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EFFECT OF DEEP PLOWING ON PRODUCTIVITY OF COMPACTED CLAYEY SOILS.

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ABSTRACT: *Field experiments were conducted in heavy compacted clayey soils at El-Gemmeiza Agricultural Research Station (El-Gharbia Governorate) during two successive cultivation seasons to evaluate the suitability of deep plowing at 30 and 60 cm depth, arranged in parallel or cross orientations with respect to one another at 2, 4 and 6 m spacing at an endeavor to alleviate the impermeability problems in this soil and to improve its productivity.*

The obtained results indicated that the rate of fuel consumption increased by increasing plow depth by about 23.0 % and the power consumption increased from 41.31 to 49.36 Kw, as the plow depth increased from 30 to 60 cm. Also, these treatments led to an increase in slip ratio. Penetration values decreased by increasing plow depth, and in case of crossed moles, also they decreased by decreasing the mole spacing.

It was found that most mole treatments used in this study significantly increased the yield and yield components of each crop in relation to the control. Deep tillage obviously increased the relative yield by 18.40 and 36.40% for maize in the first season and by 27.88 and 67.27 % for barley in the second one for 30 and 60 cm plow depth respectively over the recorded with the control.

The yield and yield components in all seasons positively responded to the crossed moles than the parallel ones. In case of the correspondence to mole numbers per area unit, the crossed and the parallel moles approximately have the same effect on the yield and yield components.

The installation of the moles at 2, 4 and 6 m spaces clearly increased yield and yield components, where the relative increasing grain yield was 34.0, 25.6 and 22.8 % respectively for the maize in the first season and by 63.64, 46.06 and 33.33 % respectively for barley in the second season.

The superior treatment was 60 cm plow depth with crossed moles at 2 m spacing since it gave the highest values of yield and its components.

According to the economic evaluation, the 60 cm plow depth with crossed moles at 2 m spacing was the most valuable compared to other treatments, since the highest net revenue was obtained by this treatment.

Key words: *Deep plow, mole pattern and spacing, fuel consumption, power consumption, penetration resistance.*

INTRODUCTION

Soil compaction, referring to the compression of soil layers, often leads to increasing the density of the soil body with a simultaneous reduction in air-filled pores. Growth and yields of crops growing on compacted soils are usually restricted owing to the poor development of root system as a result of in adequate aeration, mechanical impedance, moisture and nutrient supply (Talha *et al.* 1978 and Gupta *et al.*1989).

The suitability of soils for cropping depends heavily on readiness with which they conduct water and air, and on the aggregate properties which control the friability of the seedbed (Rhoades *et al.* 1992).

Improving the heavy clay compacted soils can be achieved by drainage and sub-soiling technique (Bailey 1978). Mole drains are conveniently used in heavy soils. A mole drain is formed by pulling a torpedo shaped object, which is attached to a vertical blade, through the soil at a depth of 50-60 cm (Hathoot, 1987).

Michael and Ojha (1981) indicated that sub-soiling by using chisel ploughs is suitable to break and shatter compacted or otherwise impermeable soil layers. Chisel plough might break hard layers from 25 to 35 cm deep, might it be suitable to operate as deep 60 to 70 cm.

Nicou *et al.* (1993) evaluated deep ploughing techniques, soil properties, plant characteristics, soil porosity, root development, microbial life, soil-water reserves, and crop yields. they concluded that deep tillage is an excellent means to improve the soil physical properties and crop yields in the semi-arid regions of west Africa.

Kooistra and Boersma (1994) reported that if no changes in management practices were made after deep tillage the study loam soil were re-compacted within 3 years with the same or worse physical properties and land qualities. The zones broken channels should be too narrow to prevent the re-compacted in a few years.

Tupper and Pringle (1997) reported that, the combination of primary and deep tillage systems is suggested to be suitable for cotton on soils that respond to sub-soiling.

Salanci *et al.* (1994) studied loads on a tractor drawbar during deep ploughing to assess the effect of some parameters such as engine speed and depth of tillage on dynamic impacts. They showed that depth of tillage, summetry of tillage implements and incorrect mounting of the implements, also affected loading. They added that as the forward speed increased, dynamic impacts increased.

