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STUDY ON THE EFFECT OF TRACTORS AND AGRICULTURAL MACHINES TRAFFIC ON SOIL COMPACTION

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ABSTRACT: Field experiments were conducted to study the effect of tractors and agricultural machines traffic on the state of soil compaction in terms of soil bulk density and soil penetration resistance. Two main experiments were carried out. The first experiment was conducted during land levelling operation for rice using three different tractors equipped with three different land levellers at four different forward speeds and two different moisture contents. The second experiment was conducted during harvesting rice using three different combines at four different forward speeds. The experimental results revealed the following points: Penetration resistance as well as soil bulk density values was higher for heavy tractors and heavy agricultural machines than for light ones under all investigated parameters. The root growth zone (20 cm depth) and crop yield were in the safe region under the following conditions.

In the case of using heavy tractor (forward speed of less than 3.6 km/h, and moisture content of about 15%).

In the case of using medium tractor (forward speed of less than 4.2 km/h, and moisture content of between 15 - 25%).

In the case of using light tractor (forward speed of less than 5.8 km/h, and moisture content of about 25%).

In the case of using the combine harvesters (forward speed of about 3.3 km/h).

Key words: Penetration resistance, tractor, combine, bulk density.

INTRODUCTION

The increase of any crop production in both quantity and quality depends on the improvement of soil and plant conditions as well as largely on using improved methods ad technology to fulfill the agricultural processes in correct time. The major concern associated with the use of tractors and agricultural machines is soil compaction. The term compaction refers to the act of artificially increasing the density of soil. It involves the pressing of soil particles together into closer contest, and expelling air or water from spaces between them.

Soil may be compacted by pressure, vibration, impact or by combinations resulting from tractors and agricultural machines traffic. Due to the excessive use of them in performing agricultural operations, there is a continuous change in the soil characteristics, especially in the root zone. As a result, the worst soil physical properties are expected consequently crop yield is highly affected by soil compaction. The motion of tractors and farm machinery compacts the soil to the point of reducing any crop productivity.

Chanceller (1977), concluded generally accepted criteria that cone index values greater than 2000 kPa frequently reduced crop yields and values above 1500 kPa frequently reduced root growth.

Korayem *et al.,* (1981) stated that increasing tillage operations increased soil compaction causing reduction in yield.

Gaultney *et al.,* (1982) indicated that the degree of soil compaction depends on soil moisture content and they added that working on wet soil may cause more compaction and more less of yield.

Abou El-Kheir and Abd El-Gaffar (1985) showed that the forward speed of ploughing was directly proportional to soil – quality indices (bulk density variation and penetration of soil resistance variation).

Awady *et al.,* (1985) investigated the effect of tractor vibration on soil compaction using a locally made proto type tractor, they concluded that cone index increases with the increased of rotating eccentric mass.

Ahmed et al., (1988) studied the effect of compaction on the soil physical properties and crop yield and concluded that the crop yield is highly reduced by compaction process.

Abo-Habaga (1989) reported that soil compaction had two forms, the first was artificial and the second was natural. He showed that compaction is affected by different factors such as mass of machine ,moisture content and soil type.

Abu-Habaga and Abu-El Eas (1990) studied the effect of tractor traffic on the variation of some soil physical properties and pressure distribution in soil. They measured the maximum and residual pressure at four different soil depths. They concluded that the residual pressure slightly increases with the number of passes whose effect diminishes with the depth of soil.

El-Banna (1990) developed two component soil compaction model, based on a soil moisture content and bulk density data from the field measurements. The model considers moisture content, clay ratio, tire pressure, tire size, axle load and number of wheels passes.

Michael (1990) reported the effect of land levelling on the compaction at soil layer of 20 cm depth .He indicated that the compaction increases as levelling uniformity coefficient increased but it was very small. He stated that the load and compaction forces of the equipment usually influence on deeper layer with damped effect causing an increase in bulk density.

Hamad *et al.*, (1992) proved that the strong and negative relationship was found between yield and root growth from one side and both of soil bulk density and penetration resistance of soil.

Morad and Arnaout (1993) reported that to control the state of soil compaction in case of using heavy tractors, the following are recommended.(1) Number of passes of less than five passes.(2) forward speed of less than 5.5 km/h.(3) soil moisture content of 21%(4) Inflation – pressure of 100 kPa. So, the objectives of the present study are:

1. Investigating the effect of tractors and agricultural machines traffic on soil compaction in terms of soil bulk density and soil penetration resistance.
2. Investigating the residual effect of compaction resulting from the use of tractors and agricultural machines at different soil depths
3. Optimizing some different parameters (forward speed and soil moisture content) to control their effect on soil physical properties and crop yield

MATERIALS AND METHODS

The main experiments were carried out to study the effect of different tractors and Agricultural machines traffic on soil compaction during land levelling and harvesting operation for rice production.

Mechanical analysis of the experimental soil was classified as clay soil as shown table (1). While Table (2) show some physical properties of first and second experimental soils

Table 1: Mechanical analysis of the experimental soil.

Soil classification	Soil fraction, %		
	Clay	Silt	Sand
Clay	42.4	26.3	25.2

Table 2: Some physical properties of the first and second experimental soils.

