THE EFFECT OF PLOUGHING DEPTH ON SOIL PENETRATION RFSISTANCE, SPECIFIC DRAUGHT AND TRACTOR PERFORMANCE.

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تأثير عمق الحرث على مقاومة التربة للاختراق ـ المقاومة النوعية للتربة وأداء الجرار

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٣ ـ مهندس بمحطة بحوث واختبارات الجرارات والآلات الزراعية

ملخص البحث

اشتمل هذا البحث على دراسة تأثير عمق الحرث باستخدام المحراث الحفار ٧ سلاح على :

١ ـ مقاومة التربة للاختراق ٢ ـ المقاومة النوعية للتربة ٣ ـ أداء الجرار

ولقد أجرى البحث بأرض طينية بمزرعة سخا بمحافظة كفر الشيخ ولقد أظهرت نتائج الدراسة الآتى : أن العلاقة بين عمق الاختراق والطاقة اللازمة للتغلب على مقاومة التربة للاختراق علاقة طردية .

ولقد أمكن ايجاد علاقة رياضية لحساب الطاقة اللازمة للتغلب على مقاومة التربة للاختراق ومنها أمكن اشتقاق علاقة لحساب مقاومة الاختراق وذلك لجهاز اختبار مقاومة الاختراق .

وقد أمكن الربط بين مقاومة التربة للاختراق وقوة الشد الأفقية النوعية فى علاقة رياضية يمكن عن طريقها بمعرفة مقاومة التربة للاختراق التنبؤ بقوة الشد الأفقية النوعية ، ومنها وبمعرفة عرض المحراث وعمق الحرث يمكن معرفة قوة الشد المطلوبة وقوة الجرار .

بالنسبة لتأثير عمق الحرث على أداء الجرار فقد أظهرت الدراسة أن
هناك علاقة طردية بين عمق الحرث وكل من قوة الشد الأفقية - معدل
استهلاك الوقود لوحدة الزمن ولوحدة المساحة م وهناك علاقة عكسية بين عمق
الحرث وكل من قوة الشد الأفقية النوعية والسرعة الأمامية للجرار - ومعدل
استهلاك الوقود بالنسبة لوحدة الحجم من الأرض المثارة .

ABSTRACT

The seed-bed preparation for corn crop is effective as far as energy and irrigation water consumption are concerned. The independent factor considered in this work is ploughing depth. A seven shares chisel plough was used in this work for primary seed-bed preparation. The effect of ploughing depth on energy needed was studied. Soil resistance to penetrometer was considered in the course of this study in order to find a relation between specific draught and soil penetration resistance to make it possible to predict the draught force in terms of the quick reading taken from the penetrometer.

However, it has been found that the total draught force increases with declining rate with ploughing depth. Nevertheless, the specific draught decreases with depth of ploughing due to the higher moisture content at deeper plots.

Also, the effect of ploughing depth on the tractor performance and fuel consumption was studied in this work. It has been found that the fuel consumption increased with depth of ploughing.

INTRODUCTION

Tillage may be defined as the practice of working the soil for the purpose of brining about more favourable conditions for plant growth. All operations that affect the soil, such as stirring, fining, firming and inverting are included. Tillage is costly but necessary in the production of crops.

The basic reasons for tillage are :

1- To prepare a suitable seed-bed.
2- To destroy weeds.
3- To improve the physical conditions of the soil (drainage, porosity and equal distribution of irrigation water).

The several operations which are necessary to prepare a suitable seed-bed for successful production of crops are of favourable effect as far as physical, chemical and biological soil properties are concerned. This preparation may be necessary to destroy native vegetation, sod or another crop in the rotation or weeds.

The optimum quantity of tillage in each soil for each crop is still a problem which needs to be thoroughly considered. Since tillage is very expensive and energy consuming, it is necessary to determine the limits of tillage operations experimentally for each case of crop and soil.

In this work, the effect of ploughing depth on some factors was studied as follows:

1- Soil penetration resistance.
2- Specific draught.
3- Tractor performance.
4- Fuel consumption.