Prinzio *et al.* (1997) compared three sub-soiling techniques (conventional subsoiler, winged subsoiler and rigid tine subsoiler followed by conventional subsoiler). They found that at a depth of 0.55-0.60 m, the winged subsoiler gave a greater increase in soil volume with a large disturbed soil area. At a depth of 0.25-0.30 m, the three tested subsoiling techniques produced similar results.

Heavy clayey compacted soils with low permeability, as in the Nile Delta are not generally adapted for crop production. Therefore, efficient drainage is an important element in the development of soil for crop production.

Koga *et al.* (1992) concluded that the combined effect of sub-soiling and deep ploughing for a soybean crop was most pronounced on plant growth parameters like root length, dry matter production and grain yield.

Wesley *et al.* (1993) conducted some experiments on a clayey soil to determine deep tillage effect on soybean yields. They noticed that average yield increased of 57% (3020 vs. 1924 Kg/ha) when compared the deep tillage to the conventional check treatment (control).

Dunker *et al.* (1995) recorded that crop yields of both maize (*zea mays*) and soybean (Glycine max) were significantly increased with increasing tillage depth.

El-Abaseri *et al.* (1996) found that most mole treatments used in his study significantly increased the yield of crop in relation to the control. The installation of the moles at 2, 4 and 6 m spacing, obviously increased the relative yield by 26.1, 20.1 and 10.1% respectively for clover in the first season, by 34.8, 19.6 and 16.7% respectively for rice grain and by 38.6, 26.6 and 11.8% respectively for rice straw in the second season, and by 31.0, 25.6 and 19.7% respectively for clover in the third season. They added that the yield in all seasons positively responded to the crossed moles more the parallel moles and the differences ranged between 11 and 15%, in case of the correspondence to mole numbers per area unit, the crossed and the parallel moles approximately have the same effect on the yield.

Varsa *et al.* (1997) reported that deep tillage increased root proliferation and the depth to which roots penetrated. They showed that approximately 35% of the maize root length in the 21-100 cm portion of the soil profile was found below 60 cm depth in the deepest tillage, whereas less than 5% was below 60 cm in the control. They also added that deep tillage, which resulted in increased maize grain yield with the greatest yield always being obtained with 90 cm tillage.

Shetawy (2001) reported that the application of (S1) machine at 30 cm depth and 450 cm drain space resulted in the lowest average soybean grain yield (1.063 ton/fed.) while the application of (S2) machine at 60 cm depth and 150 cm drain space exhibited the maximum average yields (1.347 ton/fed.). Similar yield trend was also observed in cotton field. Since, the cotton lent yield which accomplished the above mentioned applications were 1032 and 1259 Kg/fed respectively. Those results trend may be attributed to the distribution of moisture and soil strength magnitudes in the root growing zones.

For cost evaluations of deep plowing, Wesley *et al.* (1993) conducted experiments on a clayey soil to determine effects deep tillage on soybean economic returns. They showed that, deep tillage increased the average net returns of the conventional check treatment by 75 % ($ 206 vs. $ 118/ha).

Greversa and Taylor (1995) showed that the feasibility of deep tillage of soils depends on agronomic and economic considerations. They cleared that, the sub-soiling costs were recovered by revenues from increased crop production by the second or third year after sub-soiling. They concluded that continuous cropping for at least three years after sub-soiling and the selection of higher-revenue crops in the second and third crop years facilitates recovering the cost of sub-soiling.

The main objective of this study is to evaluate the effect of deep tillage at 30 and 60 cm depth by two mole patterns (parallel and cross) at three spacings (2, 4 and 6 m) along with the control (untreated soil) in relation to there effects on power requirements, soil penetration resistance and on improving soil productivity of yield and yield components.