		Depth, cm	Moisture content,%	Bulk density,g/cm	Penetration resistance, kpa
1.ex	Average soil moisture content =15%	0-10	5.3	1.82	1206
		10-20	17.3	1.63	834
		20-30	23.18	1.43	530
	Average soil moisture content =25%	0-10	8.6	1.79	1180
		10-20	25.7	1.47	616
		20-30	36	1.32	405
2.ex	Average soil moisture content =22%	0-10	12	1.82	1206
		10-20	28	1.63	834
		20-30	34	1.43	530

Materials

Machinary and Equipment

The following machines were used in carrying out the present investigation.

Tractors: Three tractors were used.

1. Heavy tractor was (Legend 165(4RM)) Landini with an engine of 165 hp, total weight of (7450 kg) and Specifications of tire was (38, 18.4)

2. Medium tractor was (M-110-(4WD)) Kubota with engine of 110 hp, total weight of (4550 kg), and Specifications of tire was (36, 18.4).

3. Light tractor was (Universal 650M) Romani with an engine of 65 hp total weight of (3000 kg) and Specifications of tire was (38, 15.8).

Combines: Three combines were used.

1. Heavy combine was (PRO 481) Kubota with an engine of 48 hp total weight of (2920 kg), and Specifications of crawler was (400×1300 mm).

(1) Adjusting screw.(2)The oil filler.
(3) The manometer. (4)The hand grips.
(5) The measuring instrument.
(6) The plunger. (7)The extension rod.
(8) The rod . (9) The cone

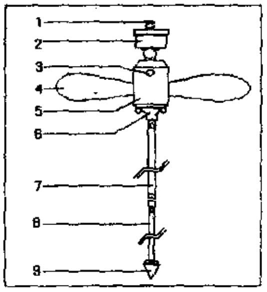

Fig. 1: Hand Penetrometer

2. Medium combine was (R1-40) Kubota with an engine of 40 hp total weight of (2700 kg), and Specifications of crawler was (400×1300 mm).
3. Light combine was (CA 385EG) Yanmar with an engine of 38 hp total weight of (2450 kg) and Specifications of crawler was (350×1300 mm).

Land levellers

Three locally land levellers were used. The first leveller (heavy) was (Mabrouk -12) with working width of 3.6 m and total weight of (770 kg),while the second (medium)was (k-10 Beheira Co) with working width of 3 m and total weight of (660 kg),and the third (light)was (Mabrouk 8) with working width of 2.4 m and total weight of (330 kg).

Instruments

Soil penetrometer

Soil penetrometer was used to estimate soil penetration resistance as shown in fig: 1

Methods

Field experiments were carried out at Diarb Nigm Farm, Sharkia Governorate during land levelling and harvesting operation of rice.

Two main experiments were carried out to study the effect of tractors and agricultural machines traffic on soil compaction and optimize some different parameters to control their effect on soil physical properties and crop yield.

The first experiment

The first experiment was conducted during land levelling operation for rice. The experimental area was about 6 feddans divided into two equal plots (3 feddans each). The first area (3 feddans) having moisture content of about 15% while the second at about 25%. Each previous plot was divided into three equal subplots (one feddan each).

Three treatments namely T1, T2 and T3 were carried out in the first area while three other treatments namely T4, T5 and T6 were carried out in the other area and replicated three times in completely randomized block design.

Treatment T1: land levelling using heavy tractor + heavy land leveller at an average soil moisture contents of 15%.

Treatment T2: land levelling using medium tractor + medium land leveller at an average soil moisture contents of 15%.

Treatment T3: land levelling using light tractor + light land leveller at an average soil moisture content of 15%.

Treatment T4: land levelling using heavy tractor + heavy land leveller at an average soil moisture contents of 25%.

Treatment T5: land levelling using medium tractor + medium land leveller at an average soil moisture contents of 25%.

Treatment T6: land-leveling using light tractor light land leveller at an average soil moisture contents of 25%.

The land levelling operation was carried out at four different forward speeds of about 3.6, 4.2, 4.9 and 5.8 km/h.

However, bulk density and soil penetration resistance were measured at three different soil depths (0-10, 10-20 and 20-30 cm).

The second experiment

The second experiment was conducted during harvesting rice. The experimental area was about 3 feddans divided into three equal plots (1 feddan each). Three treatments namely A, B and C were carried out and replicated three times in completely randomized block design.

Treatment A: Harvesting rice using heavy combine

Treatment B: Harvesting rice using medium combine

Treatment C: Harvesting rice using light combine

The harvesting operation was carried out at four different forward speeds of about 2.25, 2.75, 3.3 and 3.8 km/hr.

Both bulk density and soil penetration resistance were measured at three different soil depths (0-10, 10-20 and 20-30 cm).

Soil moisture content during harvesting was kept constant at about 22 %.

Measurements

Soil bulk density (B.D)

Soil samples were taken with cylindrical core (100-cm3 volume) at three different depths (0-10), (10-20) and (20-30) cm.

The core samples were immediately weighted before and after drying at 105 C° for 24 hours. Soil bulk density before and after each treatment was determined according to use paraffin black method, Black *et al.*, (1965) depending on the following formula:

B.d = W.d/Tv ....(1)

Where:

B.d :Soil bulk density, g/cm^3 ;

Tv : Total soil volume, cm^3;and

W.d: Weight dry, g.

The increase percentage in bulk density (ΔBd) was calculated as follows:

$$\Delta Bd = 100\ (Bd_2 - Bd_1) / Bd_1\ (\%) \qquad (2)$$

Where.

