Effect of Soil Pulverization Index and Forward Speed for Agricultural Machinery on Some Soil Properties for Compacted Soil Depths

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Abstract

In one of Agriculture college fields – Basrah University in Garmit Ali campus an experimental filed conducted in silty clay loam soil to study the effect of soil pulverization index and forward speed for agricultural machinery on some soil properties for compacted soil depths. The soil was tilled by moldboard by different speeds to get on three soil block its pulverization index 53.52, 21.06 and 7.55mm ($P.I_1$,$P.I_2$ and $P.I_3$). Then the tractor passed on these pulverized soil blocks with three forward speeds of 0.49, 0.74 and 1.05m.s^{-1} (S_1, S_2 and S_3). After that, measured soil penetration resistance (P.R.), dry bulk density (ρ_b) and total porosity (f) on four soil depths 0-5, 5-10, 10-15 and 15-20cm (D_1, D_2, D_3 and D_4). The results indicated that the S_1, $P.I_1$ and D_1 gave a lower P.R (2.07, 1.96 and 0.66 Mpa respectively) and ρ_b (1.13, 1.11 and 1.00 Mg.m^3 respectively) and a higher f (57.48, 58.10 and 62.35% respectively). The interaction between these factors gave different indicators. Where, the $S_2P.I_1$, $S_1P.I_1$ treatments had the lowest values for P.R (1.85 and 1.86 Mpa respectively) and ρ_b (1.09 and 1.10 Mg.m^3 respectively) and the highest values for f (59.05 and 58.54 %respectively). Additional that, the $S_2P.I_1D_1$ and $S_1P.I_1D_1$ reached lower values for ρ_b (0.88 and 0.91 Mg.m^3 respectively) and higher values for f (66.82 and 65.75 %respectively).

Keywords: soil compaction, tractor traffic, tractor passed, agricultural machine, pulverization index, tractor forward speed.

Introduction

Soil compaction occurs when soils are subject to stresses that exceed their strength (18). The researchers show that approximately 68 million hectare of lands in the world suffers from compaction (14). Soil compaction is one of the major problems facing modern agriculture which mainly resulted on the overuse of heavy machinery (13 and 20). The Soil Science Society of America (SSSA) defines compaction as "the process by which the soil grains are rearranged to decreases void space and bring them in to closer contact with one another, thereby increasing the bulk density" (19). So that, the compaction has negative affect on crops growth and yield (17 and 21). It had affected on crops yield by 10 to 15% (7). Addition that, the grain crops yield reduce by 10 to 40% due to soil compaction (7). The yield lose may be 50% or even more, depending upon the magnitude and severity of compaction of the soil (15).

Many studies conducted to determine the soil compaction affected on soil properties such as increases bulk density and penetrometer resistance (6 and 10). The forward speed of agricultural machines have significant effect on soil compaction where (11) recommended adoption of slow forward speed which under than 5.5 $Km.h^{-1}$ to controlled soil compaction of agricultural machine traffic. However, the forward speed for agriculture machine is important indictor to effect soil compaction which leading to increase soil bulk density and penetration resistance with increase it (12). The increase forward speed from 0.49 to 1.25 $m.s^{-1}$ leaded to increase bulk density and penetration resistance from 1.20 $Mg.m^{-3}$ and 1340.83 $kN.m^{-2}$ to 1.29 $Mg.m^{-3}$ and 2293.94 $kN.m^{-2}$ respectively corresponded that decreased porosity from 52.92 to 49.49% (4).The depth of soil compacted depended on soil type and tillage depth where closed from soil surface with heavy soil and severe traffic heavy agricultural machine, additional that it closed from soil surface with shallow tillage (1). The soil compacted on the depth of root zone (10 – 40 cm) with traffic of agricultural machines caused to resist the root growth of plant and reduce yield (16). Generally, soil compaction increase bulk density and soil strength and reduces soil porosity (15).That main factors affected on soil compaction are soil type/texture (% clay), soil moisture content (M.C.), bulk density by soil layer and size of soil structural units/pulverization (clods) (2). But do not found studies to determine traffic of agricultural machine on soil compaction with different soil pulverized. So that, this research focused on study effect of the traffic forward speed of agricultural machine on different degrees of soil pulverized and compacted soil depths.

