THE EFFECT OF THE TRACTOR PASSES ON THE SOIL BULK DENSITY IN SILTY CLAY SOIL

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SUMMARY

Silty clay soil was plowed by deep digger mold board plow at two moisture content (M.C) levels of 15% and 24.5%. The soil was plowed at three plowing depths (10, 15 and 20cm). Tractor of weight of 32.3kN was passed once to five times on the soil surface for both moisture content levels. The soil bulk density at M.C. level of 24.5%was 1.11, 1.16, 1.20, 1.25 and 1.30ton/m^3 while at M.C. level of 15% was 1.22, 1.27, 1.32, 1.35 and 1.42ton/m^3 for depths 0-5, 5-10, 10-15, 15-20 and 20-25ton/m3 respectively. The plowing operation reduced the bulk density (average) of the soil from 1.31 and 1.20ton/m^3 to 1.07 and 1.02ton/m^3 for moisture content levels 15% and 24.5% (21% and 17.6%) respectively.

When the tractor was passed once on the soil surface the bulk density of the plowed soil of M.C. level of 15% increased from 1.08 to 1.32ton/m^3 to become greater than that of unplowed (1.31ton/m^3). While for M.C. level of 24.5%, the bulk density increased from 1.02 to 1.12ton/m^3 but it remains lower than that for unplowed soil (1.20ton/m^3). However, when the tractor was passed five times, the bulk density of plowed soil for M.C. level of 15% increased to1.45ton/m^3. While for M.C. level of 24.5%, the bulk density increased to1.23ton/m^3 and in this M.C. level the bulk density of the plowed soil exceeded the unplowed soil at the fourth passes.

The soil compaction was more sever at the shallower plowing depth than the deeper operating depth for both M.C. levels. For operating depth of 10cm the bulk density for M.C. of 15% increased from 1.10 to 1.35ton/m3 for one tractor pass which exceeded the bulk density of unplowed soil (1.27ton/m^3). However, for operating depth of 20cm the bulk density increased from1.06 to1.30ton/m^3. For M.C. of 24.5% the bulk density increased from 1.03 to 1.14ton/m^3 but remained lower than that for unplowed soil 1.21ton /m^3 but for operating depth of 20cm the bulk density increased from 1.019 to 1.10ton/m^3.

Introduction

The soil bulk density is regarded the best parameter to evaluate the soil ability to supply the plant with water and the air. The bulk density in fact determines the soil water holding capacity and soil aeration and therefore the plants growth and productivity (1,2,3). These two factors are also fundamental for the activity of the soil organisms which develops soil structure and fertility through analyzing the organic matter and the residual of the crops which they supply the soil with humus and nutrient elements.

The soil bulk density should remain with in a certain range to keep the soil suitable for planting. In fact the soil bulk density changes with the time due to many factors some of them is internal due to the weight of the top layers of the soil and the other are external. The external factors are more harmful to the soil bulk density. For this reason the soil is plowed from time to time or every year to keep it more suitable for plant growth (8,10,11). The bulk density depends on the soil texture, the moisture content, and the weight of the agriculture machine, the tire inflation pressure and the contact area between the tires and soil surface. The bulk density for clay soil (heavy) is higher than light (less clay) due to the heavy weight of the top layers which causes confine pressure leading to higher bulk density (4,5,7,14). The suitable moisture content plays big roll in increasing the bulk density especially in silty clay soil. The main and the most effective factor in increasing the bulk density is the weight of the agriculture machines and the number of passes on the soil surface. As the weight of the agriculture machines and the number of passes increase as the bulk density increases (9,12,13). The tire inflation pressure has effect through reducing the contact area which increases the pressure and the tire resulting in higher soil compaction. Using the plows at the same operating depth every season or year can cause compacted layer at the bottom of furrow. The spread of the pressure into the soil body when the tractors pass whether downward and sideways depends upon the soil texture, soil moisture content, the tractor weight and the number of passes. In fact the soil compaction at shallow depths is eliminated by the plowing operation for preparing the soil for planting but the compaction in the deep layers remains and would be accumulated a long the years causing hard pan (10). The hard pan is a dense layer (high bulk density) could not infiltrate water to the soil depth causing some time water logging and that lead to soil salinity.This research was conducted to study the effect of number of tractor passes on the soil bulk density of a silty clay soil at two moisture content levels (15% and 24.5%). The soil was plowed using moldboard plow at operating depths of 10, 15 and 25cm. The numbers of passes are

1,2,3,4 and 5. The weight of the tractor and the tires inflation pressure remained constant during the experiments.

2.0 materials and methods

2.1 Moldboard plow

Deeper digger moldboard plow was used to conduct the experiments. The plow consists of three bodies. The plow is provided with pin point penetrator to increase the ability of the plow to penetrate the soil to the required depth.

