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INFLUENCE OF TRACTOR SLIP ON SOME PHYSICAL PROPERTIES OF THE SOIL AND FUEL CONSUMPTION AT VARYING TILLAGE DEPTHS AND SPEED

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Abstract

The experiments were conducted in two locations, both soil were homogeneous loamy soil. The experiments were carried out at different moisture content (18.3 and 20.4%) for the first and second locations respectively during the Agricultural Season of 2018 at Diwaniyah Province. The aim of the study was to investigate the effect of tractor types (2WD and 4WD) New Holland tractor at two levels of speeds(4.2 and 6.5 km.h^{-1}) and at two different tillage depths (15 and 20 cm) on some technical properties of machines unit and soil physical properties. Fuel consumption and slippage percentage are observed considerable rise with increase of forward speed and tillage depth in both of locations. The higher value rate of soil compaction indicators of the Bulk density and porosity at tractor tire track in the bottom of the tillage furrow was achieved while using (2WD) tractor type as compared to the (4WD) tractor type. The effect of moisture content was significant on increasing of soil compression as well as increasing fuel consumption. In addition Statistical significant effect of moisture content was found on slippage percentage which led to an increase in soil compaction and technical properties for machines unit.

Keywords **:** Tractor, speed, tillage, moisture content.

Introduction

In Diwaniyah Province, more than 3165 tractors are used for tillage and crop service in 2018 (I.A.S.D., 2018)). So any increase in number of tractors are accompanied with increase in soil compaction due to inappropriate utilization during tillage, such as tillage depths and high tractor speed more than required. Any increment in tillage depths or the level of tractor speed lead to a considerable rise to wheel slippage ,which made a big trouble under the effect of the rear wheel of the tractor which increase the soil compression(Al aridhee Jawad & Al-Sabagh Abdul Rahman, (2011). One of the most serious problems, which face agriculture operation is the loss of agricultural land. The quantity of food required to feed the rising human population. it will become more difficult to produce as more land is lost. For example, the growth of plant roots will be difficult due to compaction of soil around them. Problems of soil compaction are caused in agricultural soils mostly due to agriculture machines operation and are more severe in soils with high moisture content. The state of a soil changes with weather, machine loads, different pressures applied to the soil. The soil compaction is measured under tractor wheels, working with different wheel slippage. Wheel slippage proved to be more significant because of compaction than additional wheel loading. This effect was more obvious at the greater power of the tractor (Davies *et al*., 1972). The reduction of large soil pores leads to soil compaction increasing the strength of the soil and obstruct the movement of air and water through the soil. Thus, the soil remained wet and cool longer into the growing season (Bertrand *et al*., 1991). The soil bulk density and its porosity are the main indicator to determine this phenomenon. the tractor wheel traffic is one of the mean effect to increase soil bulk density taking in the thought the soil moisture which is the critical factor during wheel pass in the state of soil bulk density (Morad *et al*., 2007). Naeimi *et al*., 2015 revealed that the stress of soil under the wheel pass increases with pressure caused by the tractor's weight or wheels track. The magnitude of the increment depends on the load per wheel-soil contact area, depth and the place from the tractor wheel. Generally the travel of tractor and agricultural machines as well as their speed have a great effect on soil bulk density (Morad *et al*., 2007; Tanner and Dexter, 1974) determined that undisturbed soil suffers less compaction especially at higher speeds of tractor passes. Naeimi *et al*., 2015 noticed that Soil strength properties decreased with increasing of speed but increased with depth of tillage. (Ahaneku& Ogunjirin, 2005) discovered that the minimum bulk density found at the maximum forward speed thus soil was compact more at the minimum forward speed due to increase time of contact duration. Soil penetration resistance and its bulk density are being used to measure soil compaction levels. It was observed that soil compaction higher at lower operation speed. The higher speed has less effect on compression of the soil (Carman, 2002; Khodaei, 2015; Carman, 1994 and Aboaba, 1969) mentioned that forward speed influences soil compaction mainly at lower speeds and its effect decreases with increase of tractor speed due to decreasing of contact duration by increased forward speed and this lead to decrease soil compaction (Carman, 2002; Taghavifar & Mardani, 2014). The slip in soil tillage is an important factor for analysis of fuel consumption. The improvement of the transmission of the drawbar power to soil could be reached by using 4-wheel drive. The traction efficiency could be improved for a 2-wheel driven tractors with an optimal position of the virtual drawing point (adjusted via the upper link). A reduction of ploughing depth reduces the slip, hourly and area related fuel consumption Moitzi *et al*. (2006). In another hand, the tractor types were observed to have a significant impact on soil compaction through increased bulk density and reduced porosity of agricultural soils under the tractor tire in bottom of the tillage furrow. The compaction of soil while using (2WD) tractor was found very high due to

the higher slippage as compared to (4 WD) tractor (Al aridhee & Al-Sabagh, 2011). Keeping all above points in view, this study was conducted to investigate the effect of tractor types (2WD and 4WD) New Holland tractor at different forward speed with different tillage depths on some technical properties of machines unit and soil physical properties.

