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PROPER DEPTH AND SPACING BETWEEN SUBSOILING FURROWS IN CLAY-LOAM SOIL WITH HARDPANS

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ABSTRACT

Effect of sub-soiling on some soil physical properties was studied for selecting the proper depth and spacing between the furrow in clay loam soil with hardpans at depth of 25 cm, thickness more than 150 cm and has spreading in all area research place. This study included three different depths (50, 75 and 100 cm) and two spacings between the furrows of sub-soiling (1 and 2 meters). Soil bulk density, hydraulic conductivity and soil penetration resistance were determined and measured before and after ploughing. Also required energy and tire slippage were measured. Results showed that the proper depth and spacing between the furrows of sub-soiling were 50 cm and 2 meters, respectively, under clay loam soil conditions.

INTRODUCTION

Deep tillage may play an important and effective role in breaking down soil layers to improve soil bulk density and porosity (**Ansary and Mallah 1986**). Also, they found that sub-soiling at soil depths of 10, 20 and 30 cm decreased bulk density by 6.6%, 8.4% and 13%, respectively, and soil porosity increased, consequently.

Sub-soiling ploughing is not recommended in the heavy clay soils adjacent to the northern delta lakes of Egypt (**El-Araby *et al.* 1984**). Deep ploughing treatments showed a decrease in bulk density value and increasing in water intake rates but showed a little effect on other soil properties (**Handerson *et al.* 1981**).

The relation of infiltration rate physical and chemical characteristics of heavy textured soils in the part of the Nile Delta at Kafr El-Shaikh showed that both direct and indirect effects on infiltration rate could be arranged in the following descending order: initial moisture > clay > capillary pores > volume of drainable pores > total porosity > sodium adsorption ratio (**Ghazy *et al.* 1988**).

Soil bulk density decreased after tillage. The decrease was much in the upper layer than the lower one. Such decrease after tillage was due to the break down of soil structure and the increase of pore spaces. Also the soil penetration resistance increased after tillage operations. The penetration force almost linearly increased with depth. The same trend appeared before and after tillage. The fuel consumption increased with the tillage depth and slightly increased with the speed, as did the draft force (**El-Nakib and Fouad 1990**). Soil resistance values increased by increasing depth of soil profile up to 18 cm then it decreased after that by increasing depth of soil profile (**El-Banna and Helmy 1992**).

By decreasing ploughing depth the bulk density tends to increase for all ploughing machine types and by increasing the ploughing depth the soil penetration resistance and the basic infiltration rate tends to increase. By increasing ploughing depth the fuel consumption rate in L/fed tends to increase while the fuel consumption per unit area in L/fed tends to increase (**Imara 1996**).

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The values of basic infiltration rate were highest in the silt clay loam soil than clay and saline clay soils. The values of infiltration rate were 1.0, 0.7 and 0.3cm/h for the silt clay loam, clay and saline clay soil, respectively (**Hanna *et al.* 1997**).

Penetration resistance increased with ploughing depth because the soil compaction increased with soil layer depth. It was found that the ploughing energy requirement increased by increasing the ploughing depth (**El- Saeed *et al.* 1998**).

The relation between soil resistance and depth of penetration was described as follows:

$$R = (N/Z) * 48.46 + 2.27$$

(Where R = the specific soil resistance, kg/cm^2; N = number of impacts and Z = the depth of the penetration in cm) (**Mohamed and El-Saadawy 1998**).

The objective of this work is selecting the proper depth and spacing between sub-soiling furrows in clay loam soil with hardpans at depth of 25 cm, thickness more than 150 cm and has spreading in all area research place.

MATERIAL AND METHODS

The experimental work has been carried out in a private farm at Kafr-Rashwan village, north-east Tamia center El-Fayoum Governorate (قرية كفر رشوان- شمال شرق مركـز طامية-محافظـة الفيـوم) in the winter season of 2001/2002. Twelve samples of soil were taken from sizes (0-25, 25-50, 50-75 and 75-100 cm depth) randomly. These samples were taken by standard cylinder (60 mm diameter with 40 mm height) to determine the soil texture and moisture contents.

Particle size distribution of the soil, average moisture contents before tillage are shown in table (1) and the soil type is clay loam soil.