2.2 The field experiments

The experiments were conducted in silty clay soil. The local of the experiments field is agriculture college, Garmit Ali. The field was divided into three areas. The dimensions of each area are 30 and 10m. The three areas were plowed using the moldboard plow. The operating depths were 10, 15 and 25cm for the three areas respectively. The operating depth was conducted randomly. Each area was divided to halves. The tractor and the implement combination passed on the surface of the plowed area to compact the soil once, twice, three, four and five times (figure 1). The passes for more than once were repeated on the same tire lane. The same passes were repeated on the second half. The experiments were conduct at moisture content of 24.5% and were repeated at moisture content of 15%. The soil physical properties were measured for unplowed, plowed and compacted soils and for both moisture contents. The measurements were taken for depths of 0-5, 5-10, 15-20 and 20-25cm. The measurements for the compacted lanes were taken across the compacted zone as shown in figure (2). The soil physical properties measured were moisture content, bulk density, cone penetration index and porosity. The measurements were repeated three times randomly.

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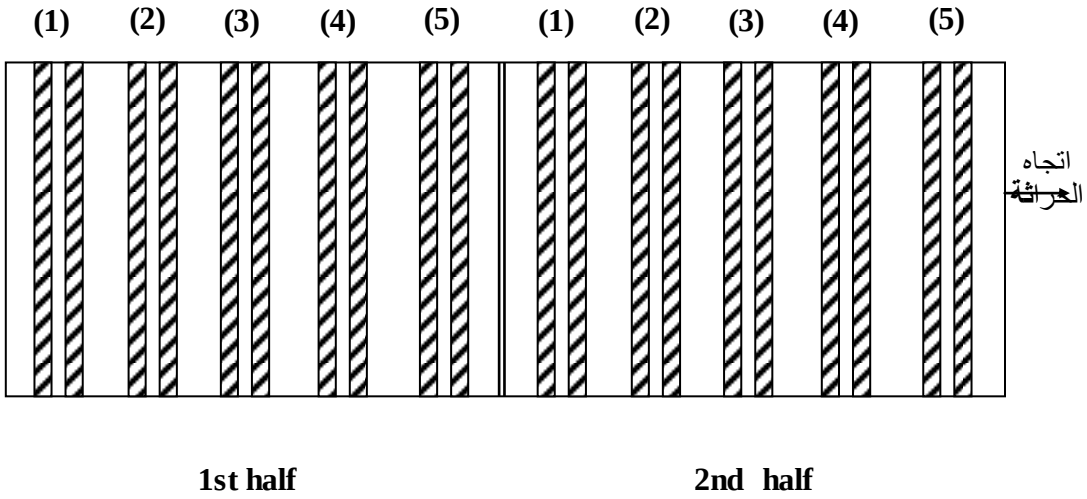

Figure (1): The numbers of passes are cross to the plowing operation for soil compaction.

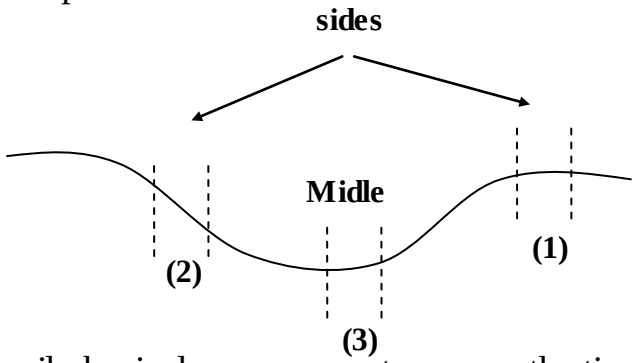

Figure (2): The soil physical measurements across the tire compacted lane.

2.3 Soil physical properties measurement

2.3.1 Soil texture

The soil texture was measured by pipette method as it is mentioned in (1). The results are shown in table (1).

Table(1): The texture of the soil of the field of the experiment

Sand ($g.kg^{-1}$)	Clay ($g.kg^{-1}$)	Silt ($g.kg^{-1}$)
15.40	45.50	39.10

2.3.2 Soil moisture content

The soil moisture content was measured by core method using dry weight for depths 0-5, 5-10, 10-15, 15-2- and 20-25cm for both soils moisture contents 15 and 24.5%. The results are shown in table (2)

Table(2): The moisture content of the soil at two moisture content levels for different depths

Moisture content 24.5%				Moisture content 15%				
Unplowed soil		Plowed soil		Unplowed soil		Plowed soil		
Moisture Content %	Bulk density t/m^3	Moisture Content %	Bulk density t/m^3	Moisture Content %	Bulk density t/m^3	Moisture Content %	Bulk density t/m^3	Depth (cm)
23.21	1.11	22.56	1.010	14.70	1.22	13.71	1.016	0-5
24.60	1.16	23.14	1.015	16.32	1,27	15.44	1.036	5-10
24.91	1.20	23.44	1.019	17.97	1.32	16.20	1.057	10-15
25.70	1.25	24.82	1.024	18.33	1.35	17.35	1.067	15-20
26.78	1.30	25.49	1.031	19.29	1.42	19.05	1.150	20-25