REVIEW OF LITERATURE

There are various methods of seed-bed preparation techniques. Philips (1984) and El-Ashry (1985) sorted them out as no-tillage, minimum tillage, mulch tillage, conventional tillage, optimum tillage, reduced tillage, strip tillage system and precision tillage.

Seed-bed preparation techniques can also be sorted out as indicated by Abo El-Ees (1978) into:

1- **Primary tillage operations:**

In this type of tillage, the mouldboard plough is a widely used implement outside of Egypt. Other implements such as the disc plough, disc harrow, chisel-type tools and rotary tillers are also employed in primary tillage operations.

2- **Secondary tillage:**

A wide variety of implements including some of those mentioned above are used in secondary tillage.

El-Ashry (1985) indicated that the soil compaction is increased by increasing tractor and heavy machinery traffic, and that the soil condition is affected by tillage operations. In this concern, Korayem et al. (1981) pointed out that the soil compaction increases with the number of passes on soil during tillage operation.

Stout et al. (1961) indicated that compaction suppresses plant emergence. Harris and Fuller (Cited by Ismail, 1980) sorted out the adverse effects of soil compaction as follows:

1) The necessity to run water longer in each irrigation.
2) Excessive waste of water and sometimes fertilizers due to irrigation runoff at the lower end of field.
3) Insufficient leaching of harmful salts.
4) Reduced root penetration.
5) Inability to sotre adequate quantities of water in root zone.
6) Unequal distribution of irrigation water.

Mostafa et al. (1977) indicated that the unit draught increases with the energy of penetration. For the conditions of the tests, the first was found to be twice as much as the energy divided by depth and probe diameter, although an error of 23% existed. Nevertheless, estimation of the drawbar pull based on penetrometer tests might still be used in virtue of its simplicity.

MATERIALS AND METHODS

1- Land:

An area of 6 feddans of clayey soil was chosen in Northern Delta Territorial Station of Researches and Farms in Sakha, Kafr El-Sheikh Governorate. It was divided into 12 plots.

Four treatments, viz, 100, 150, 200 and 250 mm depths of ploughing were considered. Three replicates for each treatment were made.

The mechanical analysis of studied soil is as entered in Table (1). Metwally (1987).

Table (1): Mechanical analysis of studied soil.

Depth mm	Fractions %			Texture
	sand	silt	clay	
0-100	24.13	34.24	41.59	clay
100-200	25.64	29.50	44.86	clay
200-300	24.25	24.86	44.89	clay

The soil moisture content and bulk density were measured at various levels of depth. The previous crop was broad beans.

2- Equipment:

Tractors:

Two tractors were simultaneously used in this work. One of the two tractors was towed by the other.

The rear (towed tractor is, thus, used as an implement carrier whereas the front one is used as a prime mover. A very near to horizontal chain with a force dynamometer linked the two tractors. This arrangement makes it possible to measure the draught force as suggested by Ismail (1980) and El-Ashry (1985).

The first tractor (the prime mover) is a "Ford T.W.30" four wheel tractor 4 x 4 wheel traction. The second tractor (towed) is "Ford 4600" four wheel tractor 2 x 4 wheel traction.

Plough:

A mounted 7 shares chisel plough was used in this work. The shares are of the chisel type.

The most relevant parameters needed to be determined in this work are moisture content, M.C., dry bulk density, ρ , soil type and chemical analysis. Each of these parameters was determined as an average of three soil layers at each plot viz, 0-10, 10-20 and 20-30 Cm depth from random plots distributed among the field.

The moisture content was measured by drying the samples in an oven at 105°C for 24 hrs.. Weighing the samples before and after drying, M.C., can be worked out.

An undisturbed soil sample was taken from the soil with a special cylindrical tin of 60.0 mm internal diameter and 40 mm height. The cut volume of soil was, then, dried and weighed to determine the dry bulk density, ρ .

The mechanical and chemical properties of the soil were carried out in the soil science laboratory in Sakha Research Station.