MATERIALS AND METHODS

An area of about 3 feddans of compacted clayey soils were chosen at El-Gemmeiza Agricultural Research Station (El-Gharbia Governorate) to study the effect of deep tillage on soil productivity. Two successive crop rotation were applied maize, 2001 and barley 2001/2002. The factors involved in this study were two plow depths (30 and 60 cm depth) in two patterns (parallel and cross) at three spacings (2, 4 and 6 m) along with the control (untreated soil). Each treatment was replicated three times where the area of the experiment was divided into 39 plots using a randomized complete block design. The area of each plot was 323 m^2.

The analysis of the field experimental soil according to Black (1965) indicated that the soil is very slowly permeable mainly because of a dense clayey compacted layer at 30-60 cm depth, this layer contains more than 40% clay and has a higher bulk density (1.57 g cm^{-3}) and a lower hydraulic conductivity (0.25 cm hr^{-1}). This soil have EC_e between 6.62 and 6.89 dSm^{-1} saturated paste extract with pH between 7.86 and 7.92 in 1 : 2.5 soil water suspension.

The moles were constructed at 30 and 60 cm depth by subsoiler. To carry out this sub-soiling, the following equipments were used, a 90 Kw tractor (120.0 hp) model Ford-Tw10 was used to perform deep tillage treatment. Also, one tin deep plow was used. The technical specifications of the used deep tillage plow are indicated in Table (1).

Table (1): The technical specifications of the used deep tillage plow.

Specificans items	Deep tillage plow
Nationality	Japanese
Mass, Kg	250
Number of shares	Single share
Main dimensions :	
Length, mm	1000
Width, mm	1800
Height, mm	1200
Depth adjusting	three hitching system
Beam length, mm	1000
Pump status	Provided with 5Kg pump
Share dimensions :	
Length, mm	1500
Width, mm	75 at its front edge, and 125 at its end
Attach angle, degree	60^{o}

Slippage percentage (S%) was calculated by using the following formula :-

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

where : L_1 = the advance per 10 wheel revolutions under no load, m.

L_2 = the advance per 10 wheel revolutions under load, m.

Fuel consumption was determined by measuring the volume of fuel required refilling the tank after operation time per each treatment. The rate of fuel consumption was calculated using the following formula:

$$Fuel\ consumption = \frac{Amount\ of\ fuel\ consumption, L}{Time, hr}, L/hr$$

The power requirement was calculated using the following equation (Embaby, 1985)

$$Er = (Fc \times \frac{1}{3600}) \times \rho_r \times L.c.v. \times 427 \times \eta_{th} \times \eta_m \times \frac{1}{75} \times \frac{1}{1.36}, Kw$$

where :Fc = Fuel consumption rate, L/hr

ρ_r = Density of the fuel Kg/l (for solar fuel= 0.85 Kg/l)

L.c.v.= Lower calorific value of fuel K cal/kg; (average L.c.v. of solar fuel is 10000 K cal/kg).

427 = Therme-Mechanical equivalent, Kg m/K cal.

η_{th} = Thermal efficiency of the engine (considered to be about 40% for diesel engine).

η_m = The mechanical efficiency of the engine (considered to be about 80 % for diesel engine).

Japanese cone penetrometer, modle SR-2Dik 5500 was used to measure the penetration resistance. This measurement was done 4 times. The first 3 times, each was done 10 days after the primary three irrigation, while the latest was done direct before harvesting in the two growing seasons.

The experimental field was treated prior to planting, and the recommended agricultural processes were practiced. In the summer season 2001 seed of maize (*zea mays L.*) single cross 10 maize hybrid were planted at the rate of 12 kg fed^{-1} during the first week of June 2001, while in winter season 2001/2002seeds of barley (*Hordum vulgar L.*) cultivar Giza 126 were planted at the rate of 50 kg fed^{-1} during the third week of December 2001. The basel doses of N, P and K were applied according to the recommendations. All normal agricultural practices as irrigation, fertilization, weeds and pest control ... etc were carried out as usual for each crop in the zone.

Total yield for each plot of each crop in each treatment was separately harvested, weighed and related to tons fed^{-1}. The yield relative to control was computed for each treatment as follow: (yield of the treatment)/(yield of the control) X100. Also, 100 corn seed and 1000 barley seed weight were determined for each treatment. Ten random plants per plot were sampled at harvest of each crop to determine the following characters.