Materials and Methods

1. Machine Used: Four wheel derived and (2WD) New Holland tractors were used in recent study and their specifications are presented in (Table.1) and disc plough (three discs) utilized for tillage operation in the experiments.

Table 1 : Tractors specifications

Tractor types	TD 80 (4WD)	TD 80 (2WD)
weight with ballast (Kg)	3677	3247
Horse power/rev/min	75/2500	75/2500

2. Soil selection: Experiments were conducted at Diwaniyah Province during the Summer agricultural season of 2018 to evaluate the effects of forward speed and tillage depth on soil compaction, The soil texture was loamy and its compositions as described in (Table 2). The experiments were carried out after harvesting wheat crop which grown in previous season. The required soil moisture for performing experiments was obtained from even irrigation to 25 cm depth of soil. Samples of soil were collected during the tillage experiments to determine the average moisture contents. The samples were weighed using a balance, and the weight of each sample was recorded. Then the samples were placed in an oven maintained at 105°C for 24 h.

Table.2 : Tractors specifications

Character		Value
Actual density (g.cm^{-3})		2.65
Bulk density (g.cm^{-3})		1.38
Porosity (%)		47
Soil texture	**sand (%)**	45
	clay (%)	21
	silt (%)	34
Soil type	**loamy**	

3. Moisture determination: The moisture content of the field was 15.5% before experiment implemented. In order to get two levels of moisture content of 18.3 and 20.4%, the field was divided two locations with the same condition such as texture of soil and moisture before experiments conduction. Initially, irrigation of soil to both locations by using centrifugal pump and check up of moisture everyday for achieving, according to the plan prepared in advance for the purpose of obtaining the level of moisture to be implemented in the two experiments of 18.3 and 20.4%. The moisture was calculated according to the formula.

$$M = \frac{Mw}{Ms} \times 100 \quad ....(1)$$

Where: M- Moisture content [%], Mw- Water mass [g] and Ms- Soil mass[g]

3. Soil physical parameters: Two parameters was used in experiments, for estimating soil compaction indicators included Bulk density and porosity at the centre of tractor tire track in the bottom of the tillage furrow. They were calculated according to the formulas.

$$Pb = \frac{Ms}{Vt} \quad ....(2)$$

Where: Pb – Bulk density [g.cm^{-3}], Ms- Soil mass [g] and Vt- Total soil sample size [cm^{-3}]

$$\Phi = 1 - \frac{Pb}{Pt} \quad ....(3)$$

Where: Φ - Total soil porosity [%], Pb – Bulk density and Pt - Actual density

4. Machine parameters: Fuel consumption and slippage percentage was measured according the following equations.

$$Fc = \frac{Fca}{Tp} \times 3.6 \quad ....(4)$$

Where: Fc- Amount of fuel consumed [L. h^{-1}], Fca-Amount fuel recorded by the device [mmL], and Tp- Real time for replication [s]

$$S = 1 - \frac{Vp}{Vt} \quad ....(5)$$

Where: S- Slippage percentage [%], Vp- Practical speed[Km.h^{-1}] and Vt- Theoretical speed

Statistical analyses: Experimental data were analyzed using Statistical, Dell Inc. (2016) version 13. Tukey's test, were used to estimate the significant differences in order to compare the means of parameters at 0.05 level ($p<0.05$).