Table (1)- Soil particle size distribution of experimental site

Soil depth, cm	Particle size distribution, %			Texture soil	Average moisture content, %
	Sand	Silt	Clay		
0-25	39	35	26	clay loam	12.90
25-50	30	42	28	clay loam	17.66
50-75	24	40	31	clay loam	21.87
75-100	27	39	34	clay loam	25.11

The aim of the experiment was drived by studying the effect of deep tillage operation on some soil physical properties (bulk density, hydraulic conductivity and soil penetration resistance), required energy and tire slippage percent to select the proper depth and spacing between the furrows of sub-soiling. One forward speed for tractor (2.5 km/h), three depths for subsoiler (50, 75 and 100 cm) and two spacing between the tillage furrows (1 and 2 meters) were carried out. The experiment area was 3600 m^2 (0.86 fed.) was divided in 6 plots each of 600 m^2 (12m x 50 m) including three replicates (total replicates were 3 x 6 =18), each replicate of 4 m x 50 m. Soil measurements were recorded before and after tillage treatments.

Equipment:

1- Tractor: Zitor, 160 hp (119.40 kW) 4WD and 4 cylinders diesel engine.
2- Subsoiler: A single bottom mounted – type with 88 kg mass.
3- Stop watch.
4- Linen tape.

Measurements:

Soil bulk density, hydraulic conductivity and soil penetration resistance were measured at three layer sizes 25-50, 50-75 and 75-100 cm depth before and direct after application of ploughing treatments in mid spacing between the furrows and calculated by the following equations:

1- Bulk density (ρb) was measured according to **Black *et al.* (1965)**.

2- Hydraulic conductivity (H.c) was determined in the laboratory (by using one cylinder 5 cm diameter, 15 cm deep and formed of 2 mm rolled steel tubes) and calculated according to the Darcy's equation **(Klute, 1986)** using following formula:

$$K = \frac{QL \times 10}{AtH}, \text{ mm/h}$$

Where:

K = Hydraulic conductivity, mm/h;
Q = Volume of water passing through soil column, cm^3 at t time;
L = Length of soil column, cm;
A = Cross section area of soil column, cm^2;
t = time, h;
H = Length of water column, cm.

3- Soil penetration resistance (P.R) was measured by using hand penetrometer. Three replicates were measured immediately at the end of the operation.

4- Fuel consumption (Fc): a fuel consumption apparatus 2000 ml capacity was built up and used to measure the decrease in fuel level immediately after executing each operation.

5- Tire slippage (S%) was determined by using the following formula.

$$S\% = \frac{L_1 - L_2}{L_1} \times 100$$

Where:

L_1 = advance per 10 wheel revolutions under no load, m;
L_2 = advance per 10 wheel revolutions under load, m.

6- Soil moisture content was determined using an electric oven adjusted at (105 C°) for 24 hours according to **Black *et al.* (1965)**. Soil samples were taken by screw auger.

7- Required energy (E): was calculated by using the following equation **(Embaby, 1985)**.

$$E = Fc \times \frac{1}{60 \times 60} \times pf \times CV \times 4270 \times \frac{1}{1000} \times \frac{1}{Pa} = \frac{10.082 \times Fc}{Pa}, \text{ kW.h/fed.}$$

Where:

Fc = Fuel consumption, L/h;
pf = Density of the fuel, kg/L; (Pf = 0.85 kg/L for Diesel fuel);
CV = Calorific value of fuel, k Cal/kg (CV = 10000 k Cal / kg for Diesel fuel);
4270 = Constant (thermo = mechanical equivalent), N.m/k Cal;
Pa = Actual field productivity, fed / h.

Data represented in this work were analysed using SPSS 10 statistical programme.

RESULTS AND DISCUSSION

1- Effect of sub-soiling depth and spacing between tillage furrows on soil bulk-density:

The effect of deep tillage under ploughing depths (50, 75 and 100 cm) and spacing between tillage furrows (one and two meters) on bulk density before and after ploughing was shown in fig.(1). Bulk density decreased as a result of sub-soiling by 13.7%, 15.1% and 14.7% under soil depths of 50, 75 and 100 cm, respectively with spacing between tillage furrows of one meter after ploughing than before ploughing. Also bulk density decreased by 12.1%, 12.9% and 13.2% under the same previous depths, respectively with spacing between tillage furrows of two meters, due to breakdown of soil compaction caused by pressures of successive soil layers. However, bulk density increased with the depth due to soil compaction increase and reduced pore spaces. On the other hand soil bulk density decreased at spacing between tillage furrows of 1 meter compared with 2 meters. This is due to increased pore spaces in case of 1 meter spacing between furrows. Ploughing depth of 50 cm, gave the lowest average values of bulk density (1.32 and 1.34 g/cm^3) with spacing between tillage furrows of 1 meter and 2 meters, respectively. There was no significant difference between 1 meter and 2 meters at depth of 50 cm. Therefore, proper depth was 50 cm with spacing of 1 meter or 2 meters.