Bd_1 and Bd_2: bulk density before and after treatments, g/cm^3.

Soil moisture content (M.C)

The moisture content of soil was determined by using the standard oven method. Soil samples were taken from three depths of (10 – 20 and 30 cm) by screw auger. Samples were weighed, to be dried to 105 C° for 24 hours using electric oven. The moisture content was calculated according to Black (1965) as follows:

$$M_c = 100\ (S_w - S_d)/S_d\ (\%) \qquad (3)$$

Where:

M_c = Soil moisture content, %;

S_w = Wet soil mass, g; and

S_d = Dry soil mass, g.

Penetration resistance (P)

The soil Penetration resistance was measured by using the soil penetrometer before and after each treatment as follows.

P = manometer reading / area of cone=10xF/ A(kPa) .... (4)

Where

P: Penetration resistance, kPa;

F: Force required, N ;and

A: Area of cone, cm^2.

The increase percentage in soil penetration resistance (ΔP) was calculated as follows:

$$\Delta P = 100\ (P_2 - P_1)/ P_1(\%) \qquad (5)$$

Where:

P_1 and P_2: Soil penetration resistance before and after treatments N/cm^2.

Performance of farm machinery

Operational time, actual field capacity and field efficiency were calculated for both tractors and combines.

Fuel consumption:

Fuel consumption during the operation was calculated by measuring the quantity of fuel required to refill the fuel tank after the working period.

Power required (P.R.).

The following formula was used to estimate the required power **(Embaby, 1985)**.

$$\mathbf{P.R. = F_C\ (1/3600)\ P_f \times C.V. \times 427 \times \eta_{th} \times \eta_m \times 1/(75 \times 1.36)(\ kW)} \ldots\ldots(11)$$

Where:

F_C = The fuel consumption per time, Lit/h;

P_f = The density of fuel (for solar = 0.85) kg/Lit;

C.V. = calorific value of fuel,(average C.V. of solar is 10.000 kCal/kg);

427 = Constant (Thermo-mechanical equivalent) kg. m/k Cal ;and

η_{th} = The thermal efficiency of engine, % (consider about 35% for combine diesel engine and about 40% for tractor diesel engine);

η_m = The mechanical efficiency of engine. (Consider about 80% for diesel engine).

$$\mathbf{P.R. = 2.77\ F_C}\text{, kW (combine)}\ldots(12)$$

$$\mathbf{P.R.= 3.16\ F_C}\text{,kW (tractor)}\ldots\ldots(13)$$

Energy requirements (E.R):

The energy requirements for a particular operation was calculated as the following:

$$\mathbf{E.R. = P.R. / A.F.C} \quad \text{(kW.h /fed.)}\ldots\ldots(14)$$

Where

E.R.= Energy requirements, kW.h/fed;

P.R. = Required power for operation, kW; and

A.F.C. = Actual field capacity. fed/h.

Crop yield

Average grain yield in ton per feddan was measured for each treatment

RESULTS AND DISCUSSION

Effect of Tractors and Agricultural Machines Traffic on Soil Bulk Density at Different Forward Speeds and Different Soil Moisture Contents.

Tractor and agricultural machines traffic as well as their forward speeds have a great effect on soil bulk density added to that soil moisture content is considered the most critical factor in the state of soil bulk density.

Concerning the effect of tractors traffic on soil bulk density, Figs. 2 and 3 represent the bulk density values after levelling

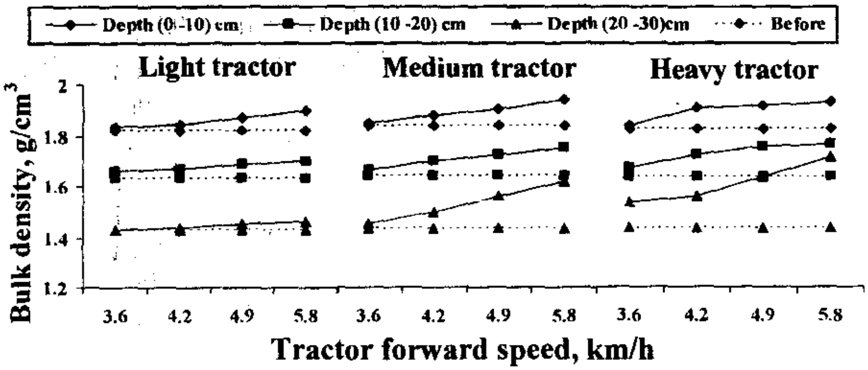

Fig. 2 :Effect of tractor traffic on soil bulk density at different depth and moisture content (15%)

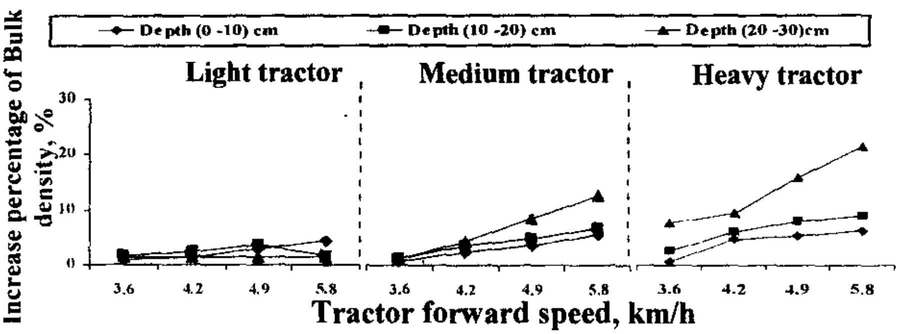

Fig. 3:Effect of tractor traffic on increase percentage of soil bulk density at different depth and moisture content (15%)