Maize growth characters:

1- Plant height, (cm)
2- Ear length, (cm)
3- Ear diameter, (cm)
4- Number of rows per ear.
5- Number of kernels per row
6- Dry matter, g $plant^{-1}$

Barley growth characters:

1- Plant height, (cm)
2- Spike length, (cm)
3- Number of kernels per spike
4- Number of spikes per m^2
5- Dry matter, g $plant^{-1}$

The collected data were statistically analyzed according to procedure out lined by Snedecor and Cochran (1981).

Economic evaluation was done to compare between different treatments to state which one is more valuable. The test was executed according to the price of the yield (450 L.E./ton maize in the first season and 750 L.E./ton grain of barley and 200 L.E./ton straw of barley in the second season), as well as the cost of different treatments including the price of sub-soiling which was calculated considering conventional method of estimating both fixed and variable costs.

Total per-fed cost was calculated by multiplying the hourly cost by the actual time required by the machine to cover one feddan.

RESULTS AND DISCUSSION

I- Evaluation of the power requirements and slip performances:

1- The power requirements

Data presented in Table (2) showed that, the rate of fuel consumption increased by increasing the plowing depth with all mole spacing and mole pattern because of increased soil draft. The results also indicate that, by increasing plowing depth from 30 to 60 cm the fuel consumption increased by about 23.0 %

In the present study, the power requirements were evaluated as a function of the fuel consumption. From the obtained data presented in Table (2), it is clear that the power requirement was varying with the plowing depth. As the plowing depth increased from 30 to 60 cm, the power consumption increased from 41.31 to 49.36 Kw.

Table (2): Effect of plow depth, mole pattern and mole spaces on fuel consumption, power requirement and slip percent.

Plow depth, cm	Mole pattern	Mole space, m	Fuel consumption, L/hr	Power req., Kw	Slip, %
30	P*	2	12.85	41.12	6.90
		4	12.28	39.30	6.95
		6	12.75	40.80	6.82
	C**	2	12.75	40.80	8.29
		4	13.21	42.27	8.13
		6	13.62	43.58	8.32
60	P*	2	14.82	47.42	13.80
		4	14.65	46.88	13.90
		6	15.92	50.94	13.87
	C**	2	15.82	50.62	13.82
		4	16.05	51.36	14.42
		6	15.30	48.96	14.22

P* = Parallel mole pattern.
C** = Cross mole pattern.

2- Slip ratio

From the obtained data in Table (2), it is clear that, for all mole spaces (2, 4 and 6 m) and for both moles pattern (parallel and cross) and increasing the plow depth, the slip ratio tended to increase.

The maximum values of slip ratio were found to be 8.85 and 14.42 % at operating forward speed of about 3.75 Km/h for plow depth of about 30 and 60 cm respectively.

II- Soil penetration resistance:

Data demonstrated in Table (3) shows that the effect of plow depth, moles pattern and moles spacing on penetration resistance at sequence measuring timed. The results indicated that, the penetration values decreased by increasing plow depth since increasing soil tillage depth decreased the soil compaction, in the two growing seasons.

On the other hand, it is obvious that mole pattern also affect soil penetration resistance where crossed moles were better than parallel ones on decreasing the values of penetration resistance in the two growing seasons.

Table (3): Effect of the different treatments on penetration resistance (MPa) at sequence measuring time.