Penetration measurements:

An impact penetrometer was used in this work for measuring the penetration resistance. (Fig. 1).

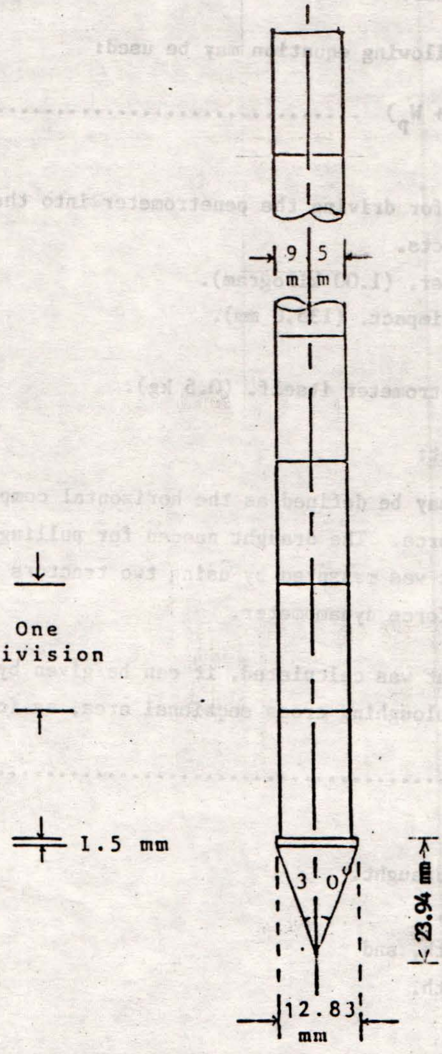

Fig. (I) The impact penetrometer used.

In fact, the soil specific resistance to penetrometer is composed of two parts. The first part is due to the hammer potential energy. The other part is the weight of both the hammer and the penetrometer itself.

Accordingly, the following equation may be used:

$$E = n.W_h.d + Z\,(W_h + W_p) \quad \text{.................................} \quad (1)$$

where:

- E = energy needed for driving the penetrometer into the soil.
- n = number of impacts.
- W_h = weight of hammer. (1.00 kilogram).
- d = stroke of one impact. (135.0 mm).
- Z = final depth.
- W_p = weight of penetrometer itself. (0.5 kg).

Draught force measurement:

The draught force may be defined as the horizontal component of the total tractive force. The draught needed for pulling the plough in each treatment was measured by using two tractors and a calibrated hydraulic force dynamometer.

The specific draught was calculated, it can be given by dividing the draught by the ploughing cross sectional area, as follows:

$$d = \frac{D}{lZ} \quad \text{...} \quad (2)$$

where:

- d = the specific draught.
- D = draught force.
- l = ploughing width, and
- Z = ploughing depth.

Determination of fuel consumption:

The fuel consumption was measured throughout ploughing. The fuel consumption per unit time or unit area can, thus, be worked out as follows:

$$F.C_t = \frac{F}{t} \quad \text{.......} \quad (3)$$

$$F.C_a = \frac{F}{A} \quad \text{.......} \quad (4)$$

where:

$F.C_t$ = the fuel consumption rate per unit time.
$F.C_a$ = the fuel consumption rate per unti area.
F = the quantity of fuel consumed throughout the work.
t = time of work.
A = the ploughing area.

RESULTS AND DISCUSSION

The soil moisture content and bulk density were measured and the data are as entered in Table (2). It may be shown from this table that both the bulk density (bd), and the moisture content MC, increase with the depth.

Table (2): Moisture content and soil bulk density at different levels of depth of the soil.

Layer depth mm	Average moisture content, M.C. %	Average bulk density kg/m^3
From 000 to 100	15.33	1230
From 100 to 200	26.85	1300
From 200 to 300	30.89	1320

Effect of depth on penetration resistance:

The results of the penetration test are as entered in Table (3) below. Equation (1) is used for calculating the energy for penetration.