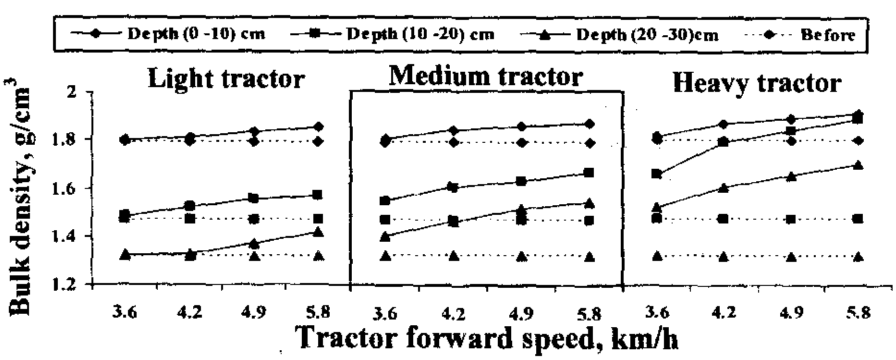

Fig. 4:Effect of tractor traffic on soil bulk density at different depth and moisture content (25%)

operation using three different tractors at an average soil moisture contents of 15% and 25% while Figs. 4 and 5 represent the increase percentage in soil bulk density under the same previous conditions.

Results in Fig. 4 show that at soil moisture content of 25% the maximum percentage of increase in soil bulk density of 19.4% was observed under treatment (**T1**) at depth of (20 – 30) cm. While the minimum percentage of 0.07% was observed under treatment (**T2**)at the same depth . Mean while results in Fig.5 show that at soil moisture content of 25% the maximum percentage of increase in soil bulk density of (28%) was observed under treatment (**T4**) at depth of (20 – 30) cm., while the minimum percentage of 0.08% was observed under treatment (**T6**) at the same depth.

As to the effect of combines traffic on soil bulk density, Figs. 6 and 7 represent the bulk density values after harvesting operation and the increase percentage in soil bulk density using three different combines at an average soil moisture content of 22%.

Results in Fig. 7 show that maximum percentage of increase in soil bulk density of (17.3) % was observed under treatment (**A**) at depth of (20 – 30) while the minimum percentage of increase of 0.92% was observed under treatment (**C**) at depth of (10 – 20) while at depth of (0 – 10) cm results show that maximum percentage of increase of (-3.3) % was observed under treatment (**A**) at high forward speed (3.8 km/h). While minimum percentage of increase of (-7.3) % was observed under treatment (**A**) at low forward speed (2.25 km/h).

Results indicate that the values of soil bulk density increased by increasing forward speed and the same was noticed with the increase percentage in bulk density this may be due to series vibrations of tractor and agricultural machine

Data obtained also show that values of bulk density decreased with increasing soil moisture content (natural effect) while the increase percentage of soil bulk density increased with increasing soil moisture content this may be due to the mechanical effect of tractors and agricultural machines traffic.

In the case of using combines during harvesting operation results show that the increase percentage of soil bulk density at the soil surface is lower than at the other depths of (10 – 20) and (20 – 30)

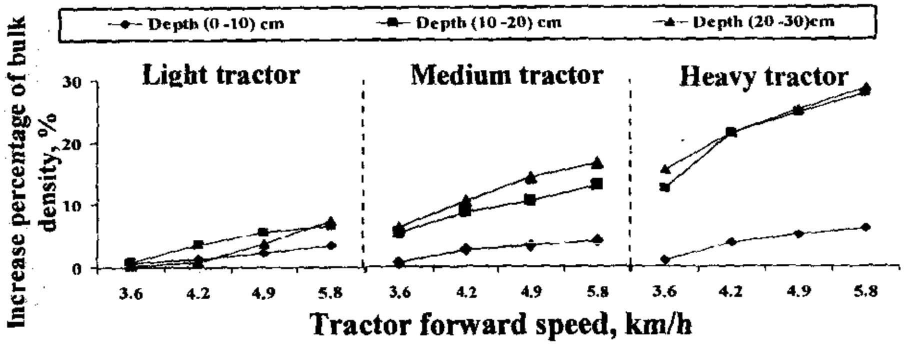

Fig. 5:Effect of tractor traffic on increase percentage of soil bulk density at different depth and moisture content (25%)

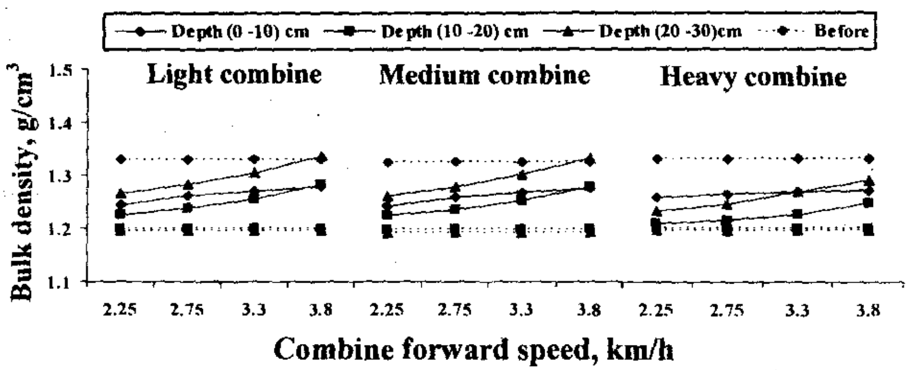

Fig. 6:Effect of combine traffic on soil bulk density at different depth and moisture content (22%)