Plow depth, cm	Mole pattern	Mole space, m	First season (maize)				Second season (barley)			
			10 days after 1st irri.	10 days after 2nd irri.	10 days after 3rd irri.	Just before harvesting	10 days after 1st irri.	10 days after 2nd irri.	10 days after 3rd irri.	Just before harvesting
30	P*	2	1.61	1.63	1.67	1.83	1.64	1.68	1.69	1.93
		4	1.83	1.90	1.94	2.12	1.88	1.95	1.99	2.15
		6	1.93	1.95	1.96	2.15	1.98	2.05	2.09	2.22
	C**	2	1.60	1.67	1.71	1.81	1.63	1.69	1.73	1.88
		4	1.72	1.78	1.80	2.11	1.78	1.85	1.91	2.05
		6	1.83	1.89	1.94	2.13	1.91	1.93	2.02	2.14
60	P*	2	1.54	1.56	1.57	1.80	1.56	1.60	1.60	1.82
		4	1.70	1.74	1.76	2.01	1.72	1.77	1.86	2.04
		6	1.92	1.95	1.98	2.13	1.99	2.01	2.07	2.20
	C**	2	1.53	1.53	1.50	1.79	1.55	1.57	1.59	1.80
		4	1.66	1.72	1.72	1.96	1.70	1.75	1.82	2.00
		6	1.79	1.80	1.85	2.10	1.81	1.90	1.97	2.14
Control			2.97	2.98	2.98	2.99	3.03	3.03	3.04	3.06

P* = Parallel mole pattern.
C** = Cross mole pattern.

The effect of different spaces on decreasing the values of penetration resistance during the two seasons can be arranged in the following descending order: 2m >4m >6m > the control.

The results indicated also that the application of 6 m mole space causes higher soil penetration values, especially in the parallel sectors tilled at 30 cm plow depth. This may be due to the rapid movement of the drain water from the mid zone of the narrow mole space than the wider one.

Also, it can be seen that soil penetration resistance just before harvesting have the highest values. This may be because of natural dries of soil during the growing period. These results are in line with Dunker *et al.* (1995), they reported that, the average soil strength decreased with increasing depth of tillage.

Concerning the combined effect of different treatments on soil penetration resistance, it could be observed that all mole treatments decreased soil penetration resistance values comparing to the control. The best treatment was found to be 60 cm plow depth with crossed moles at 2m spacing during the two studied seasons, since it recorded the lowest values which were 1.53, 1.53,1.50 and 1.79 MPa respectively in the first season, and 1.55, 1.57, 1.59 and 1.80 MPa respectively in the second one, for the primary three irrigation and just before harvesting. while the control detected the highest values which were 2.97, 2.98, 2.98 and 2.99 MPa respectively in the first season and were 3.03, 3.03, 3.04 and 3.06 MPa respectively in the second one for the same times.

III- Effects on yield and yield components:

Results in Tables (4 and 5) and Figs. (1-3) show that almost all mole treatments exhibited significant differences on yield and yield components at the end of the two studied seasons comparing to the control (untreated soil). In general, it has been noticed that deep tillage led to a relative increase in the yield by 18.40 and 36.40 % for maize in the first season and by 27.88 and 67.27 % for barley in the second one for 30 and 60 cm plow depth respectively, over the recorded with the control. Also, the same treatments led to a significant increases in 100-seed weight and plant height for maize in the first season and in biological yield, 1000-seed weight, harvest index and plant height for barley in the second season while the straw yield was non significant. These findings corresponding with those reported by Meharban *et al.* (1998) and Kaoud (1994) who found that deep tillage treatment increased yields of cotton and clover as compared to conventional tillage, because the deep tillage breaks up the impediment in the subsoil, and encourage root growth and water extraction more from deeper soil layers.

With respect to the effect of mole pattern the mean values of the yield revealed that the crossed moles were significantly better than the parallel ones in all seasons. The yield obtained by crossed moles was greater than the parallel ones by 0.22 ton grain corn / fed. in the first season and by 0.27 ton seed barley /fed. in the second season. This trend may be attributed to that the number of moles per unit area, with the crossed pattern is twice as with the parallel one at the same spacing. Consequently, the crossed pattern improves the soil condition to be more suitable for crop production. Therefore the yield of the plots that correspond in numbers of both parallel or crossed moles per unit area showed negligible differences between the two patterns during the two seasons. Also, the same treatments led to a significant increases in 100-seed weight and plant height for maize in the first season and in biological yield, 1000-seed weight and plant height for barley in the second season, while the straw yield was non significant. These results are in harmony with those obtained by El-Abaseri *et al.* (1996).

Table (4) : Effect of different mole treatments on yield and yield components of maize in the first season (summer season 2001) .