Since the soil resisting force is defined as the rate of change of energy with respect to depth, hence:

$$P = \frac{dE}{dZ} \quad \text{..} \quad (5)$$

where:

P = soil resistance force to penetration.

E = energy needed for driving the penetrometer in the soil.

Z = depth of penetration.

From the data in Table (3) a graph has been plotted as shown in Fig. (2).

Table (3): Effect of penetration depth on penetration energy.

Penetration depth, Z mm	Average number of impact, n	Calculated penetration energy E J
40	6	18.54
80	10	31.10
120	12	37.67
160	13	44.25
200	15	47.22
240	16	51.40
280	17	55.00
320	19	61.56

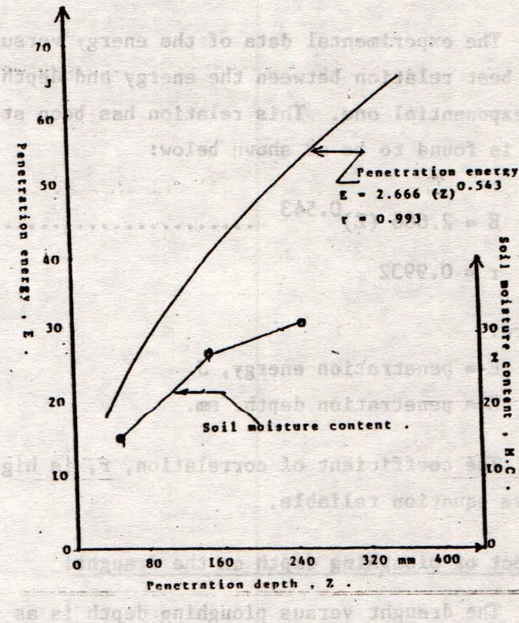

Fig.(2) Relation between penetration depth with energy.

The experimental data of the energy versus depth showed that the best relation between the energy and depth of penetration is an exponential one. This relation has been statistically derived and is found to be as shown below:

$$E = 2.666\,(Z)^{0.543} \quad \ldots\ldots \quad (6)$$

$$r = 0.9932$$

where:

E = penetration energy, J.

Z = penetration depth, mm.

The coefficient of correlation, r, is high enough to make the above equation reliable.

Effect of ploughing depth on the draught:

The draught versus ploughing depth is as shown in Fig. (3). This relation can be considered to be a linear one. However, this relation has been statistically derived and was found to be as given in Equation (7) below:

$$D = 4.76 + 0.1\,(Z) \quad \ldots\ldots \quad (7)$$

$$r = 0.998$$

where:

D = draught, kN.

Z = depth of ploughing, mm.

The high value of the coefficient of correlation, r, proves the authenticity of the proposed linear relation. This relation means that the rate of increase of draught with depth is constant. (in the shown range of depth 100, 150, 200 and 250 mm). This phenomenon can be attributed to moisture distribution with the soil

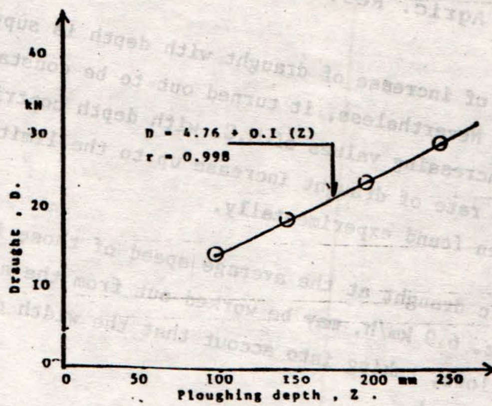

Fig. (3) The relation between draught and plouing depth .