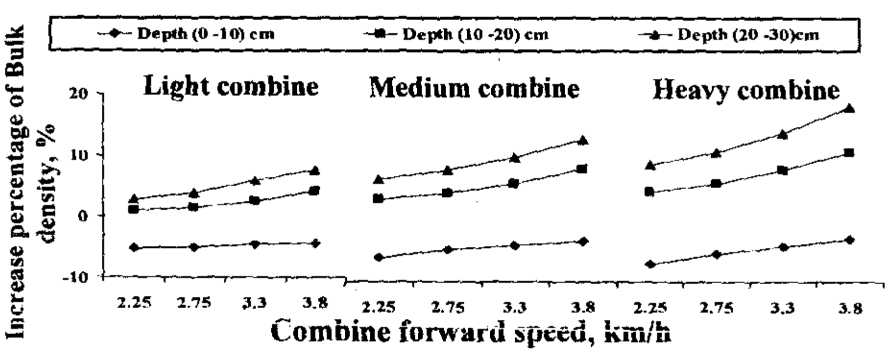

Fig. 7:Effect of combine traffic on increase percentage of soil bulk density at different depth and moisture content (22%)

this may be due to the growing root of rice at the depth of (0 – 10) and the reduction in the moisture content which give the depth of (0 – 10) cm elastic prosperity that breaks down the soil at that depth under the combine dynamic load.

In the case of using heavy tractors equipped with heavy leveller, soil bulk density values were high comparing with light tractor equipped with light leveller this attributed to high pressure generated under heavy tractors wheels that caused severer compaction beneath the tracks which tends to increase soil bulk density. The same behavior was found with the use of combines

Effect of Tractors and Agricultural Machines Traffic on Soil Penetration Resistance at Different Forward Speeds and Different Soil Moisture Contents

Tractors and agricultural machines traffic as well as their forward speeds have a great effect on soil penetration resistance added to that soil moisture content is considered the most critical factor in the state of soil compaction.

Concerning the effect of tractors traffic on soil penetration resistance Figs. 8 and 9 represent the penetration resistance values after levelling operation using three different tractors at an average soil moisture content of 15%and 25%, while and Figs. 10 and 11 represented the increase percentage of soil penetration resistance under the same previous conditions.

Results in Fig. 10 show that at soil moisture content of 15% the maximum percentage of increase in soil penetration resistance of 68.0% was observed under treatment (**T1**) at depth of (20 – 30) cm. While the minimum percentage of 0.4% was observed under treatment (**T3**) at the same depth. Mean while results in Fig.11 show that at soil moisture content of 25% the maximum percentage of increase in soil penetration resistance of (102) % was observed under treatment (**T4**) at depth of (20 – 30). While the minimum percentage of increase of 0.3% was observed under treatment (**T6**) at the same depth.

As to the effect of combines traffic on soil penetration resistance Figs. 12 and 13 represented the penetration resistance values after harvesting operation and the increase percentage of soil penetration resistance using three different

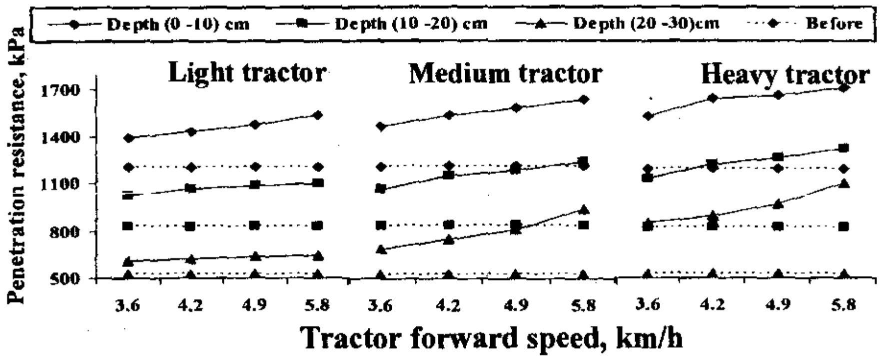

Fig. 8:Effect of tractor traffic on soil penetration resistance at different depth and moisture content (15%)

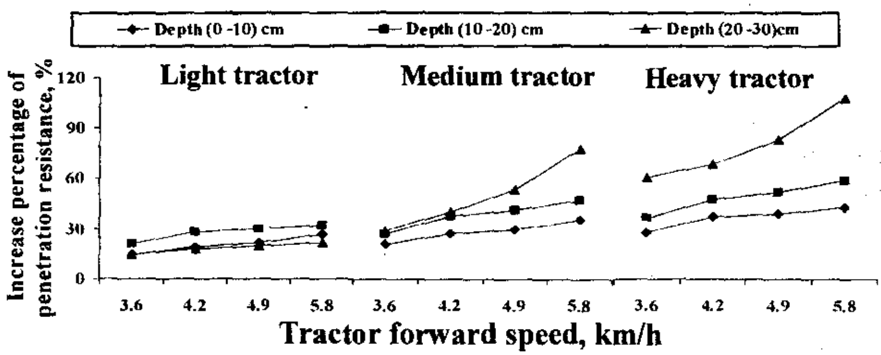

Fig. 9:Effect of tractor traffic on increase percentage of soil penetration resistance at different depth and moisture content (15%)