3.0 Results and Discussion

3.1 The effect of the plowing operation and soil depth on the bulk density

The bulk density of soils S1 and S2 increased as the depth increased (table 2) and that related to the effect of the weight of the surface layers which compacted the deep layers. Soil S1 had higher bulk density than soil S2 and that was due to the effect of the moisture content which was higher for soil S2 and the moisture content created films about the soil particles lead to pushing the soil particles a part. The average of the soil bulk densities of soils S1 and S2 before plowing are 1.29 and 1.20ton/m^3 respectively but the plowing operation reduced them to 1.08 and 1.023ton/m^3 (16.3% and 14.7%) respectively. The plowing operation disturbed the soil clods which increased the volume and the soil porosity.

The soil bulk density of both soils increased with depth even after the plowing operation (table 2) and that because the effect of the weight of the soil of the surface despite of the disturbance by the plow. However the increase in the bulk density depends on the soil moisture content. For example in the soil S2 (wetter soil) the bulk density for depth of 0-5cm is 1.01t/m^3 increased to 1.031t/m^3 for depth of 20-25cm but for soil S1 (dryer) the bulk density of depth of 0-5cm is 1.016t/m^3 increased to 1.15t/m^3 for depth of 20-25t/m^3.

3.2 The effect of the number of passes on the soil bulk density

The plowing operation reduced the soil bulk density considerably but the passes of the tractor and the implement (total weight =32kN= 3.2ton) on the soil surface increased the bulk density due to the compaction. The soil compaction depends on the number of passes, the moisture content and the depth relative to the soil surface. The results showed that when the tractor-implement combination passed one time on the plowed soil surface (S2), the bulk density of the surface layer (0-5cm) increased from 1.01 to 1.12ton/m^3 (10%) and became higher than that for the unplowed soil(1.11ton/m^3) (Figure 1). For depth of 5-10cm the increase in the bulk density was greater, it increased from1.015 to1.18ton/m^3 (14%) and it is also higher than that for unplowed soil (1.16t/m^3). For the remaining depths (10-15, 15-20 and 20-25cm) the increase in the bulk density is at reduction ratio. For depth of 10-15 the bulk density increased from 1.019 to 1.10ton/m^3 whereas for unplowed soil is 1.20ton/m^3. For depth of 20-25cm the increase was very limited, from 1.031to1.06ton/m^3 (2.7%) but for unplowed soil is 1.30ton/m^3. The clear increase in the bulk density at the surface was because the tire pressure is concentrated at the contact area between the tire and the soil causing rut on the soil surface. The peak of the pressure is in the middle of the rut and underneath the tires lugs which penetrate the soil surface up to 5cm causing bigger increase in the soil bulk density within the depth of 5-10cm. Beneath this depth the pressure of the tires scattered downwards and sideways and that reduced the effect of the pressure which reduced the increase in the bulk density. In additional to that the forward movement of the tractor did not give enough time to the pressure to penetrate to deeper layer to compact the soil. The effect of the tire pressure on the soil bulk density was greater in the lower soil moisture content (S1) than in the higher moisture content (S2). The effect of pressure is also depends upon the soil layer depth. For one pass the soil bulk density for the surface layer (0-5cm) increased from 1.016 to 1.32ton/m^3 which is higher the bulk density of the soil before the plowing operation (1.22ton/m^3) (Figure 2). For soil layer of 5-10cm the bulk density increased from 1.036 to 1.34 which also exceeded the bulk density of the soil before the plowing operation (1.27t/m^3). The bulk density of the lower depths increased but at lower rate and did not exceeded the bulk density of unplowed soil. For depth of 20-25cm the bulk density increased from 1.15 to 1.26t/m^3 where as before plowing was 1.42t/m^3. The higher bulk density of the soil S1 was because the moisture content of 15% reduced the soil clods strength considerable which render the clods to be crashed easily under the tire pressure and that increased its compaction. Where as for soil S2 the clods strength was high because the soil is near the plastic state

which caused the soil clods to with stand the tire pressure to some extant and that reduced the soil compaction. For two passes, the bulk density for both soils (S1 and S2) increased further and the bulk density of soil surface (0-10cm) remained the highest. The bulk density of soil S1 increased by 13-33% while, for soil S2 increased by 5.7-19%. For three passes the bulk density of S1 and S2 increased by 15-38% and 10-24% respectively (Figure 3). For four passes the bulk density for soils S1 and S2increased by 18-41% and 13-28% respectively (Figure4)When the tractor-implement combination passes five times the bulk density increased by 16-34% for soil S2 and by 20-50.5% for soil S1 (Figure5). The highest bulk density was recorded for depth of 5-10cm. The deeper depth suffered less than the shallow depths and their bulk density did not exceed that before the plowing operation. The third and fourth passes had medium effect on the bulk density. The results showed that the tractor- implement passes on the soil surface ended the advantage of the plowing which reduced the soil bulk density and increased the soil porosity at the surface layer but at the deeper layers the effect of passes was not sever as much as at the top layers. But the effect of the passes depends on the soil moisture content, it is more harmful when the moisture content within the soil friable state (10-20%).