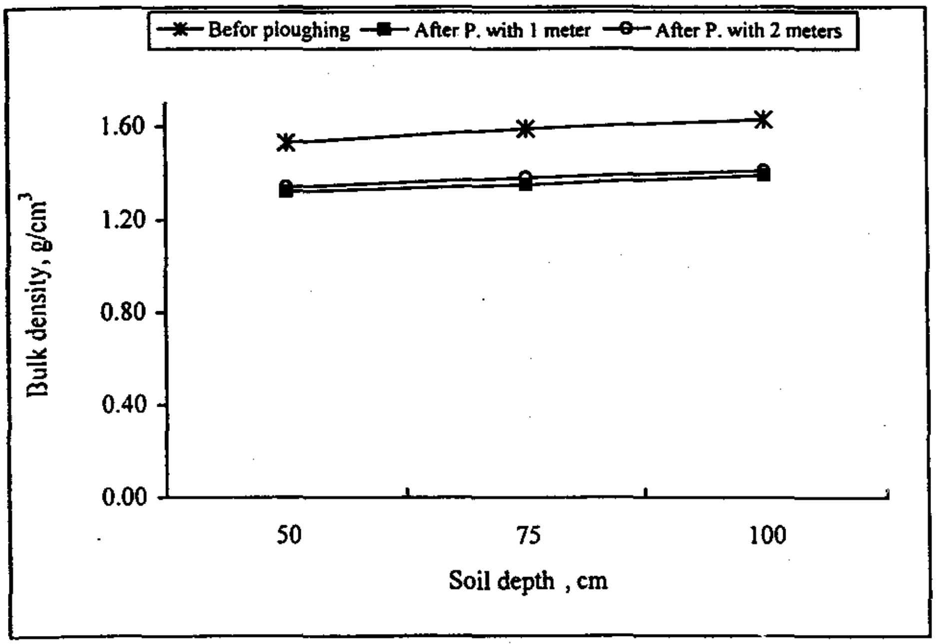

Fig (1)- Effect of sub-soiling depth and spacing between tillage furrows 1 and 2 meters on soil bulk density.

2- Effect of sub-soiling depth and spacing between tillage furrows on soil penetration resistance:

The effect of deep tillage under ploughing depths (50, 75 and 100 cm) and spacing between tillage furrows (one and two meters) on soil penetration resistance before and after ploughing was shown in fig.(2). As a result of sub-soiling, soil penetration resistance decreased by 46.93%, 47.98% and 48.02% under soil depths of 100, 75 and 50 cm, respectively with spacing between tillage furrows of one meter after ploughing than before ploughing at the same depth. Also soil penetration resistance decreased by 39.58%, 39.62% and 40.73% under the same previous depths, respectively with spacing between tillage furrows of two-meters. The penetration resistance increased by increasing ploughing depth from 75 to 100 cm since increasing soil layer depth increased soil compaction. This, was despite increased soil moisture content with depth.

Soil penetration resistance decreased at spacing between tillage furrows of 1 meter compared with 2 meters, this due to decreased soil compaction at spacing of 1 meter. Ploughing depth of 50 cm, gave the lowest average values of soil penetration resistance (40.50 and 46.18 N/cm^2) with spacing between tillage furrows of 1 meter and 2 meters, respectively. Since there was no significant difference between 1 meter and 2 meters at depth of 50 cm, therefore, proper depth was 50 cm with spacing of 1 meter or 2 meters.

