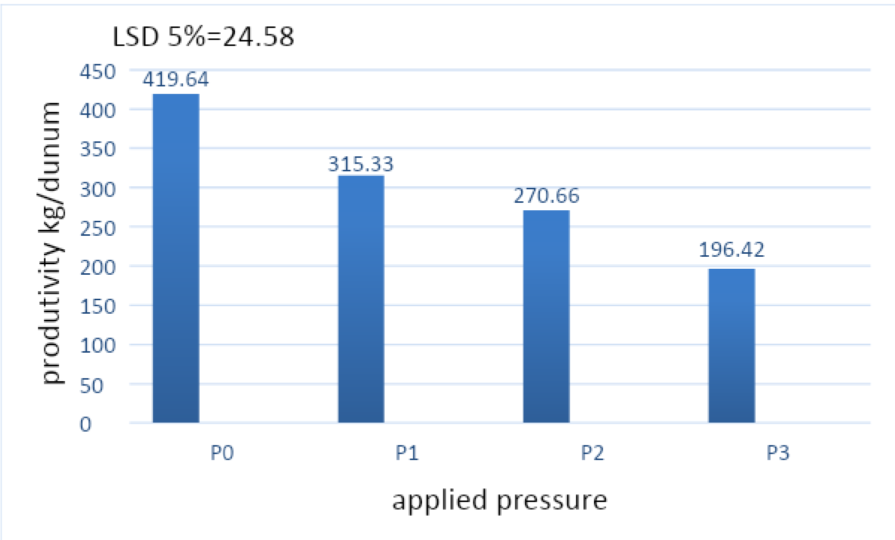

Fig. 5. The change in the productivity kg/dunum along with the change in the applied pressure
P1= 163 kpa, p2= 216 kpa, p3= 297 kpa

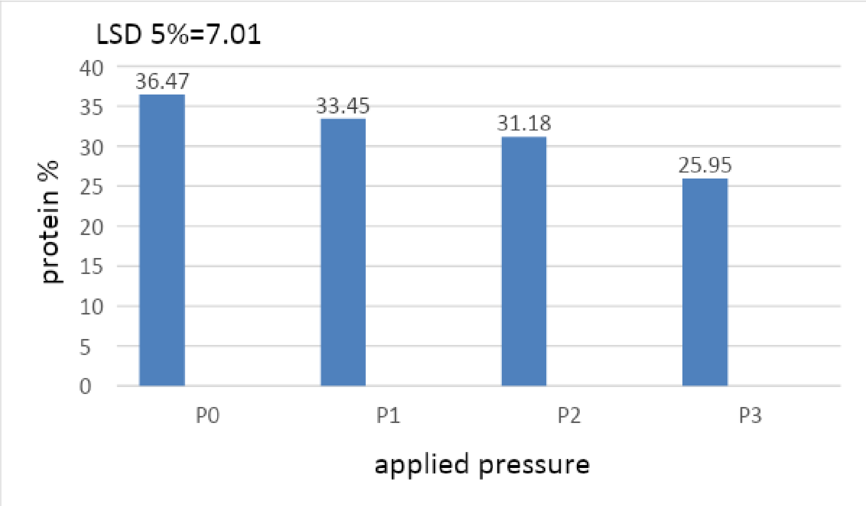

Fig. 6. The change in the protein percentage in the seeds along with the change in the applied pressure
P1= 163 Kpa, P2= 216 kpa, P3= 297 kpa

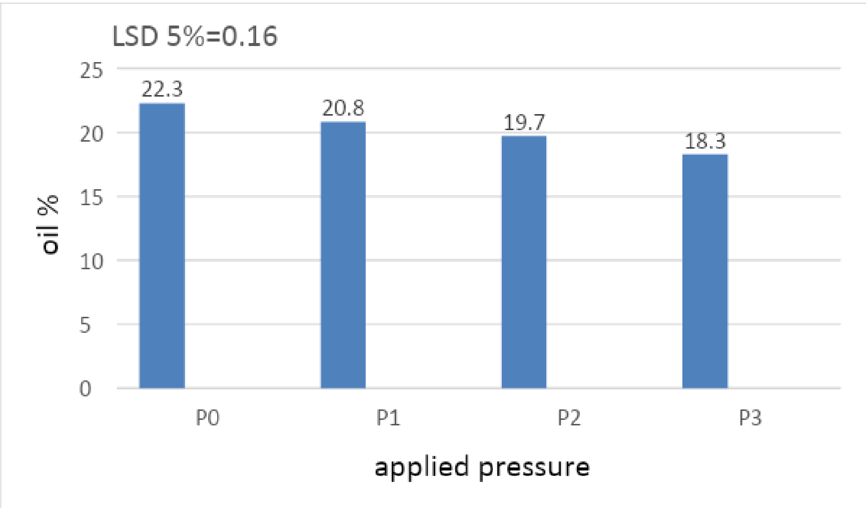

Fig. 7. The change in the oil percentage in the seeds along with the change in the applied pressure
P1= 163 kpa, P2= 216 kpa, P3= 297 kpa

(Fig. 4) showed a significant decrease in the leaf area with increasing the applied pressure.

