J. Agric. Sci. Mansoura Univ., 33 (1): 257 - 272, 2008

STUDY ON THE EFFECT OF SOME FARM IMPLEMENTS TRAFFIC ON SOIL COMPACTION

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ABSTRACT

Field experiments were carried out to study the effect of some farm implements 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:

1. 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.
2. 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 at forward speed of less than 3.6 km/h, and moisture content of about 15%.
- In the case of using medium tractor at forward speed of less than 4.2 km/h, and moisture content ranged between 15 - 25%.
- In the case of using light tractor at forward speed of less than 5.8 km/h, and moisture content of about 25%.
- In the case of using the combine harvesters at forward speed of about3.3 km/h.

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 and technology to fulfill the agricultural processes in proper 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 under conditions of clay soil..

Korayem *et al.,* (1981) stated that by increasing tillage operations soil compaction increased 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 increased by increasing of rotating eccentric mass.

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

Abo-Habaga (1989) reported that soil compaction had two forms, the first one 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 depth ranges. They concluded that the residual pressure slightly increased by increasing with the number of passes whose affect diminishes by increasing the depth of soil.

El-Banna (1990) developed two component soil compaction models, 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 increased as levelling uniformity coefficient increased but it was very small. He also 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 point 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 may be summarized as follows:

1. Investigating the effect of some farm implements 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 these farm implements at different soil depth ranges.
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 during the season (2005 /2006)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 in Table 1.

Table 1: Mechanical analysis of the experimental soil.

Soil classification	Soil fraction, %		
	Clay	Silt	Sand
Clay	45.5	29.3	25.2

Materials:

Machinery and Equipment
The following machines were used in the present investigation.
Tractors: Three tractors were used.
1. Heavy tractor (Legend 165(4RM)) Landini with an engine of 121kW (165 hp) and total mass of 7450 kg.
2. Medium tractor (M-110-(4WD)) Kubota with engine of 81 kW (110 hp) and total mass of 4550 kg.
3. Light tractor (Universal 650M) Romani with an engine of 48kW (65 hp) and total mass of 3000 kg .

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

Combines: Three combines were used.
1. Heavy combine (PRO 481) Kubota with an engine of 35.29 kW (48 hp) and total mass of 2920 kg.
2. Medium combine (R1-40) Kubota with an engine of 29.41 kW (40 hp) and total mass of 2700 kg .
3. Light combine (CA 385EG) Yanmar with an engine of 28 kW (38 hp) and total mass of 2450 kg .

Instruments
Soil penetrometer
Soil penetrometer was used to estimate soil penetration resistance as shown in Fig. 1

1- Adjusting screw,

2- Oil filler,

3- Manometer,

4- Hand grips,

5- Measuring instrument,

6- Plunger,

7- Extension rod,

8- Rod,

9- Cone.

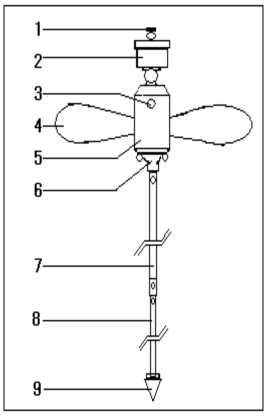

Fig. 1: Hand Penetrometer

Methods

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

Two main experiments were carried out to optimize some different parameters to control the implement 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 depth ranges (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 2.25, 2.75, 3.3 and 3.8 km/hr. Both bulk density and soil penetration resistance were measured at three different soil depth ranges (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-cm^3 volume) at three different depth ranges (0-10), (10-20) and (20-30) cm.

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

$$B.d = D_m/Tv \quad \ldots\ldots(1)$$

Where:

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

Tv : Total soil volume, cm^3;and

D_m: dry Mass, g.

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

$$\Delta Bd = 100\ (Bd_2 - Bd_1)\ /\ Bd_1\ ,\ \% \quad \ldots\ldots(2)$$

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 depth ranges of (10 – 20 and 30 cm) by screw auger. Samples were weighed, to be dried to 105 C^o for 24 hours using electric oven. The moisture content was calculated according to Black (1965) as follows:

$$M_c = 100\ (S_w - S_d)/S_d,\ \% \quad \ldots\ldots(3)$$

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.

$$P = \text{manometer reading / area of cone} = 10xF/\ A\ ,\text{kPa} \quad \ldots\ldots(4)$$

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:

$$\Delta P = 100\ (P_2 - P_1)/\ P_1,\ \% \quad \text{……………………………………………(5)}$$

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

RESULTS AND DISCUSSION

Effect of tractors and agricultural machines traffic at different forward speeds and different soil moisture contents on:

1- soil bulk density

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

Results in **Fig. 3** 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 ranges of (20 – 30) cm. While the minimum percentage of 0.07% was observed under treatment (**T2**)at the same depth ranges. Meanwhile results in **Fig.3** 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 ranges 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, **Fig. 4** 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. 4** show that maximum percentage of increase in soil bulk density of (17.3) % was observed under treatment **(A**) at depth ranges of (20 – 30) while the minimum percentage of increase of 0.92% was observed under treatment (**C**) at depth ranges of (10 – 20) while at depth ranges of (0 – 10) cm results show that maximum percentage of increase of (-3.3) % was observed under treatment (**A**) at high forward speed of 3.8 km/h. While minimum percentage of increase of -7.3 % was observed under treatment (**A**) at low forward speed of 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

The obtained data 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.

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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 depth ranges of (10 – 20) and (20 – 30) 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

2- Soil Penetration Resistance

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. 5** and **6** represent the penetration resistance values after levelling operation using three different tractors at an average soil moisture content of 15% and 25%, and the increase percentage of soil penetration resistance under the same previous conditions.

Results in **Fig. 5** 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 ranges of (20 – 30) cm. While the minimum percentage of 0.4% was observed under treatment (**T3**) at the same depth. Meanwhile results in **Fig. 6** 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 ranges 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 **Fig. 7** represented the penetration resistance values after harvesting operation and the increase percentage of soil penetration resistance using three different combines at an average soil moisture content of 22%. Results in **Fig. 7** show that maximum percentage of increase in penetration resistance of 73.05 % was observed under treatment **(A**) at depth ranges of (20 – 30) cm.

While the minimum percentage of increase of 7.78 % was observed under treatment (**C**) at the same depth range . While at the depth range 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.

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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 (under conditions of clay soil) according to 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 than 4.2 km/h] in the case of using heavy tractors are recommended to decrease soil compaction. This is in agreement with Abu-Habaga and Abu-El Ees (1990).

As to the effect 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 did not exceed this value. 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.

The obtained data also show that soil moisture content increased by increasing soil depth, which in turn, decreased values of soil penetration resistance the maximum penetration resistance value of 1763 kPa (more than the recommended value of 1500 kPa) was remarked under the use of heavy tractor at soil moisture content of 15% while at soil moisture content of 25%, the values of soil penetration resistance did not exceed the recommended value. So, the soil moisture content range from 15-25 % is considered the proper moisture for the experimental soil

Conclusion

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

1. In the case of using heavy tractor, the forward speed of less than 3.6 km/h, at soil moisture content of 15% is recommended.
2. In the case of using medium tractor, the forward speed of less than 4.2 km/h, at soil moisture content range of 15 - 25% is recommended.
3. In the case of using light tractor, the forward speed of less than 5.8 km/h at soil moisture content of about 25% is recommended.
4. In the case of using the combine harvesters, the forward speed of about 3.3 km/h is recommended.

REFERENCES

Abo-Habaga, M.M. (1989). Effect of different seedbed preparation system on soil compaction and crop yield. Egyptian German Con. Agric. Mech., Mansoura Univ., Egypt: 71 -80.

Abo-Habaga, M.M. and N.A. Abu El-Ees. (1990). Effect of tractor traffic on some soil physical properties and pressure distribution in the soil. Misr J. Ag. Eng., 7(4): 371-377.

Abou- El-Kheir, M.M. and E.A.M. Abd El-Ghaffar. (1985). Performance evaluation of a locally made combined tillage machine. Misr J. Ag. Eng., 2(4): 3-19.

Ahmed, S.F.; S.M. Ismail and S.S. Sadaka. (1988). Compaction by different tractyor types in silt-loam and sandy clay soils. Misr J. Ag. Eng., 5(2): 129-138.

Awady, M.N.; H.A. Found; S.A. Tayelor; M.F. Wahby and M.F. Khairy. (1985). Tractor vibration effect on soil compaction. Misr J. Ag. Eng.,2(3): 40-60.

Black, C.A.; D.D. Evan; J.L. White; L.E. Ensimenger and F.E. Clark (1965). Methods of soil analysis. Part I, American Soc. of Agronomy. Inc., Publisher, Wisconsin, USA.

Carter, L.M. and M. Tavernetti (1968). Influence of precision tillage and soil compaction on cotton yields. Transactions of the ASAE, 11(1): 65-67, 73.

Chancellor, W.J. (1977). Compaction of soil by agricultural equipment. Univ. of California Bul. (1881). 53 (Cited from Thread Gill, 1982).

El-Banna, E.B. (1990). Effect of traffic ability on soil compaction. Misr J. Ag. Eng., 7(2): 160-172.