Results and Discussion

Tables 3, 4 showed impact of tractor types on slippage percentage at different humidity (18.3 and 20.4%) in two locations are presented. The higher value of 16.6 and 18.6 % was achieved for tractor (2WD), whereas the lower value of 9.3 and 11.2 % was achieved for tractor (4WD) in location 1st and 2nd respectively. This may be due to the fact that the total weight of (4WD) tractor acted on the rear and front wheels while the weight of (2WD) tractor acted on its rear wheels only. The weight increases the soil strength underneath the traction wheels of the tractor and this reduces the wheels slippage which is the main source of power loss (Aday *et al.*, 2011). The results showed that the slippage percentage considerable increased with the increase of tillage depth from 15 to 20 cm in both locations. The higher values were found at the second location as compared to the first location as set in table (3 and 4). From The same tables, it can be noticed significant differences in slippage percentage with changing of foreword speed from 4.2 to 6.5 Km.h^{-1} for both locations. The results obtained in the second location were observed very high as compared to the first location because of the high moisture content. Statistical differences between means of each tractor types, depth and forward speed levels were calculated by applying Tukey procedures and their results are shown in the tables.

Table 3 : Influence of tractor types, depth of tillage and forward speed on the slippage percentage at first location.

Effect	Descriptive statistics of the slip [%]					
	Level of Factor	Mean	Std.Dev.	Std.Err	-95.00%	+95.00%
Type tractor	2WD	16.6[a]	3.54	1.022	14.39	18.89
Type tractor	4WD	9.3[f]	1.20	0.346	8.58	10.11
Depth [cm]	15	12.6[d]	4.36	1.259	9.82	15.37
Depth [cm]	20	13.3[c]	4.85	1.402	10.30	16.47
Speed[km.h^{-1}]	4.2	10.7[e]	2.81	0.811	8.99	12.57
Speed [km.h^{-1}]	6.5	15.2[b]	4.93	1.425	12.06	18.34

Table 4 : Influence of tractor types, depth of tillage and forward speed on the slippage percentage at second location.

Effect	Descriptive statistics of the slip [%]					
	Level of Factor	Mean	Std. Dev.	Std. Err	-95.00%	+95.00%
Type tractor	2WD	18.6[a]	3.54	1.022	16.39	20.89
Type tractor	4WD	11.2[f]	1.20	0.346	10.58	12.11
Depth [cm]	15	14.6[d]	4.36	1.259	11.82	17.37
Depth [cm]	20	15.3[c]	4.85	1.402	12.30	18.47
Speed[km.h^{-1}]	4.2	12.7[e]	2.81	0.811	10.99	14.57
Speed [km.h^{-1}]	6.5	17.2[b]	4.93	1.425	14.06	20.34

The fuel consumption of (4WD) tractor was significantly less at both locations. The values were 6.6, 7.8 and 7.9, 9.1 L.h^{-1} for first and second respectively (Table 5,6). This may be due to, the slippage increased while using (2WD) tractor as compared to (4WD) tractor. Moreover, as the depth of tillage increased from 15 to 20 cm and the forward speed increased for 4.2 and 6.5 Km.h^{-1}, the fuel consumption also increased in both locations. This may be due the fact that the required power increase with the increase of depth of tillage and forward speed as it mentioned by (Kassar *et al*., 2018; Safari *et al*., 2014).

Table 5 : Influence of tractor types, depth and speed on fuel consumption at first location

Effect	Descriptive statistics of the fuel consumption [L.h^{-1}]					
	Level of Factor	Mean	Std.Dev.	Std.Err	-95.00%	+95.00%
Type tractor	2WD	7.84[b]	1.557	0.448	6.854	8.829
Type tractor	4WD	6.64[e]	1.554	0.448	5.654	7.629
Depth [cm]	15	5.88[f]	0.956	0.276	5.275	6.490
Depth [cm]	20	8.60[a]	0.822	0.237	8.077	9.122
Speed[km.h^{-1}]	4.2	6.66[d]	1.658	0.478	5.612	7.720
Speed [km.h^{-1}]	6.5	7.81[c]	1.464	0.422	6.886	8.746

Table 6 : Influence of tractor types, depth and speed on the fuel consumption at second location.

Effect	Descriptive statistics of the fuel consumption [L.h^{-1}]					
	Level of Factor	Mean	Std.Dev.	Std.Err	-95.00%	+95.00%
Type tractor	2WD	9.11[c]	1.556	0.448	8.154	10.129
Type tractor	4WD	7.92[de]	1.554	0.448	6.954	8.929
Depth [cm]	15	7.14[f]	0.956	0.276	6.575	7.790
Depth [cm]	20	9.90[a]	0.822	0.237	9.377	10.422
Speed[km.h^{-1}]	4.2	7.91[e]	1.658	0.478	6.912	9.020
Speed [km.h^{-1}]	6.5	9.15[b]	1.464	0.422	8.186	10.046

Table 7, 8 revealed that tractor types had a significant effect on bulk density. The maximum value was obtained while using 2WD tractor with comparison to 4WD tractor at both locations and this agreed with results obtained by (Al-aridhee & Al-Sabagh, 2011) who revealed that slippage is higher during using 2WD tractor as compared to 4WD tractor. The maximum values were (1.66 &1.76) g.cm^{-3} for 1st and 2nd location respectively. The compaction index(bulk density) was superior at 2nd location as compared to 1st location because the compaction increased with increase of moisture for both tractors due to high slippage. Moreover, it was found a considerable rise in bulk density as forward speed and tillage depth increased.