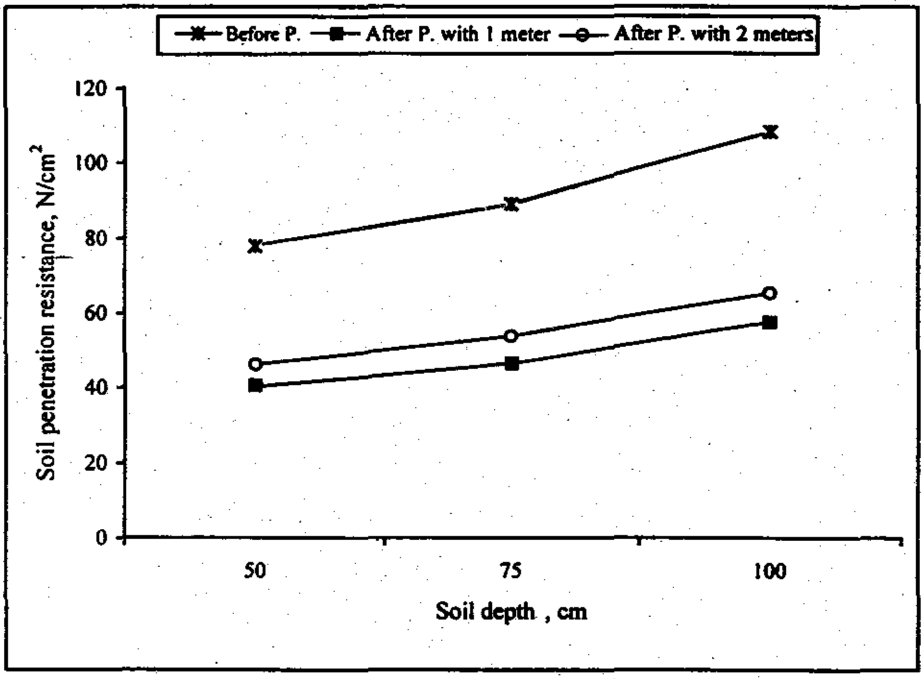

Fig. (2)- Effect of sub-soiling depth and spacing between tillage furrows of 1 and 2 meters on soil penetration resistance.

3- Effect of sub-soiling depth and spacing between tillage furrows on hydraulic conductivity :

The effect of deep tillage under ploughing depths (50, 75 and 100 cm) and spacing between tillage furrows (one and two meters) on hydraulic conductivity before and after ploughing was illustrated in fig.(3). As a result of sub-soiling, hydraulic conductivity increased by 357.89%, 336.23% and 273.85% under depths of 50, 75 and 100 cm, respectively with spacing between subsoiling tillage furrows of one meter after ploughing than before ploughing. Also hydraulic conductivity increased by 246.05%, 215.94% and 155.38% under the previous depths, respectively with spacing between tillage furrows of two meters.

Hydraulic conductivity increased after ploughing than before ploughing while it decreased by increasing ploughing depth. This is attributed to the variation in pore size distribution, which is affected by soil texture and structure.

Hydraulic conductivity increased at spacing between tillage furrows of 1 meter compared with 2 meters. This is attributed to increase in pore space size distribution at spacing of 1 meter. Ploughing depth of 50 cm, gave the highest average values of hydraulic conductivity (3.48 and 2.63 mm) with spacing between tillage furrows of 1 meter and 2 meters, respectively. There was no significant difference between 1 meter and 2 meters furrow spacings at depth of 50 cm. Thus, proper depth was 50 cm with spacing of 1 meter or 2 meters.