3.3 The effect of the compaction and the plowing depth on the soil bulk density.

For soil S1 (table 3) which its moisture content within the friable state its bulk density increased with depth and that was because the weight of the soil at surface compact the soil at depth and this occurred because the clods strength at depth is weak. For soil S2 the contrary occurred, there is trending that the bulk density decreasing as the depth increasing. This can be related to the increase in the moisture content at depth which forms thick films around the soil particles which push them a part and that increased the volume of the soil (swelling). When the both soils were plowed their bulk density decreased considerably compared with unplowed soils. However, in the soil S1the reduction in the bulk density increased as the operating depth increased. This was because the moisture content of the top layer of soil S1less than at depth (suitable for plowing) which resulted in smaller clods and this lead to higher bulk density. For soil S2 the bulk density was almost the same and that was because the moisture content at the surface and depth is high (not suitable for plowing) which gave almost the small soil pulverization and that gave almost the same bulk density.

When both soils were compacted the bulk density of soil S1 increased and exceeded that of unplowed soil but it was not so for the soil S2. The

percentage of increase in soil S1 compared with that of the unplowed soil is 27%, 25% and 29% while for soil S2 is 14.5%, 13.7% and 15.8% for depths 10, 15 and 25% respectively. This means the improvement in the physical properties such as low bulk density and high porosity are lost.

The shallow depth (10cm) in soil S1 had higher bulk density (1.40ton/m^3)than the other operating depths (15 and 25cm) after compaction and that was because the plowed soil in the shallow depth squeezed between the tire contact area of the tractor tire and the unplowed soil underneath the plowed soil. This effect decreased as the plowing depth increased because the tractor tire moves forward before the pressure underneath it approach the bottom of the soil furrow. This means the effect of the tractor weight on the soil compaction decreased as the plowing depth increased. For soil S2 the results of the bulk density for the three depths are indecisive. The bulk density of the shallow depth (10cm) and the deeper

Table (3): The average of the bulk density for the operating depths, two soil moisture content levels and for unplowed, plowed and compacted soil.

Moisture content			Operating depths (cm)		
			10	15	25
	24.5	Unplowed soil	1.27	1.29	1.30
		Plowed soil	1.10	1.09	1.06
		Compacted soil	1.40	1.36	1.37
	15	Unplowed soil	1.21	1.19	1.20
		Plowed soil	1.03	1.02	1.019
		Compacted soil	1.18	1.16	1.18

depth (25cm) is same and that was because in this soil of high moisture content the clods were big which withstand the pressure of the tractor tire to some extent (higher ability to resist the pressure of the agriculture implements).

3.4 The interaction effect of the number of passes and the operating depth on the soil bulk density.

The most effective factor on the bulk density is the moisture content while the effect of the operating depth became second and is marginally higher than the number of passes. For operating depth of 10cm and one pass the bulk density of the plowed soil increased from 1.10 to 1.35ton/m^3 for the moisture content of 15% (22.7%), while for moisture content of 24.5% the bulk density increased from 1.03 to 1.14ton/m^3 (10.7%). When the soil moisture content is 15% the soil clods strength is lower than when the moisture content is 24.5% so they broke down easily. When the operating depth decreased from 25 to 10cm the bulk density increased from 1.30 to 1.35ton/m^3 (3.8%) for one pass and moisture content of 15%, while for moisture content of 24.5% the bulk density increased from 1.10 to 1.14ton/m^3 (3.6%). However for two passes and operating depth of 10cm the bulk density increased from 1.35 to 1.37ton/m^3 (1.5%) for moisture content of 15% while it increased from 1.14 to 1.15ton/m^3 (0.8%)

When the moisture content of the soil is suitable for compaction (15%) the bulk density of the plowed soil exceeded the value of the bulk density of the unplowed soil for one pass. While for higher moisture content of 24.5% the plowed soil regained the value of the bulk density of unplowed soil at the fourth passes.

Table (4): The average of the soil bulk density for three operating depths, different tractor passes, two moisture content levels and for plowed unplowed soils

Moisture content %		Unplowed soil				plowed		
		10	**15**	**25**		**10**	**15**	**25**
		1.27	**1.29**	**1.30**		**1.10**	**1.09**	**1.06**
	15%			**No. of passes**	**1**	**1.35**	**1.32**	**1.30**
					2	**1.37**	**1.34**	**1.34**
					3	**1.39**	**1.35**	**1.38**
					4	**1.42**	**1.38**	**1.41**
					5	**1.47**	**1.42**	**1.46**
		Unplowed soil				plowed		
		10	**15**	**25**		**10**	**15**	**25**
		1.21	**1.19**	**1.20**		**1.03**	**1.02**	**1.019**
	24.5%			**No. of passes**	**1**	**1.14**	**1.12**	**1.10**
					2	**1.15**	**1.15**	**1.14**
					3	**1.18**	**1.16**	**1.18**
					4	**1.20**	**1.19**	**1.23**
					5	**1.23**	**1.21**	**1.26**

4.0 Conclusions

The following conclusions can be drawn from the results:

(1) The bulk density of the soil increased as the soil depth increased for both soil M.C levels 24.5% and 15% and it was higher for the soil of lower M.C for the same soil depth.