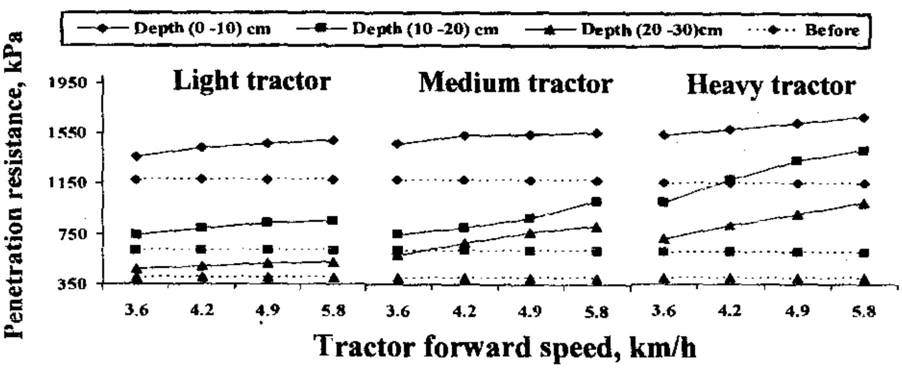

Fig. 10:Effect of tractor traffic on soil penetration resistance at different depth and moisture content (25%)

combines at an average soil moisture content of 22%.

Results in Fig. 13 show that maximum percentage of increase in penetration resistance of (73.05) % was observed under treatment (**A**) at depth of (20 – 30) cm while minimum percentage of increase of (7.78) was observed under treatment (**C**)at the same depth . While at the depth of (0 – 10) cm, the maximum percentage of increase in soil penetration resistance of (-13.2)% was observed under treatment (**C**). while the minimum percentage of increase of (-28.05)% was observed under the treatment (**A**).

The obtained results show that the values of soil penetration resistance increased by increasing forward speed and the same were noticed with the increase percentage in soil penetration resistance. This may be attributed to the series vibration generated from tractors and agricultural machines that tends to press soil particles together, reduces soil void ratio, which in turn increases soil penetration resistance.

Results also show that values of soil penetration resistance increased by increasing tractors and agricultural machines mass. In the case of heavy tractors equipped with heavy leveller, soil penetration resistance values were high comparing with light tractors equipped with light leveller and the same behavior was noticed with the use of combines. This attributed to the high pressure generated under heavy tractors and combines wheels that caused severe compaction beneath the tracks, which tends to increase soil penetration resistances.

Referring to the effect of different tractors on soil penetration resistance, the maximum penetration resistance value of 1763 kPa [more than the recommended value 1500 kPa, Carter and Travernetti (1968) and chancellor (1977)] was remarked under the use of heavy tractor at a forward speed of (5.8 k/h) while the light tractor did not exceed this value. Thus, low speeds [less that 4.2 km/h] in the case of using heavy tractors are commended to decrease soil compaction. This is in agreement with Abu-Habaga and Abu-El Ees (1990).

As to affect of different combines on soil penetration resistance, the maximum penetration resistance values of 580 kPa more than the recommended value was remarked under the use of heavy combine at a forward speed of 3.8 km/h, while the light combine didn't exceed

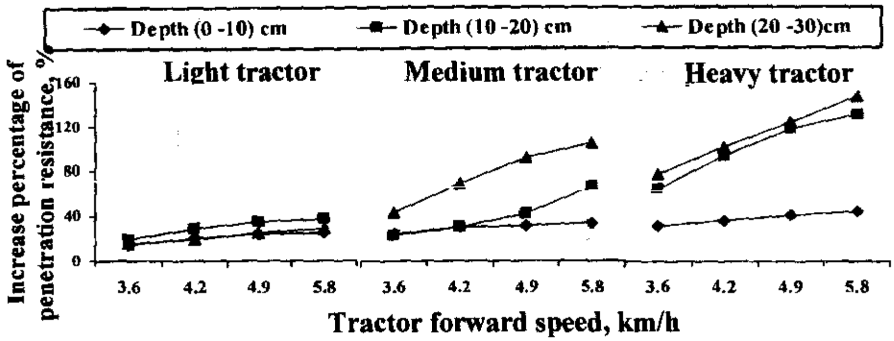

Fig. 11:Effect of tractor traffic on increase percentage of soil penetration resistance at different depth and moisture content (25%)

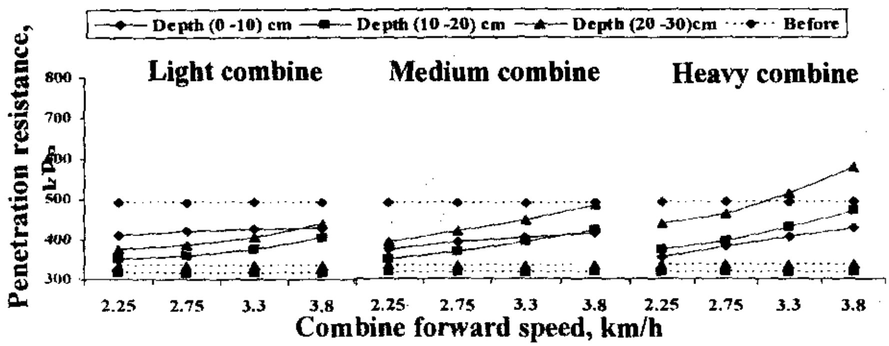

Fig. 12:Effect of combine traffic on soil penetration resistance at different depth and moisture content (22%)