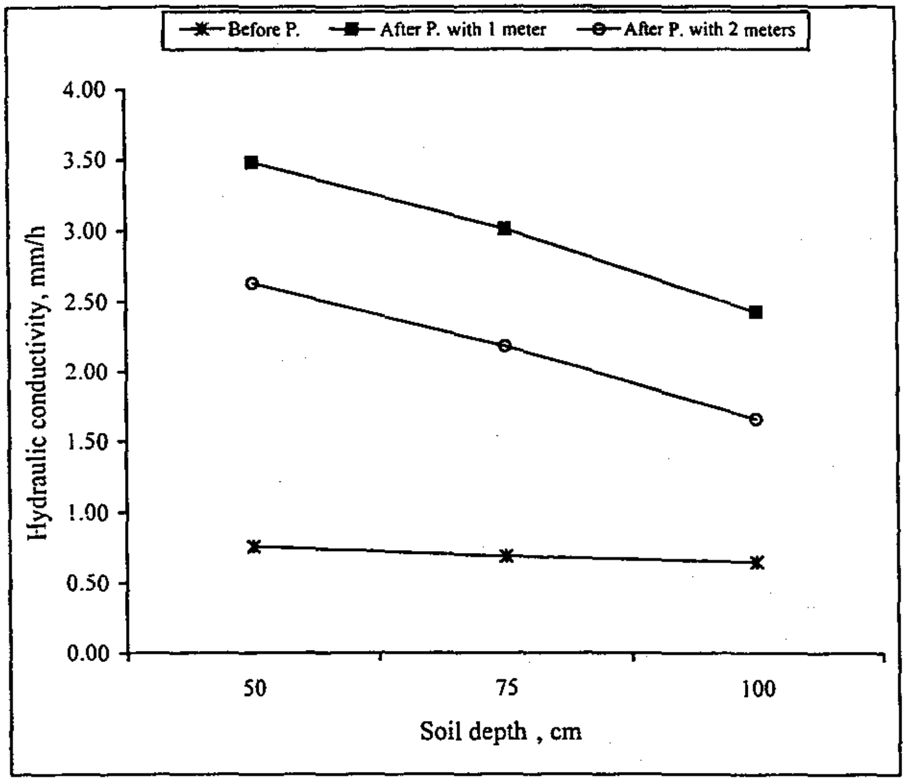

Fig.(3)- Effect of sub-soiling depth and spacing between tillage furrows of 1 and 2 meters on hydraulic conductivity.

4- Effect of sub-soiling depth and spacing between tillage furrows on required energy:

The effect of deep tillage under ploughing depths (50, 75 and 100 cm) and spacing between tillage furrows (one and two meters) on required energy was demonstrated in fig.(4).

As a result of sub-soiling, required energy increased by increasing the ploughing depth, this is due to soil draft and draw bar pull increase with the depths. On the other hand, required energy increased with spacing between tillage furrows of 1 meter. This is, due to decreased productivity (fed/h) with 1 meter spacing compared with 2 meters spacing, due to increased number of subsoil furrows in the first case. Ploughing depth of 50 cm, gave the lowest average value of required energy (58.46 kW.h/fed) with spacing between furrows of 2 meters, while the average value of required energy was 122.46 kW.h/fed with spacing of 1 meter at depth of 50 cm. There was no significant difference between 1 meter and 2 meters at depth of 50 cm. Thus, proper depth was 50 cm with spacing of 1 meter or 2 meters.

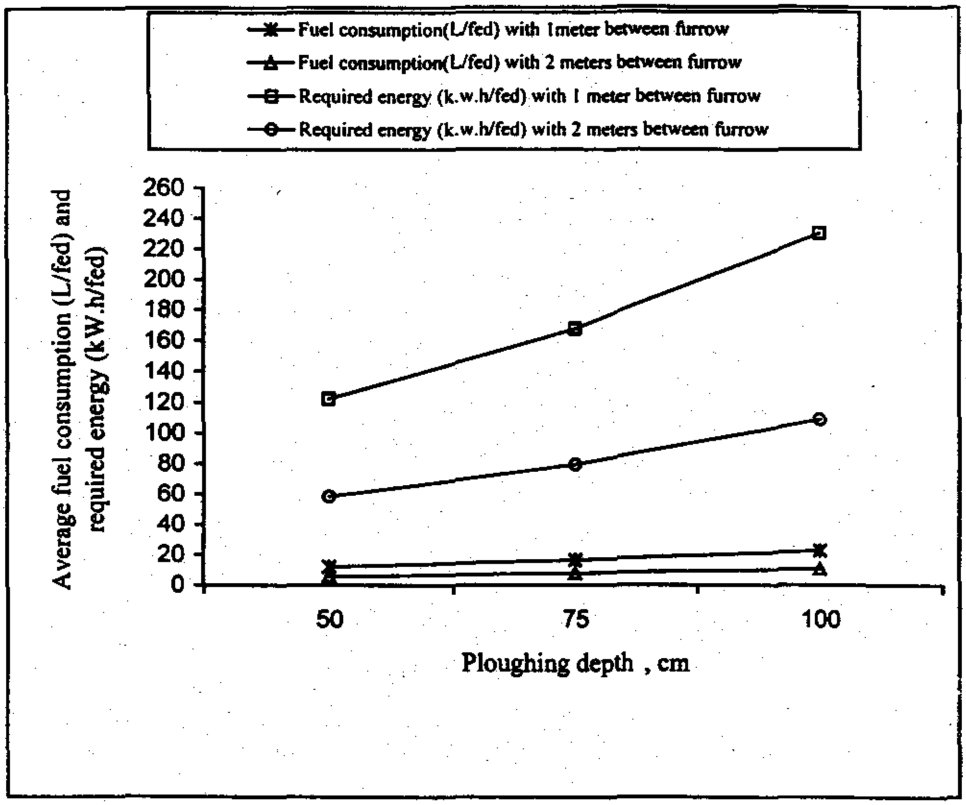

Fig. (4)- Effect of sub-soiling plough depth and spacing between tillage furrows of 1 and 2 meters on average fuel consumption and required energy.