Materials and Methods

The research was conducted in one of Agriculture college fields – Basrah University in Garmit Ali campus in the soil appeared its properties in table (1) by the tractor which its properties shown in table (2) to study the effect of three forward speed of tractor 0.49, 0.74 and 1.05 m.s^{-1} (S_1, S_2 and S_3) with three of pulverized degrees (pulverization index) 53.52, 21.06 and 7.55mm ($P.I_1$,$P.I_2$ and $P.I_3$) and four depths of compacted soil 0-5, 5-10, 10-15 and 15-20cm (D_1, D_2, D_3 and D_4) on soil dry bulk density (ρ_b), penetration resistance (P.R) and total porosity (*f*).The experiment carried out with factorial Randomly Complete Block Design (RCBD) which it's statically analysis of F appeared in table 3. The soil was tilled by moldboard plow on 30 cm with three forward speeds which produced three layers of soil pulverization index. The tractor and moldboard plow passed on the soil tilled block and the soil properties below measured on the paths of tractor tiers traffics.

1. Soil bulk density (ρ_b)

Determined before and after tillage and after compacted by the Core Sampler Method (5) and calculated from equation 1.

$$\rho_b = \frac{M_s}{V_t} \text{ ....(1)}$$

ρ_b: Soil dry bulk density (Mg.m^{-3}).

M_s: Mass of dry soil (Mg).

V_t: Total volume soil (m^3).

2. Soil penetration resistance (P.R)

Soil penetration resistance was measured by penetroloagger which measuring penetration resistance each 1cm depth from soil. The cone of 30° penetrated angle and base area 1cm^2 used before tillage and after compaction while the cone of 60° penetrated angle and base area 3.3 cm^2 used after tillage (2 and 3).

3. Soil total porosity (*f*)

Calculated before, after tillage and after compaction from equation 2, depended on Vomocil method (5).

$$f = \{1 - \frac{\rho_b}{\rho_s}\} \times 100 \text{ ....(2)}$$

f: Soil total porosity (%).

ρ_b: Soil dry bulk density (Mg.m^{-3}).

ρ_s: Soil particle density (2.65 Mg.m^{-3}).

Table 1. Physical soil properties.

Before Tillage

Depth (cm)	P.R (Mpa)	ρ_b (Mg.m^{-3})	f (%)	M.C (%)	Soil Particles (g kg^{-1}) Sand	Silt	Clay	Texture
0-5	0.83	1.14	56.98	7.73	35.29	546.54	418.17	silty clay
5-10	2.01	1.29	51.32	15.59	36.20	592.66	371.14	Silty clay loam
10-15	3.46	1.39	47.55	17.09	38.63	650.83	310.54	Silty clay loam
15-20	4.01	1.41	46.79	17.91	51.06	657.07	291.87	Silty clay loam
average	2.58	1.31	50.66	14.58	40.29	611.78	347.93	Silty clay loam

After Tillage

Pulverization index (mm) / Depth (cm)	P.I$_1$ 53.52				P.I$_2$ 21.06				P.I$_3$ 7.55			
	P.R (Mpa)	**ρ_b (Mg.m^{-3})**	**f (%)**	**M.C (%)**	**P.R (Mpa)**	**ρ_b (Mg.m^{-3})**	**f (%)**	**M.C (%)**	**P.R (Mpa)**	**ρ_b (Mg.m^{-3})**	**f (%)**	**M.C (%)**
0-5	0.11	0.88	66.77	4.66	0.11	0.96	63.76	5.17	0.10	0.83	68.53	4.28
5-10	0.30	0.93	64.78	5.81	0.28	0.86	67.55	6.14	0.19	0.87	67.29	7.73
10-15	0.73	1.00	62.27	4.29	0.62	0.95	64.24	7.44	0.49	0.90	66.17	4.02
15-20	0.98	1.06	59.88	8.80	0.83	1.01	62.00	7.32	0.60	0.94	64.55	5.89
average	0.53	0.97	63.42	5.89	0.46	0.94	64.39	6.52	0.34	0.88	66.64	5.48

Table 2. The properties of tractor used.