(2) The plowing operation reduced the bulk density from 1.31ton/m^3 to 1.07ton/m^3 (21%) and from 1.20ton/m^3 to 1.02ton/m^3 (17.6%) for the soils of M.C levels of 15% and 24.5% respectively.

(3) When the tractor passes once on the soil surface the bulk density of the soil of M.C level of 15% increased from 1.08ton/m^3 to 1.32ton/m^3, exceeded the bulk density of the soil before the plowing operation, while for the soil of M.C of 24.5% increased from 1.02 to 1.12ton/m^3, lower than the bulk density before the plowing operation.

(4) For five tractor passes the bulk density of soil of M.C of 15% increased to1.45ton/m^3 but for soil of M.C of 24.5% increased to 1.23ton/m^3.

(5) The moist soil is more resisting to the compaction than the soil of lower moisture content. The bulk density of soil of M.C of 24.5% exceeded the value of the bulk density before the plowing operation at the forth tractor passes while for soil of M.C of 15% at the first pass.

(6) The soil compaction was more sever as the plowing depth decreased.

References

1- Black C.A., D.D. Evans. J.L. White, J.E. Ensminger and F.E. Clark (1993): Methods of soil analaysis. 6th ed. Am. Soc. Argo. MadisonWisconsin. U.S.A.

2- Busscher, W.J. (1990): Adjustment of Flat-Tipped penetrometer resistance data to common water content. Transaction of ASAE, Vol,(33), No.(2), pp. 519-524.

3- Byrd, C.D. and D.K. cassel (1980): The effect of sand content upon cone index and selection physical properties. Soil science Journal, Vol.(129), N0.(4).

4- Gill, W.R. and Vanden berg (1968): Soil dynamics in tillage and traction. Hand book 316. Agric. Dept. Washington, D.C.

5-Herrich, J.E. and T.L. Jones(2002): A dynamic cone penetrometer for measuring soil penetration resistance. Journal of soil science. American society of soil science. pp: 1320-1324.

6- Hummel, J.W. ; I. S. Ahmad; S. C. Newman; K.A. Sudduth and S.T. Drummond (2004): Simultaneous soil moisture and cone index measurement. Transaction of ASAE, Vol,(47), No.(3), pp. 607-618.

7- Hillel, D. (1980). Application of soil physical. Academic press. New York.

8- Kepner, R.A., R. Bainer and Bragers (1982). Principle of farm machinery. 3th ed. Avi. Pub co. west part, conn. U.S.A.

9- Lampurlanes, J. and C. Cantero-Martinez (2003): Soil Bulk density and penetration resistance under different tillage and crop

management systems and their relationship with barley root growth. Agronomy Journal. Vol. (95). Pp526-536.
10- Mckyes, E. (1985): Soil cutting and tillage. 1th edition. Elsevier Science
11- Nadel, H. (2003): Compaction and soil sub soiling effect on corn growth and soil bulk density. Soil science society of American Journal. pp: 1213-1219.
12- Schuler, R.T and B. Lowery (1992): Subsoil compaction effect in corn production with two soil type. ASAE St. Joseph. pp1028-1032.
13- PedroVaz, C. M. and J.W.Hopmans (2001): Simultaneous measurement of penetration resistance and water content with a combined penetrometer- TDR moisture probe. Soil science society of America Journal, Vol. (65), No. (4).
14-Tekeste, M.Z.; R.L. Raper and Schwab (2005): Spatial variability of soil cone penetration resistance as influenced by soil moisture on pacolet sandy loam soil in the southeastern united states. Tillage system conference, Clemson university. Oral proceeding.