5- Effect of sub-soiling depth and spacing between tillage furrows on tire slippage:

The effect of deep tillage under ploughing depths (50, 75 and 100 cm) and spacing between tillage furrows (one and two meters) on slip percentage was shown in fig.(5). Slip percentage increased with increasing of ploughing depth as a result of sub-soiling. This is due to the increased displacement of soil under the wheel by increasing the ploughing depth.

On the other hand, slip percentage values were similar under spacing between tillage furrows of 1 meter and 2 meters, and were allowable (< 15%). Ploughing depth of 50 cm, gave the lowest values of tire slippage (7.85 –8.10%) with spacing between tillage furrows of 1 meter and 2 meters, respectively. There was no significant difference between 1 meter and 2 meters at depth of 50 cm. Thus, proper depth was 50 cm with spacing of 1 meter or 2 meters.

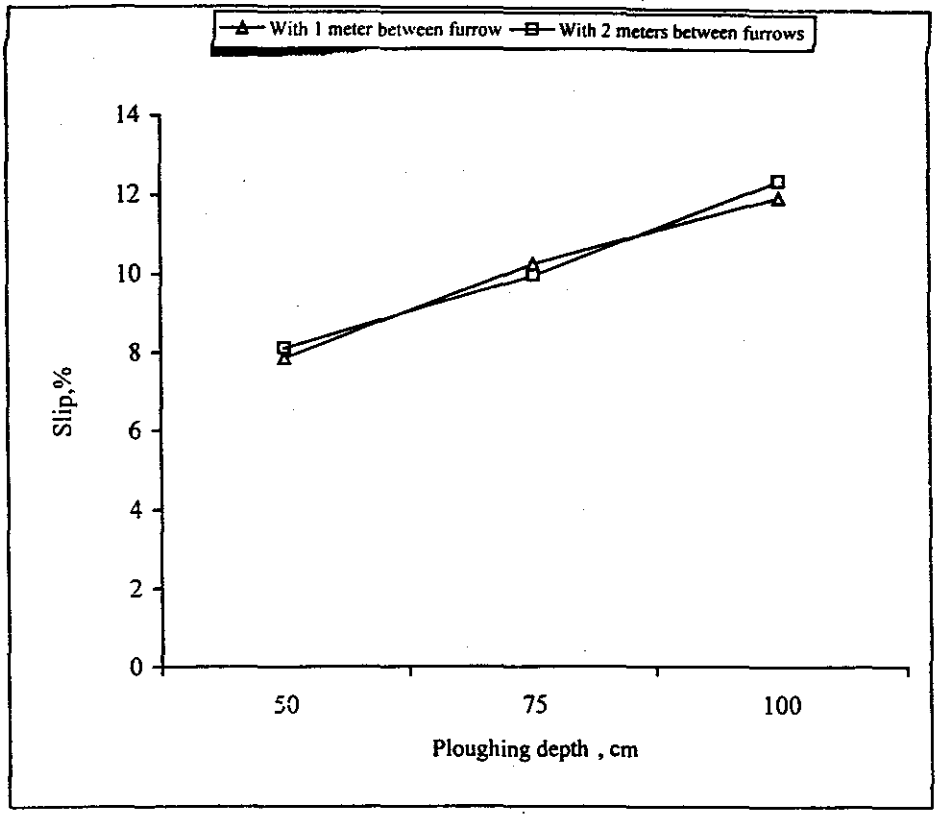

Fig.(5)- Effect of sub-soiling depth and spacing between tillage furrows of 1 and 2 meters on slip percentage.

CONCLUSIONS

From the previous results the main recommendations may be summarized in the following:

1- Depth of 50 cm with subsoil spacing of 1 meter gave the lowest values for bulk density (1.32 g/cm^3), penetration resistance (40.50 N/cm^2) and tire slipping (7.85%), highest value for hydraulic conductivity (3.48 mm/h), while gave highest value for required energy (122.40 kW.h/fed).