Tractor type		Case Hi
Model		JX75T
Tractor total weight		2700 kg
Traction type		4WD
Front wheels	volume	11.2/24
	pressure	35 psi
Rear wheels	volume	16.9/30
	pressure	34 psi

Table 3. The statically analysis of F for P.R., ρ_b and *f*.

Source of Variation (S.O.V.)	**d.f**	**P.R.**	ρ_b	f
A	2	3.190*	7.647**	6.899**
B	2	5.738**	19.978**	7.322**
C	3	124.230**	156.054**	77.287**
A×B	4	3.337*	12.547**	8.603**
A×C	6	0.832n.s	4.194**	3.000*
B×C	6	0.681n.s	1.249n.s	0.389n.s
A×B×C	12	0.740n.s	3.234**	3.182**
Error	71	0.390	0.002	1.943

A: forward speed, B: pulverization index, C: soil depth, *: significant, **: high significant, n.s: no significant.

Results and Discussion

1. **Effect of forward speed (S) on P.R., ρ_b and *f*.**

The results in table (3) show that the effect of the traffic forward speed of the tractor was significant on P.R., with high significance on ρ_b and *f*. The results in table (4) represent that the P.R. and $\rho_b$increased by 15.16 and 3.42% respectively, with decreased *f* by 2.90% when increase the traffic forward speed from S_1 to S_3 and without significant difference between S_2 and S_3. The highest traffic forward speed caused excess of tires collision on soil and vibration for tractor to upper the pressure of tractor on soil. (4 and 12).

Table 4. The effect of forward speed (S) on P.R., ρ_b and *f*.

Forward Speed (m.sec^{-1})	P.R (Mpa)	ρ_b (Mg.m^{-3})	*f* (%)
0.49 (S_1)	2.07	1.13	57.48
0.74 (S_2)	2.22	1.16	56.34
1.05 (S_3)	2.44	1.17	55.86
RLSD	3.12	0.020	0.826

2. Effect of Pulverization Index (P.I.) on P.R., ρ_b and *f*.

The traffic of tractor on soil has differences pulverization index affected by a higher significant on the P.R., ρ_b and *f* (table 3). The table 5 pointing to increase the P.R. by 18.67% with decrease pulverization index from $P.I_1$ to $P.I_3$, without significant difference between $P.I_2$ and $P.I_3$. While, the results indicated that the decrease of the pulverization index from $P.I_1$ to $P.I_2$ leaded to increase ρ_b by 5.93%, corresponded that the *f* reduced by 4.50%, without significant difference from $P.I_2$ and $P.I_3$. Generally, the reduction of the pulverization index values with increase soil pulverized from $P.I_1$ to $P.I_2$ and $P.I_3$ means the increase of soil pulverized leading to the soil strength become weak. So that, the soil has been responded more to the compaction of the tractor traffic (9).

Table 5. The effect of Pulverization Index (P.I) on P.R., ρ_b and *f*.

Pulverization Index (mm)	P.R (Mpa)	ρ_b (Mg.m^{-3})	*f* (%)
53.52 ($P.I_1$)	1.96	1.11	58.10
21.06 ($P.I_2$)	2.37	1.18	55.60
7.55 ($P.I_3$)	2.41	1.17	55.99
RLSD	2.86	0.019	0.775

3. Effect of soil depth (D) on P.R., ρ_b and *f*.

The table 3 indicated that the soil depth affected with a higher significant on the P.R., ρ_b and *f*. The table 6 showed that the P.R. and ρ_b excessed by 81.87 and 20% respectively while the *f* reduced by 18.40%. The pressure for the traffic of tractor is distributed in the depths of tilled soil from upper to down (4). Additional that, the highest values of P.R. and ρ_b were in D_4 before and after tillage as a shown in table 1.

Table 6. The effect of soil depth (D) on P.R., ρ_b and *f*.