تأثير عدد مرات مرور الجرار على الكثافه الظاهريه للتربه الغرينيه الطينيه المحروثه

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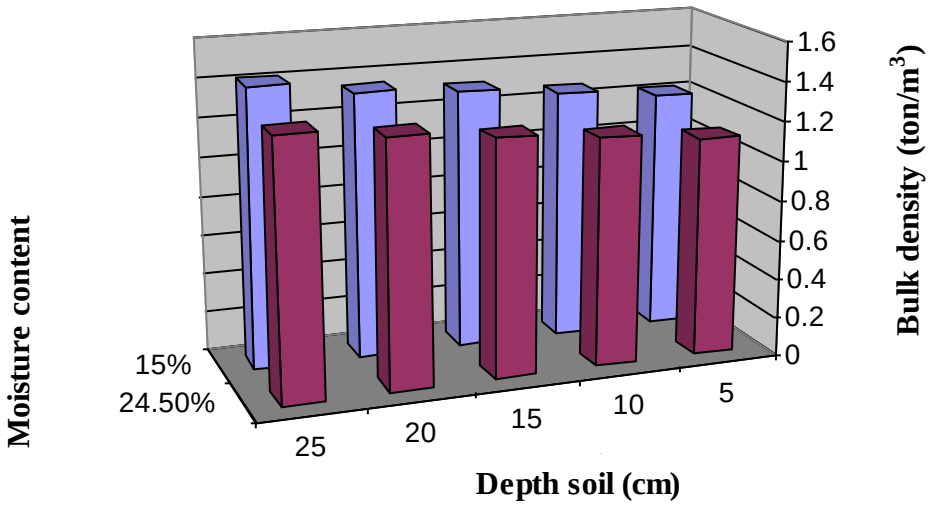
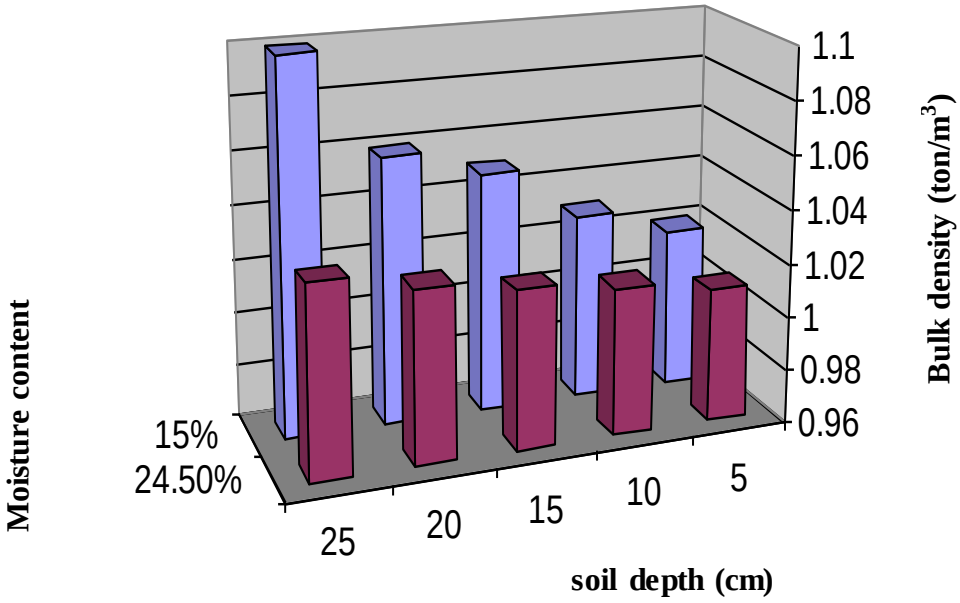
الخلاصة

أجريت تجربه فى تربه غرينه طينيه بعد حراثتها بمحراث مطرحى قلاب من النوع دوالمطرحه الحفاره العميقه للاعماق 10,15,20cm ولمستوين من الرطوبه 24.5% ,15%. مرر على سطح التربه جرار وزنه 32kN لغرض كبسها. مرر الجرار على التربه مره واحده ومرتين وثلاثه وأربعه وخمسه مرات وكررت عمليه الكبس ثلاثه مرات. قيست كثافه التربه بطريقه الاسطوانه وحسب طريقه الوزن الجاف وللاعماق. 0-5 و 5-10 و15-20 و 10-15 و 20-25 cm . حللت النتائج بأستخدام تصميم القطاعات المنشقه المنشقه Split-Split Block Design.الكثافه الظاهريه للتربه غير المحروثه للمستوى الطوبي 24.5% كانت 1.11 و 1.16و 1.20 و 1.25 و 1.30 ton/m^3 بينما للمحتوى الطوبي 15% كانت 1.27 و 1.22 و1.32 و 1.35 و1.42ton/m^3 للاعماق0 – 5 و 5- 10 و 10 – 15و 15 - 20 و 20 – 25 cm على التولى. خفضت عمليه الحراثه معدل الكثافه الظاهريه من 1.31ton/m^3 الى 1.07ton/m^3 (21%) للتربه دات المحتوى الرطوبي 15% ومن 1.20ton/m^3 الى 1.02ton/m^3 (17.5%) التربه ذات المحتوى الرطوبى 24.5% . أدى مرور الجرار لمره واحده على التربه الى زياده الكثافه الظاهريه للتربه ذات المحتوى الرطوبى 15% من 1.08ton/m^3 الى 1.32ton/m^3 وهى اعلى من كثافه التربه قبل الحراثه أما الكثافه الظاهريه للتربه ذات المحتوى الرطوبي 24.5% زادت من 1.02ton/m^3 الى 1.12ton/m^3 وهى اقل منها للتربه غير المحروثه. وعند المرور خمسه مرات زادت الكثافه الظاهريه للتربه دات المحتوى الرطوبي الاول زادت الى 1.45ton/m^3 وهى اعلى من تلك لغير المحروثه بمقدار 10.7% ومن المحروثه بمقدار 34.3% وزادت للتربه ذات المحتوى الثانى الى 1.23ton/m^3 وهى اعلى من تلك لغير المحروثه بمقدار 2.5% ومن المحروثه بمقدار 20.6%.