2- Depth of 50 cm with subsoil spacing of 2 meter gave 1.34 g/cm^3 for bulk density, 46.18 N/cm^2 for penetration resistance, 8.10% for tire slipping and 2.63 mm/h for hydraulic conductivity, while gave the lowest value for required energy (58.46 kW.h/fed).

3- Statistical analysis showed that the difference were not significant between subsoil spacing of 1 meter and 2 meters for bulk density, penetration resistance, hydraulic conductivity and tire slipping. On the other hand the differences were significant for required energy (58.46 and 122.40 kW.h/fed at spacing of 2 and 1 meters, respectively).

4- Finally, the proper depth was of 50 cm to growing natural and extension for most crop roots and the proper subsoil spacing was 2 meters, to save required energy by more than 100% (compared with spacing 1 meter). Thus 50 cm depth and 2 meters spacing were the most suitable under clay loam soil with hardpans at depth of 25 cm, thickness more than 15 cm and has spreading in all research place.

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الملخص العربي

العمق الأنسب للحرث والمسافة الأنسب بين خطوط محراث تحت التربة فى أرض طينية طميية بها طبقات صماء.

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أجرى هذا البحث بهدف اختيار عمق الحرث الأنسب والمسافة الأنسب بين خطوط محراث تحت التربة في أرض طينية طميية بها طبقات صماء على عمق ٢٥سم وبسمك تعدي ١٥٠سم وكانت منتشرة في كل مساحة

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البحث. وللوصول لهذا الهدف، تم دراسة تأثير المسافة بين خطوط الحرث (١ متر ، ٢ متر) وأعماق الحرث (٥٠ سم و ٧٥ سم و ١٠٠سم) على كل من الكثافة الظاهرية للتربة ومقاومة الاختراق والتوصيل الهيدروليكي (قبل وبعد الحرث) والطاقة المطلوبة للحرث ونسبة الانزلاق هذا وقد أجرى البحث فى أحد المزارع الخاصة بمحافظة الفيوم خلال موسم ٢٠٠١/٢٠٠٢ وقد أظهرت نتائج الدراسة ما يلى :

١- عمق الحرث ٥٠سم مع المسافة بين خطوط الحرث ١ متر أعطت أقل القيم لكل من الكثافة الظاهرية (١,٣٢ جم/سم^{3})، ومقاومة التربة للاختراق (٤٠,٥٠ نيوتن/سم^{2}) وانزلاق الإطار (٧,٨٥%) وأعلي قيمة للتوصيل الهيدروليكي (٣,٤٨مم/ساعة). بينما أعطت قيمة مرتفعة لاحتياجات الطاقة (١٢٢,٤٠ كيلو وات.ساعة/فدان).

٢- عمق الحرث ٥٠سم مع المسافة بين خطوط الحرث ٢ متر أعطت كثافة ظاهرية (١,٣٤ جم/سم^{3})، ومقاومة اختراق (٤٦,١٨ نيوتن/سم^{2})، وانزلاق (٨,١٠%) وتوصيل هيدروليكي ٢,٦٣مم/ساعة. بينما أعطت أقل القيم لاحتياجات الطاقة (٥٨,٤٦ كيلو وات.ساعة/فدان).

٣- أظهر التحليل الإحصائي عدم وجود فروق معنوية بين النتائج المتحصل عليها لكل من الكثافة الظاهرية ، مقاومة الاختراق ، التوصيل الهيدروليكي والانزلاق وذلك عند مسافات بين خطوط المحراث ١ متر ، ٢ متر. ومن ناحية أخري كانت الفروق معنوية في احتياجات الطاقة (٥٨,٤٦ ، ١٢٢,٤٠ كيلو وات.ساعة/فدان) للمسافات ٢متر ، ١متر علي الترتيب.

٤- في النهاية ، كان عمق الحرث ٥٠سم هو الأنسب وذلك لملاءمته لطبيعة نمو وامتداد جذور معظم المحاصيل ، وكانت المسافة بين خطوط الحرث ٢متر هي الأنسب وذلك للتوفير في احتياجات الطاقة بما يزيد عن ١٠٠% (بالمقارنة بمسافة ١متر بين خطوط الحرث). وعلية يكون عمق الحرث ٥٠سم مع المسافة بين خطوط الحرث ٢متر هي الأنسب لظروف التربة الطميية الطينية التي ظهرت في قطاعها الأرضي طبقات صماء منتشرة بعمق ٢٥سم وبسمك يزيد عن ١٥٠سم في كل المنطقة مكان البحث.