Soil Depth (cm)	P.R (Mpa)	ρ_b (Mg.m^{-3})	F (%)
0-5 (D_1)	0.66	1.00	62.35
0-10 (D_2)	1.67	1.13	57.36
10-15 (D_3)	3.02	1.22	53.88
15-20 (D_4)	3.64	1.25	52.66
RLSD	2.97	0.021	0.860

4. Effect of the interaction between forward speed (S) and pulverization Index (P.I) on P.R., ρ_b and *f*.

The traffic of tractor on a soil has a different pulverization index leaded to significant effect on P.R. with a higher significant on ρ_b and f (table 3). The table 7 showed that the $S_2P.I_1$ treatment had lower values for P.R and ρ_b which reached 1.85 Mpa and 1.09 Mg.m^{-3} respectively, and it had an upper value for f was 59.05%. Additional that the $S_2P.I_1$ treatment had not significant differences compared $S_1P.I_1$ and $S_1P.I_2$ for these properties. The lowered values of $S_2P.I_1$ and $S_1P.I_1$ was a result of the capability of soil with $P.I_1$ to resistance of compaction by tractor due to its saved some internal strength compared other treatment. While the decrease values of $S_1P.I_2$ were due to decrease collation force of tractor on soil and its vibration with slow forward speed.

The major values reached 2.75 Mpa and 1.25 Mg.m^{-3} for P.R. and ρ_b respectively, and a lower value for f was 52.92% for $S_2P.I_2$ treatment. The medium of soil pulverization ($P.I_2$) was great respond to compaction of tractor traffic compared $P.I_1$ and $P.I_3$ because the $P.I_1$ treatment have saved some of its strength to resistance the compaction for tractor traffic, while the $P.I_3$ treatment was very fine so that it displaced to the deferent victors under tractor tire through traffic which distributed the pressure of tractor on soil. Beside that the S_2 gave long traffic time to compact of soil from S_3. Also, the S_2 gave a higher collation and vibration for tractor on soil from S_1. These reasons were combined to resulted the $S_2P.I_2$ was gave a higher P.R. and ρ_b and a lower f.

Table 7. The effect of interaction between forward speed (S) and pulverization index (P.I) on P.R., ρ_b and f.

Forward Speed ($m.sec^{-1}$)	Pulverization Index (mm)	P.R (Mpa)	ρ_b ($Mg.m^{-3}$)	f (%)
	53.52 ($P.I_1$)	1.86	1.10	58.54
0.49 (S_1)	**21.06 ($P.I_2$)**	1.91	1.12	57.61
	7.55 ($P.I_3$)	2.46	1.16	56.30
	53.52 ($P.I_1$)	1.85	1.09	59.05
0.74 (S_2)	**21.06 ($P.I_2$)**	2.75	1.25	52.92
	7.55 ($P.I_3$)	2.07	1.14	57.05
	53.52 ($P.I_1$)	2.17	1.15	56.71
0.49 (S_3)	**21.06 ($P.I_2$)**	2.46	1.16	56.27
	7.55 ($P.I_3$)	2.70	1.20	54.61
RLSD		555.876	0.034	1.364

5. Effect of the interaction between traffic forward speed (S) and soil depth (D) on P.R., ρ_b and f.

The table 3 indicated that the interaction between forward speed and soil depth has not significant effect on P.R. while the interaction affected by a higher significant on ρ_b and significant on f. The results in table 8 shown that the S_1D_1 treatment was gave a lower ρ_b and a higher f which reached 0.98 $Mg.m^{-3}$ and 63.20% respectively. Also the S_1D_1 treatment was not significant differences compared S_2D_1 and S_3D_1. The luges of tractor tires displaced the soil through traffic which cancels the effect traffic compaction for the soil surface.

The S_2D_4 treatment was reached a higher ρ_b and a lower f which gave 1.29 $Mg.m^{-3}$ and 51.24% respectively. Without significant differences compared S_1D_4 treatment. The slow and medium speed (S_1 and S_2) give the traffic pressure enough time to distribute in deep soil to compact soil on D_4.

Table 8. The effect of interaction between forward speed (S) and soil depth (D) on ρ_b and f.