Figure(1): the relationship between the soil bulk density and the soil depth for two moisture content levels for unplowed soil (RLSD=2.281)



Figure(2): the relationship between the soil bulk density and the soil depth for two moisture content levels for plowed soil (RLSD=2.281)

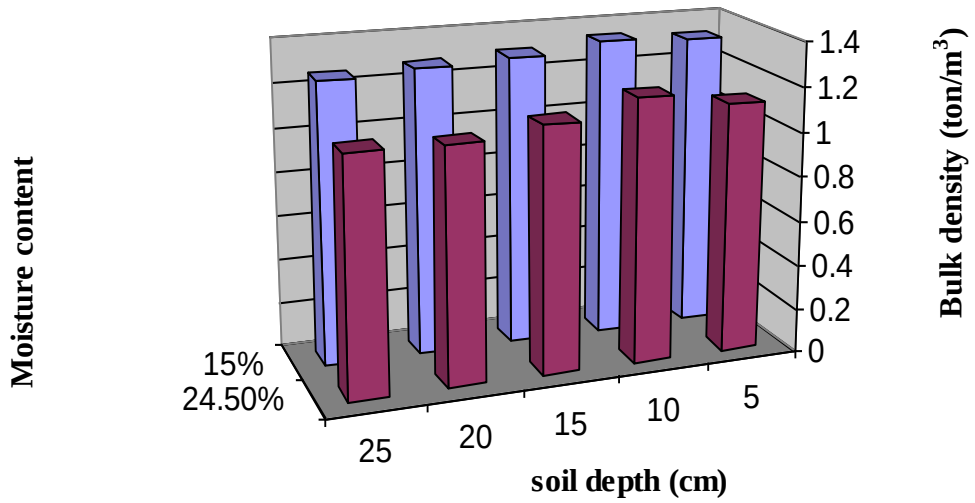


Figure (3): the relationship between the soil bulk density and the soil depth for two moisture content levels for one tractor-implement pass on the soil surface (RLSD=2.281)

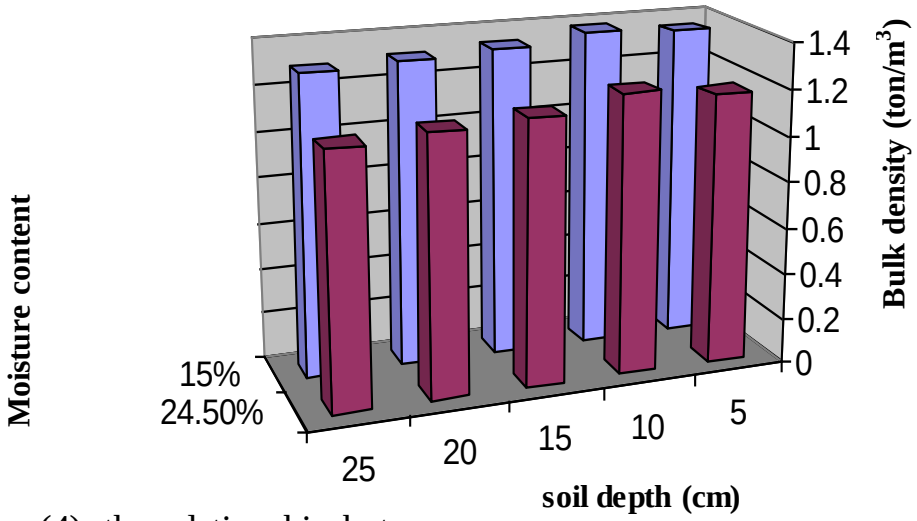


Figure (4): the relationship between e soil depth for two moisture content levels for two tractor-implement pass on the soil surface (RLSD=1.293)