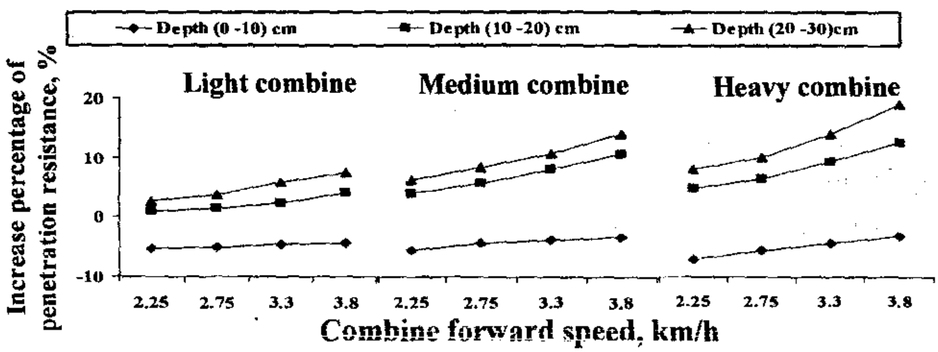

Fig. 13:Effect of combine traffic on increase percentage of soil penetration resistance at different depth and moisture content (22%)

this values. So, low speeds (less than 3.8 km/h) in the case of using heavy combines are recommended to decrease compaction.

In general, speeds of less than 3.8 km/h are suitable for most agricultural processes.

Data obtained also show that soil moisture content increased by increasing soil depth, which in turn, decreases values of soil penetration resistance the maximum penetration resistance value of 1763 kPa more than the recommended value – 1500 kPa was remarked under the use of heavy tractor at soil moisture content of (15%) while at soil moisture content of 25%, values of soil penetration resistance didn't exceed the recommended value. So, the soil moisture content of between 15-25 % is considered the prepare moisture for the experimental soil

Fuel, Power and Energy Requirements

Fuel consumption as well as power and energy requirements are highly affected by the different types of tractors and agricultural machines and their forward speeds.

Figs. 17 and 18 Show the effect of tractor forward speed during the land levelling operation on fuel consumption, power and energy requirements. While fig. 19 show the effect of combine forward speed during the harvesting operation on fuel consumption, power and energy requirements.

Results obtained for both tractor and combines show a remarkable drop in both fuel consumption and energy requirements with a consequent rise in the power required by increasing forward speed.

The decrease of both fuel consumption and energy requirement values by increasing forward speed is attributed to the increase of machine field capacity. From the obtained data it is noticed, that heavy tractor equipped with heavy leveller as well as heavy combine consumed the highest values of fuel and power while light tractor equipped with light leveller as well as light combine consumed the lowest values of fuel consumption and power especially at high forward speeds.

CONCLUSION

The root growth zone (20 cm depth) and crop yield were in the safe region under the following conditions.

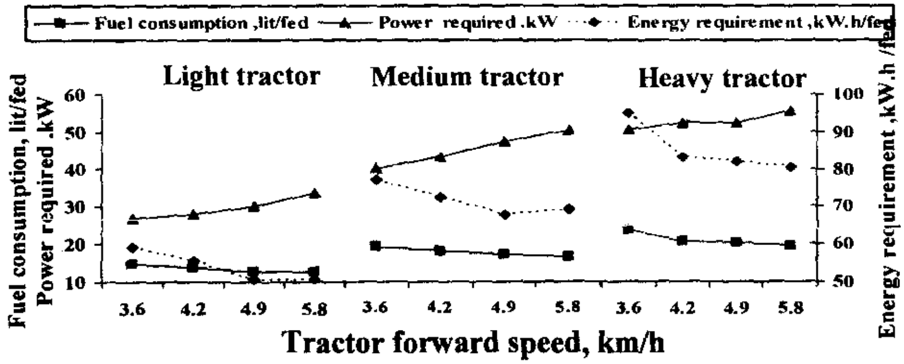

Fig. 14:Effect of tractor traffic on fuel ,power and energy requirement at different forward speed and moisture content (15%)

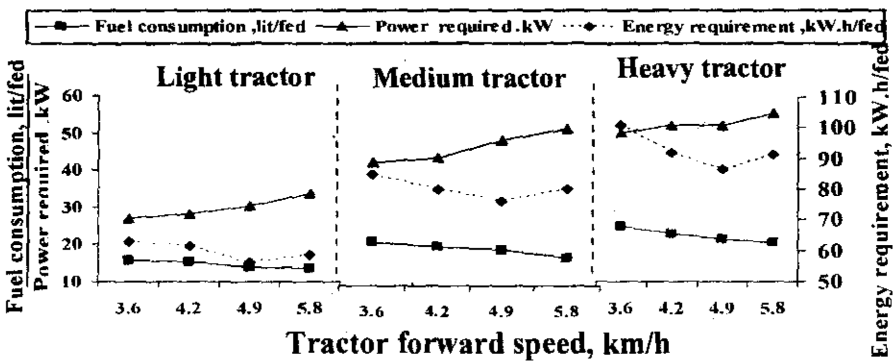

Fig.15:Effect of tractor traffic on fuel ,power and energy requirement at different forward speed and moisture content (25%)