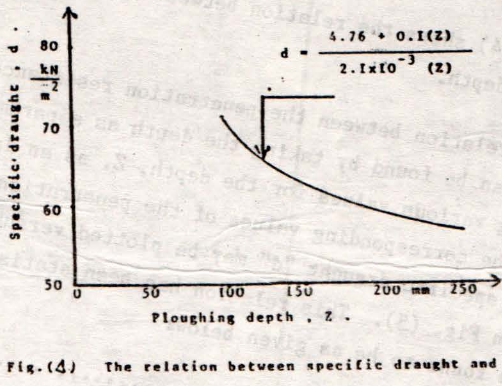

Fig.(4) The relation between specific draught and ploughing depth.

profile. The rate of increase of draught with depth is supposed to be increasing. Nevertheless, it turned out to be constant in this work. The increasing values of M.C. with depth contributed in decreasing the rate of draught increase up to the limit of being linear as has been found experimentally.

The specific draught at the average speed of those indicated in Table (4) viz. 6.9 km/h, may be worked out from the above relation as follows, taking into accout that the width of ploughing is 2.1 m in this work.

$$d = \frac{4.76 + 0.1\ (Z)}{2.1 \times 10^{-3}\ (Z)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (8)$$

where:

d = specific draught kN/m^2

Fig. (4) shows the relation between specific draught and ploughing depth.

The relation between the penetration resistance and specific draught can be found by taking the depth as a parameter. Substituting various values for the depth, Z, as an independent parameter, the corresponding values of the penetration resistance "P" and the specific draught "d" may be plotted versus each other as shown in Fig. (5). This relation has been statistically derived and was found to be as given below:

$$d = 28.96 + 249.1\ (P) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (9)$$

$$r = 0.982$$

where:

d = specific draught, kN/m^2.

P = penetration resistance, N.

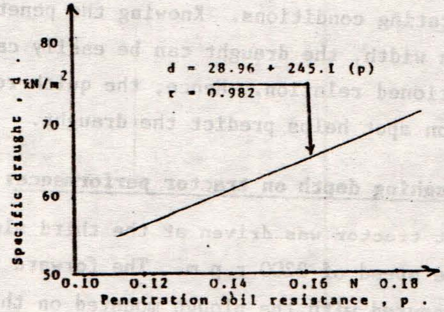

Fig. (5) The relation between specific draught and penetration soil resistance .

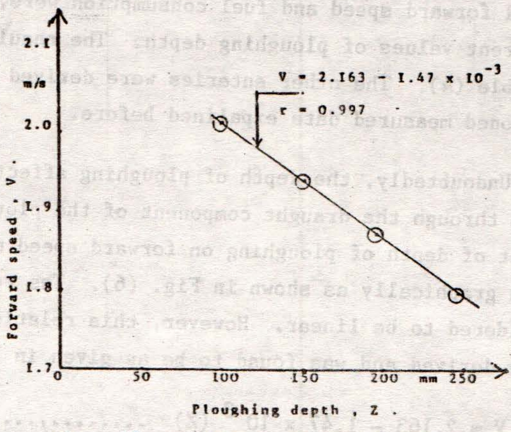

Fig. (6) The relation between the forward speed and depth of ploughing .

This relation is only applicable in the shown studied range of depth in clayey soil and with the penetrometer used in this work.

This relation may be helpful in predicting the draught under the known operating conditions. Knowing the penetration resistance and the plough width, the draught can be easily calculated by using the above mentioned relation. Hence, the quick reading of the penetrometer on spot helps predict the draught.

Effect of ploughing depth on tractor performance:

The front tractor was driven at the third slow gear at an average engine speed of 2200 r.p.m. The forward speed with no load was, then, measured with the plough mounted on the rear tractor which was towed to the front one. The measured no-load speed amounted to 2.14 m/s, i.e., 7.7 km/hr. The draught values, the actual forward speed and fuel consumption were, then, measured at different values of ploughing depth. The results are as entered in Table (4). The other enteries were derived from the above mentioned measured data expalined before.

Undoubtedly, the depth of ploughing affects the tractor forward speed through the draught component of the ploughing resistance. The effect of depth of ploughing on forward speed may be more clearly shown graphically as shown in Fig. (6). The relation can be considered to be linear. However, this relation has been statistically derived and was found to be as given in Equation (10) below:

$$V = 2.163 - 1.47 \times 10^{-3} (Z) \quad \ldots\ldots\ldots\ldots \quad (10)$$

$r = 0.997$

where:

V = forward speed, m/s.