Gaultney, L.; G.W. Krutz; G.C. Steinhardt and J.B. Liljedahl (1982). Effect of subsoil compaction on corn yields. Transaction of the ASAE,. 25: 563-569, 575.

Hamad, S.A.; H.N. Abd El-Mageed and S. El-Kawaga (1992). Effect of tillage methods on soil physical characteristics and corn yield. Misr J. Ag. Eng., 9(1): 32-42.

Hatim, M.A. (1970). The effect of chisel blade angle on the soil specific resistance.M.Sc.Thesis Agric. Eng. Dept., Fac. of Agric., Cairo Univ. Egypt.

Koraym, A.Y.; S.M. Younis and K.M. Ismail. (1981). Effect of different tillage methods on power requirements and corn yield. Alex. J. Agric. Res., 29(2): 217-219.

Michael, K.M. (1990). Effect of levelling on performance of some farm machinery. Ph.D. Thesis. Fac. of Agric.,Moshtoher, Zagazig Univ., Egypt.

Morad, M.M. and M.A. Arnaout (1993). Effect of tractors traffic on soil compaction. Misr J. Ag. Eng., 10(2): 103-110.

دراسة عن تأثير مرور بعض المعدات الزراعية على تضاغط التربة

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تم إجراء التجارب الحقليةِ في ديرب نجم بمحافظة الشرقية لدراسة تأثير ِمرور بعض المعدات الزراعيةِ المختلفةِ على تضاغط التربةِ أثناء إجراء عمليتي التسوية على الجاف والحصاد لمحصول الأرز. وكانت الأهدافَ كالآتي:

١- دراسة تأثير سرعةِ مرور المعدات الزراعيةِ المختلفة على تضاغط التربةِ من ناحية الكثافة الظاهرية ومقاومةَ الاختراق للتربة.
٢- دراسة الأثر المتبقي لتضاغط التربة من استخدام المعدات الزراعية.
٣- اختيار الظروف المثلى لعوامل التشغيل المختلفةِ (سرعة أمامية ومحتوى رطوبة التربة) للتحكم فى تأثيرهما على الخواص الطبيعية للتربة.

وقد تم تقسيم التجارب إلى تجربتين رئيسيتين نُفذتَا كالآتي:
التجربة الأولى أجريتْ أثناء عملية التسوية للأرض لزراعة محصول الأرز، وتم باستخدام ثلاثة جراراتَ مختلفةَ مجهزة بثلاث قصابيات مختلفةِ على أربع سرعاتِ أماميةِ مختلفةِ وكانت المساحة التجريبية الأولى حوالي(٦ أفدنة) قسمتْ إلى مساحتين متساويتينِ مساحة كل منها(٣ أفدنة) المنطقة الأولى كَان َمتوسط رطوبةِ التربةِ بها حوالي(١٥ %) بينما الثانية حوالي (٢٥ %). وأما التجربة الثانية أجريتْ أثناء عملية الحصاد لمحصول الأرز ِباستخدام ثلاثة أنواع من آلات الحصاد المجمعة المختلفةَ علي أربع سرعاتِ أماميةِ مختلفةِ، والمساحة التجريبية للتجربة الثانية كَانتْ حوالي(٣ أفدنة) بينما المحتوى االرطوبى للتربة كان حوالي (٢٢ %) وقد بينت التجارب ما يلى من نتائج:-

١. أن السرعة الأمامية للمعدات الزراعية ومحتوى رطوبةِ التربة يعتبرا متغيران هامان للغاية فى التأثير على تضاغط التربة.
٢. قيم مقاومة الإختراقِ للتربة وكذلك قِيم الكثافةِ الظاهرية للتربةِ كَانتْ أعلى للمعدات الزراعية الثقيلة من مثيلتها الخفيفة تحت تأثير المتغيرات المختلفة.
٣. أن منطقة النمو الجذري (٢٠ سنتيمتر عمقِ) وكمية المحصولِ كَانت في المنطقةِ الآمنةِ تحت الشروط التالية:

- فى حالة المعدات الزراعية الثقيلة عند سرعة أمامية أقل من ٣,٦ كم/ساعة ومحتوى رطوبة للتربة أقل من ١٥%.
- فى حالة المعدات الزراعية المتوسطة عند سرعة أمامية أقل من ٤,٢ كم/ساعة ومحتوى رطوبة للتربة تتراوح بين ١٥ – ٢٥%.
- فى حالة المعدات الزراعية الخفيفة عند سرعة أمامية أقل من ٥,٨ كم/ساعة ومحتوى رطوبة تربة أقل من ٢٥%.
- فى حالة آلة الحصاد الجامعة (الكومباين)عند سرعة أمامية حوالى ٣,٣ كم/ساعة.