Table 7 : Influence of tractor types, depth and speed on the bulk density at first location.

Effect	Descriptive statistics of the bulk density [g.cm^{-3}]					
	Level of Factor	Mean	Std.Dev.	Std.Err	-95.00%	+95.00%
Type tractor	2WD	1.66^{a}	0.030	0.0087	1.641	1.680
Type tractor	4WD	1.55^{f}	0.048	0.0138	1.524	1.585
Depth [cm]	15	1.57^{e}	0.069	0.0201	1.532	1.621
Depth [cm]	20	1.63^{b}	0.048	0.0139	1.608	1.669
Speed[km.h^{-1}]	4.2	1.59^{d}	0.071	0.0207	1.553	1.644
Speed [km.h^{-1}]	6.5	1.61^{c}	0.063	0.0182	1.576	1.656

Table 8 : Influence of tractor types, depth and speed on the bulk density at second location.

Effect	Descriptive statistics of the bulk density [g.cm^{-3}]					
	Level of Factor	Mean	Std.Dev.	Std.Err	-95.00%	+95.00%
Type tractor	2WD	1.76^{a}	0.030	0.008	1.741	1.780
Type tractor	4WD	1.65^{f}	0.048	0.013	1.624	1.685
Depth [cm]	15	1.67^{e}	0.069	0.020	1.632	1.721
Depth [cm]	20	1.73^{b}	0.048	0.013	1.708	1.769
Speed[km.h^{-1}]	4.2	1.69^{d}	0.071	0.020	1.653	1.744
Speed [km.h^{-1}]	6.5	1.71^{c}	0.063	0.018	1.676	1.756

Finally, the second index of compaction (the porosity) was minimum while using 2WD tractor at both locations. This indicted a higher compaction while using 2WD tractor due to high slippage. However, forward speed and tillage depth had a contrary effect on porosity. This due to the fact that porosity and bulk density in divergent relationship.

Table 9 : Influence of tractor types, depth and speed on the porosity at first location.

Effect	Descriptive statistics of the porosity [%]					
	Level of Factor	Mean	Std.Dev.	Std.Err	-95.00%	+95.00%
Type tractor	2WD	0.37^{e}	0.011	0.003	0.366	0.380
Type tractor	4WD	0.41^{a}	0.018	0.005	0.401	0.424
Depth [cm]	15	0.40^{b}	0.026	0.007	0.388	0.421
Depth [cm]	20	0.38^{d}	0.018	0.005	0.369	0.393
Speed[km.h^{-1}]	4.2	0.39^{c}	0.027	0.007	0.379	0.413
Speed [km.h^{-1}]	6.5	0.38^{d}	0.023	0.006	0.374	0.405

Table 10 : Influence of tractor types, depth and speed on the porosity at second location.

Effect	Descriptive statistics of the porosity [%]					
	Level of Factor	Mean	Std.Dev.	Std.Err	-95.00%	+95.00%
Type tractor	2WD	0.33^{e}	0.011	0.003	0.328	0.342
Type tractor	4WD	0.37^{a}	0.018	0.005	0.363	0.387
Depth [cm]	15	0.36^{b}	0.026	0.007	0.350	0.384
Depth [cm]	20	0.34^{d}	0.018	0.005	0.332	0.355
Speed[km.h^{-1}]	4.2	0.35^{c}	0.027	0.007	0.341	0.376
Speed [km.h^{-1}]	6.5	0.35^{c}	0.023	0.006	0.337	0.367

Conclusions

It was noted from the above results that the fuel consumption and slippage parameters were higher significantly while using 2WD tractor as compared to 4WD tractor. Moreover, The indicates of compaction (bulk density and porosity) showed that the soil compaction decreased significantly while using 4WD tractor. This indicate that 4WD tractor is superior to 2WD tractor economically and in mechanical performance. However, moisture content, forward speed and tillage depth had inverse effect on all studied parameters. Therefore, it is recommended to use 4WD tractor rather than 2WD Tractor.

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