The leaf area recorded 4329.93 cm^2/plant in the treatment without pressure, whereas it decreased to 3652.41 cm^2/plant at the pressure 163 kpa and decreased to 2862.65 cm^2/plant at the pressure 216 kpa as well as decreased to 1746.71 cm^2/plant at the pressure 297 kpa. This confirms the effect of the pressure on hindering the growth and the root distribution and hence a decrease in the growth of the shoot system, and this is similar to what was found by [13].

3.6 Produstivity

Successful soybean cultivation is assessed through two indicators, the first is the production and the second is the technological properties of this production, which are the percentage of oil and protein in the dry seeds. After the harvest, the pods were air –dried then the seeds were weighed on the plant in order to calculate the productivity in the studied treatment.

Results in (Fig. 5) showed that the productivity of the soybean crop was 419.64 kg/dunum in the treatment without pressure. While it significantly decreased at the pressure 163 kpa to 315.33 kg/dunum by 95.31 kg/dunum, and significantly decreased at the pressure 216 kpa to 270.66 kg/dunum by 139.98 kg/dunum as well as it significantly decreased to 196.42 kg/dunum by 223.22 kg/dunum at the pressure 297 kpa.

3.7 Protein Percentage

Soybean, in terms of protein content, surpasses all leguminous crops in addition to the high percentage of protein content in its seeds which ranges between 35-50%.

A decrease in the protein percentage was noticed in the seeds due to the increasing pressure in the studied treatments. Hence, the protein percentage insignificantly decreased by 3.02% at the pressure 163 kpa and insignificantly decreased by 5.29% at the pressure 216 kpa, while it significantly decreased by 10.52% at the pressure 297 kpa and that was similar to what was found by [12].

3.8 Oil Percentage

The oil percentage in the soybean seeds ranges between 6.5% and 19% and up to 28.7%, depending on soil variation, cultivar and climatic conditions [27]. Oil percentage was determined in the seeds due to its importance as an indicator of the production quality. It was noticed from (Fig. 7), a significant decrease in the oil percentage was recorded in all studied treatments resulted from the applied pressure, which the decrease was by 1.5% at the pressure 163 kpa and by 2.6% at the pressure 216 kpa, as well as by 4% at the pressure 297 kpa. The above-mentioned results indicated the effect of the pressure on the Soybean technological properties through the increase in the bulk density in the surface soil, the decrease in the total porosity values, and the imbalance in the distribution of the porous system of soil.

4. CONCLUCIONS AND RECOMMENDATIONS

Bulk density increased with increasing the pressure, whereas the effect of pressure on density diminished with increasing the depth. The greatest effect was at the depth (5-20cm), where the density increased at this depth by 0.33 g/cm^3 compared to the treatment without pressure (the control).

- Percentage of total porosity and the percentage of the pores bigger than 50 µm as well as those bigger than 10 µm, decreased with increasing the pressure. The increase in the pressure also accompanied with a decreased in the mesopores and an increase in the percentage of pores holding unavailable water.

- Hydraulic conductivity coefficient of saturated soils decreased with increasing the pressure at the studied depths. In addition, it recorded, in the treatment without pressure, high values greater than 1 m/day. Although it decreased the pressure, it didn’t exceed its limit value (0.1 m/day) except at the pressure 297 kpa at the depth (5-20)cm.

- A significant decrease in the leaf area with increasing the pressure in all studied treatments, where the greatest decrease recorded at the pressure 297 kpa by 2583.22 cm^2/plant compared to the control treatment.

- The production of the Soybean crop decreased with increasing the pressure which was 419.64 kg/dunum in the treatment without pressure and decreased at the pressure 297 kpa to 196,42 kg/dunum by 223.22 kg/dunum.

- The percentage of both protein and oil in the dry soybean deeds decreased with increasing the applied pressure. Regarding Protein, the greatest decrease was in the treatment of the pressure 297 kpa which recorded a significant decrease by 10.52% compared to the control treatment. As for the oil, the decrease was significant at all levels of the applied pressure, where the greatest decrease was at the pressure 297 kpa by 4% compared to the control treatment.

Based on the aforementioned, it is recommended to continue the research on other types of soils and crops at the aim of finding the limit value of pressure in order to limit the soil compaction in the future, which would reflect positively on growth and productivity of crops, quantitatively and qualitatively

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that generative AI technologies such as Large Language Models, etc have been used during writing or editing of this manuscript. This explanation will include the name, version, model, and source of the generative AI technology and as well as all input prompts provided to the generative AI technology.

Details of the AI usage are given below:

1.Natural Language Processing Natural language processing (NLP) uses deep learning algorithms to interpret, understand, and gather meaning from textual data. ...
2.Deep learning techniques are used to extract information and insights from videos and images.
3.Generative AI ...
Speech Recognition

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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