Z = depth of ploughing, mm.

Table (4): Effect of ploughing depth on tractor performance.

average depth of ploughing (Z) mm	average draught (D) kN	specific draught (d) kN/m^2	forward speed with load (V)		average fuel consumption (F.C)	
			m/s	km/hr	lit/hr ($F.C_t$)	lit/fed ($F.C_a$)
100	15.205	63.3	2.015	7.25	10.66	2.5
150	19.620	54.5	1.940	6.98	10.68	2.6
200	24.505	51.1	1.880	6.76	10.75	2.7
250	30.411	50.7	1.790	6.44	10.99	2.9

This relation is only applicable in the shown range of depth and speed. This relation means that the rate of decrease of forward speed with depth is constant. This phenomenon can be attributed to slippage percentage increase with depth.

The fuel consumption, F.C., versus ploughing depth is as plotted in Fig. (7). This relation can be considered to be a linear one. However, this relation has been statistically derived and was found to be as given in the following:

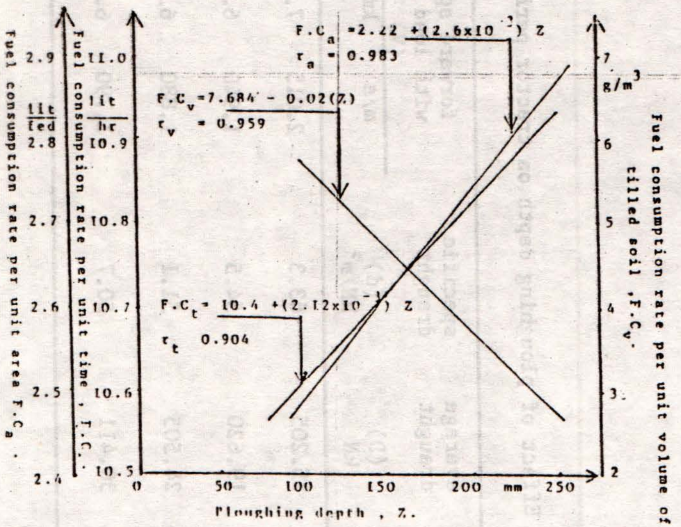

Fig. (7) The relation between the fuel consumption rates and ploughing depth.

$$F.C_t = 2.22 + (2.6 \times 10^{-3})Z \quad (11)$$
$$r = 0.983$$

$$F.C_a = 10.4 + (2.12 \times 10^{-3})Z \quad (12)$$
$$r = 0.904$$

$$F.C_v = 7.684 - (0.02)Z \quad (13)$$
$$r_v = 0.959$$

where:

$F.C_t$ = rate of fuel consumption per unit time, lit./hr.

$F.C_a$ = rate of fuel consumption per unit area, lit./fed.

$F.C_v$ = rate of fuel consumption per unit volume of tilled soil, g/m^3.

These relations mean that the rate of increase of fuel consumption with depth is constant at $F.C_t$ and $F.C_a$, but at $F.C_v$ the relation means that the specific fuel consumption per unit volume of tilled soil decreases with depth.

CONCLUSIONS

Some conclusions may be drawn from this work as given in the following:

1- To make use of the penetrometer testing in predicting the draught force on the plough, a relation between the penetrometer resistance and specific draught has been statistically derived from experimental data as given below:

$$d = 28.96 + 249.1\ (P)$$

where:

d = specific draught KN/m^2.

P = soil penetration resistance, N.

Such a relation may be helpful in determining the total draught force from a quick test with the penetrometer in the field.

2- Concerning tractor performance, the draught force increased with decreasing rate with the depth of ploughing, whereas the specific draught decreased with depth.

3- The fuel consumption per unit area increased with the depth of ploughing. The equations controlling these relation have been derived in this work.

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