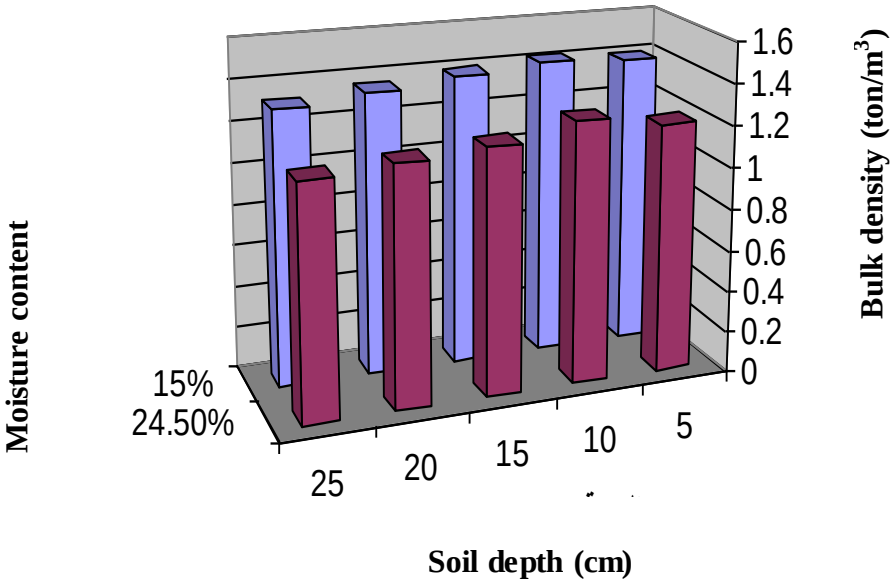


Figure (5): the relationship between the soil bulk density and the soil depth for two moisture content levels for three tractor-implement pass on the soil surface (RLSD=1.293)

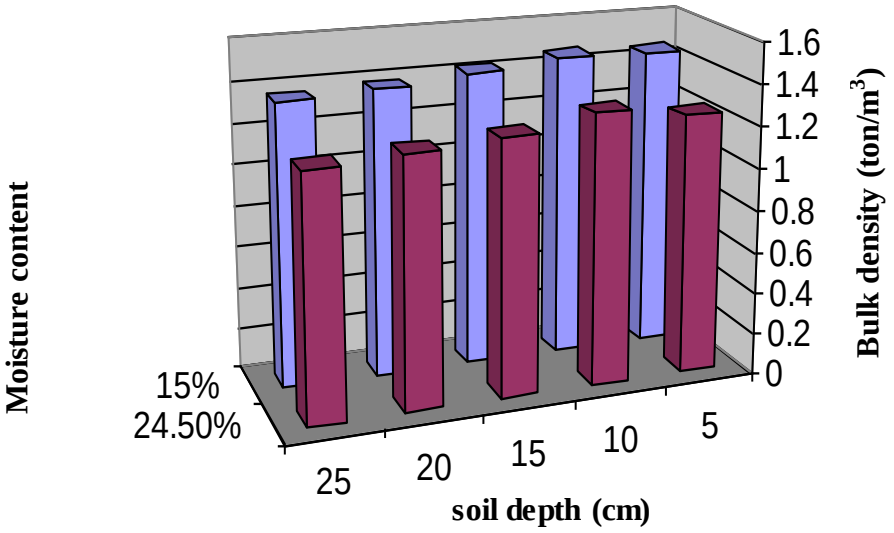


Figure (6): the relationship between the soil bulk density and the soil depth for two moisture content levels for four tractor-implement pass on the soil surface (RLSD=1.293)

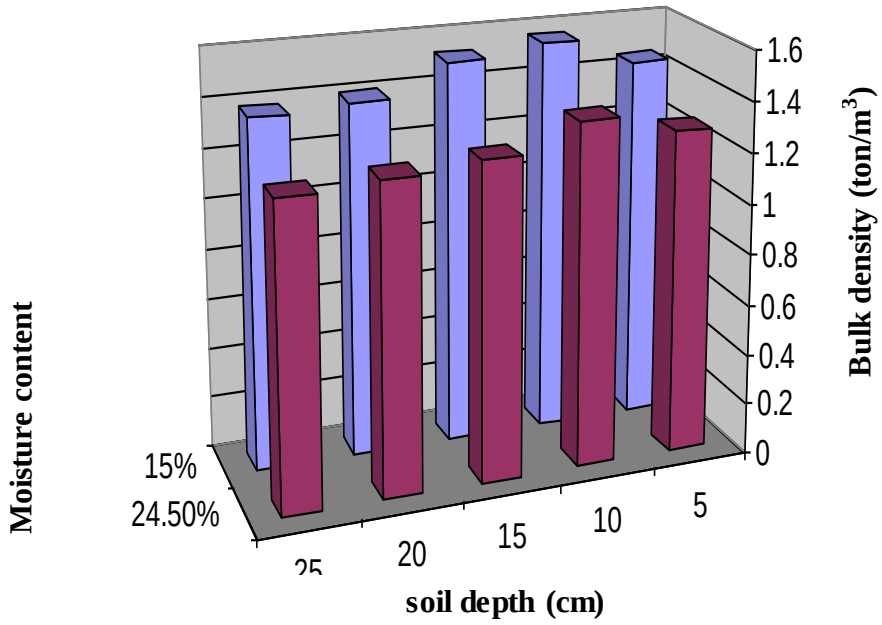


Figure (7): the relationship between the soil bulk density and the soil depth for two moisture content levels for five tractor-implement pass on the soil surface (RLSD=1.293)