Forward Speed ($m.sec^{-1}$)	Soil Depth (cm)	ρ_b ($Mg.m^{-3}$)	f (%)
0.49 (S_1)	0-5 (D_1)	0.98	63.20
	0-10 (D_2)	1.10	58.44
	10-15 (D_3)	1.18	55.51
	15-20 (D_4)	1.25	52.80
0.74 (S_2)	0-5 (D_1)	1.00	62.32
	0-10 (D_2)	1.11	57.97
	10-15 (D_3)	1.22	53.83
	15-20 (D_4)	1.29	51.24
0.49 (S_3)	0-5 (D_1)	1.02	61.54
	0-10 (D_2)	1.18	55.68
	10-15 (D_3)	1.26	52.29
	15-20 (D_4)	1.22	53.96
RLSD		0.043	1.745

6. Effect of the interaction between traffic forward speed (S), pulverization index (P.I) and soil depth (D) on P.R., ρ_b and f.

The results in table 3 pointed that the forward speed of traffic on soil has differences pulverization index was not significant effect on P.R. while affected by a higher significant on ρ_b and f for different soil depths. The table 9 represented that the $S_2P.I_1D_1$ treatment reached the lower values of ρ_b and f ware 0.88 $Mg.m^{-3}$ and 66.82% for these properties respectively. The $S_2P.I_1D_1$ treatment did not register significant differences compared the $S_1P.I_1D_1$ treatment. The luges of tractor tires displaced the soil through traffic which canceled the effect traffic compaction for the soil surface. Additional, that the capability of soil with $P.I_1$ to resistance of tractor compaction due to its saved some internal strength compared other treatment. Corresponding that, decrease collation force on soil and tractor vibration with slow and medium forward speed (S_1 and S_2).

The results in table 9 indicated that the higher values were $S_2P.I_2D_4$ treatment gave 1.43 $Mg.m^{-3}$ and 45.92% for ρ_b and f

respectively. Because the S_2 gave the traffic pressure enough time to distribute in deep soil to compacted soil on D_4. Additional that the higher responsible of $P.I_2$ to compact of tractor traffic.

Table 9. The effect of interaction between forward speed (S), pulverization index (P.I) and soil depth (D) on ρ_b and *f*.

Forward Speed (m.sec^{-1})	Pulverization Index (mm)	ρ_b (Mg.m^{-3})				*f* (%)			
		0-5 D_1	5-10 D_2	10-15 D_3	15-20 D_4	0-5 D_1	5-10 D_2	10-15 D_3	15-20 D_4
0.49 (S_1)	53.52 ($P.I_1$)	0.91	1.04	1.18	1.27	65.75	60.76	55.52	52.13
	21.06 ($P.I_2$)	0.98	1.11	1.16	1.24	63.02	58.06	56.20	53.16
	7.55 ($P.I_3$)	1.04	1.15	1.20	1.24	60.82	56.49	54.80	53.10
0.74 (S_2)	53.52 ($P.I_1$)	0.88	1.05	1.19	1.22	66.82	60.25	55.02	54.11
	21.06 ($P.I_2$)	1.11	1.16	1.28	1.43	58.02	56.12	51.64	45.92
	7.55 ($P.I_3$)	1.00	1.13	1.20	1.23	62.13	57.53	54.85	53.69
1.05 (S_3)	53.52 ($P.I_1$)	1.02	1.19	1.18	1.20	61.45	55.13	55.54	54.74
	21.06 ($P.I_2$)	1.00	1.18	1.27	1.20	62.45	55.48	52.28	54.87
	7.55 ($P.I_3$)	1.04	1.16	1.35	1.27	60.71	56.41	49.04	52.27
RLSD		0.080				3.230			

Conclusion

The results pointed that the single factors of forward speed and soil depth effected on soil penetration resistance, bulk density with a direct relationship and an inverse relationship with soil porosity. While, the soil pulverization index gave different effects on these properties (soil penetration resistance, bulk density and soil porosity) depended on the capability of soil to respond the compaction according to degrees of soil pulverize. Thereby, the interaction between these factors gave differences effect on these properties. Where, the interaction between forward speed and soil pulverization index with $S_2P.I_1$, $S_1P.I_1$ treatments had the lowest values for soil penetration resistance and bulk density while the highest values for soil porosity with interaction of these factors with soil depth. Traffic of tractor on soil was positive affected on the surface soil depth by decreased soil penetration resistance and bulk density and increased soil porosity.

Conflict of interest

The authors declare no conflict of interest.

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