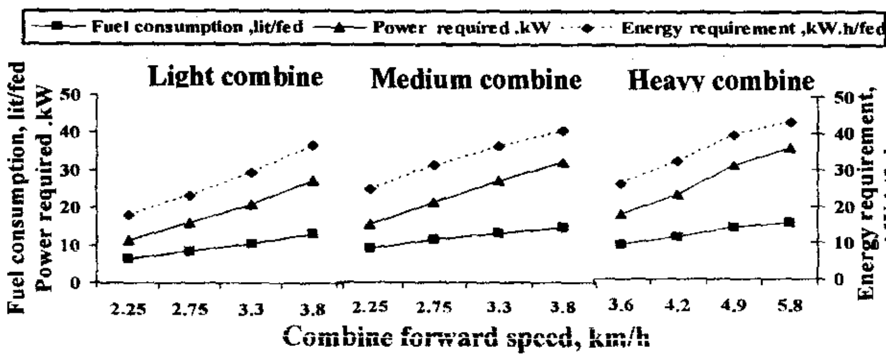

Fig. 16:Effect of combine traffic on fuel ,power and energy requirement at different forward speed and moisture content (22%)

In the case of using heavy tractor (forward speed of less than 3.6 km/h, and moisture content of about 15%).

In the case of using medium tractor (forward speed of less than 4.2 km/h, and moisture content of between 15 - 25%).

In the case of using light tractor (forward speed of less than 5.8 km/h, and moisture content of about 25%).

In the case of using the combine harvesters (forward speed of about 3.3 km/h).

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دراسة عن تأثير مرور الجرارات والآلات الزراعية على تضاغط التربة

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تم إجراء التجارب الحقلية في ديرب نجم بمحافظة الشرقية لدراسة تأثير مرور الجرارات والآلات الزراعية المختلفة على تضاغط التربة أثناء إجراء عمليتي التسوية على الجاف والحصاد لمحصول الأرز.

وكانت الأهداف الخاصة بهذه الرسالة كالآتي:

١- دراسة تأثير مرور الجرارات و الآلات الزراعية المختلفة على تضاغط التربة من ناحية الكثافة الظاهرية ومقاومة الاختراق للتربة.

٢- دراسة الأثر المتبقي لتضاغط التربة من استخدام الجرارات والآلات

٣- اختيار الظروف المثلى لبعض عوامل التشغيل المختلفة (سرعة أمامية ومحتوى رطوبة التربة) للتحكم فى تأثيرهم على الخواص الطبيعية للتربة وإنتاجية المحصول.

وتم تقسيم التجارب إلى تجربتين رئيسيتين نفذتا كالآتي:

التجربة الأولى أجريت أثناء عملية التسوية للأرض لزراعة محصول الأرز، وتم باستخدام ثلاثة جرارات مختلفة مجهزة بثلاثة قصابيات مختلفة على أربعة سرعات أمامية مختلفة وكانت المساحة التجريبية الأولى حوالي(٦ فدان) قسمت إلى مساحتين متساويتين مساحة كل منها(٣ فدان) المنطقة الأولى كان عندها متوسط رطوبة التربة حوالي(١٥ %) بينما الثانية حوالي (٢٥ %). ثم التجربة الثانية أجريت أثناء عملية الحصاد لمحصول الأرز باستخدام ثلاث أنواع من الكومبينات المختلفة علي أربعة سرعات أمامية مختلفة، والمساحة التجريبية للتجربة الثانية كانت حوالي(٣ فدان) كان المحتوى الرطوبي للتربة حوالي (٢٢ %)

وتم تقييم المعاملات المختلفة أخذ بنظر الإعتبار المؤشرات التالية:

(الكثافة الظاهرية للتربة، مقاومة إختراق التربة، إحتياجات الوقود والطاقة، كمية المحصول).

وقد كشفت النتائج التجريبية النقاط التالية:

١.أن حركة الجرارات والآلات الزراعية، والسرعة الأمامية لهما، ومحتوى رطوبة التربة تعتبر متغيرات مهمة جداً تؤثر على حالة تضاغط التربة

٢. قيم مقاومة الإختراق للتربة وكذلك قيم الكثافة الظاهرية للتربة كانت أعلى للجرارات الثقيلة والآلات الزراعية الثقيلة من مثيلتها الخفيفة تحت تأثير المتغيرات المختلفة.

٣. أن منطقة النمو الجذري (٢٠ سنتيمتر عمق) وكمية المحصول كانت في المنطقة الآمنة تحت الشروط التالية:

- في حالة الجرارات الثقيلة عند سرعة أمامية أقل من ٣,٦ كم/ساعة ومحتوى رطوبة التربة أقل من ١٥%.
- في حالة الجرارات المتوسطة عند سرعة أمامية أقل من ٤,٢ كم/ساعة ومحتوى رطوبة تربة بين ١٥ – ٢٥%.
- في حالة الجرارات الخفيفة عند سرعة أمامية أقل من ٥,٨ كم/ساعة ومحتوى رطوبة تربة أقل من ٢٥%.
- في حالة آلة الحصاد الجامعة (الكومباين)عند سرعة أمامية حوالي ٣,٣ كم/ساعة.