Plow depth, cm	Mole pattern	Mole space, m	Grain yield, ton/fed	Relative increasing grain yield, %	100 seed weight, g	Plant height, cm	Ear length, cm	Ear diameter, cm	No.of rows per ear	No.of kernels per row	Dry matter, g/plant		
											Root	Shoot	Grain
30	P*	2	3.00	20.00	48.07	264.00	23.80	4.30	13.30	47.40	13.97	187.91	247.06
		4	2.85	14.00	44.06	254.00	22.40	4.20	12.80	46.80	11.06	146.73	203.61
		6	2.77	10.80	43.52	250.00	22.00	4.12	12.70	46.20	11.03	144.34	202.41
	C**	2	3.15	26.00	50.28	268.00	24.90	4.40	13.50	47.60	14.09	196.95	258.45
		4	3.03	21.50	47.83	263.00	23.70	4.30	13.30	47.40	13.58	186.67	245.74
		6	2.96	18.40	45.65	255.00	23.40	4.20	12.90	47.33	12.59	152.92	209.47
60	P*	2	3.45	38.00	55.51	306.00	25.40	4.80	14.40	49.60	24.53	229.48	369.81
		4	3.22	28.80	54.51	278.00	23.40	4.50	13.80	48.60	16.86	212.06	272.01
		6	3.15	26.00	50.73	272.00	23.20	4.50	13.60	48.30	13.12	209.29	247.48
	C**	2	3.79	51.60	56.75	311.00	25.90	4.90	14.60	50.20	26.23	235.16	380.77
		4	3.44	37.60	55.45	304.00	25.40	4.80	14.30	49.50	23.92	225.83	265.54
		6	3.39	35.60	54.71	288.00	24.60	4.60	14.10	48.80	18.10	216.59	282.53
Control			2.50	0.00	41.14	242.00	21.40	3.90	12.30	43.40	6.98	117.48	197.63
A . Plow depth	30 cm		2.96	18.45	46.57	259.00	23.37	4.25	13.08	47.12	12.72	169.25	227.79
	60 cm		3.41	36.27	54.61	293.17	24.65	4.68	14.13	49.17	20.46	221.40	303.02
	F - test		42.86**	42.27**	311.92**	239.13**	6.27*	16.60**	56.97**	187.13**	2030.07**	532.34**	824.72**
	L.S.D 0.05		0.14	5.66	0.94	4.56	1.06	0.22	0.29	0.31	0.37	4.67	6.60
B . Mole pattern	P*		3.07	22.93	49.40	270.67	23.37	4.40	13.43	47.82	15.10	188.30	257.06
	C**		3.29	31.78	51.78	281.50	24.65	4.53	13.78	48.47	18.09	202.35	273.75
	F - test		10.38**	10.44**	27.28**	24.04**	6.27*	1.51 NS	6.33*	19.24**	175.35**	38.65**	108.64**
	L.S.D 0.05		0.14	5.66	0.94	4.56	1.06	0.22	0.29	0.31	0.37	4.67	6.60
C . Mole space	2		3.35	33.90	52.65	287.25	25.00	4.60	13.95	48.70	19.71	212.38	314.02
	4		3.14	25.48	50.46	274.75	23.73	4.45	13.55	48.08	16.36	192.82	246.73
	6		3.07	22.70	48.65	266.25	23.30	4.36	13.33	47.66	13.71	180.79	235.47
	F - test		6.05**	6.05**	25.80**	30.48**	3.97*	1.82 NS	6.90**	16.41**	285.34**	66.34**	201.24**
	L.S.D 0.05		0.17	6.93	1.15	5.59	1.30	0.27	0.35	0.38	0.46	5.71	8.09

P* = Parallel mole pattern.
C** = Cross mole pattern.

Table (5) : Effect of different mole treatments on yield and yield components of barley in the second season (winter season 2001/2002) .

Plow depth, cm	Mole pattern	Mole space, m	Biological yield, ton/fed	Grain yield, ton/fed	Straw yield, ton/fed	Relative increasing grain yield, %	1000 seed weight, g	Harvest index, %	Plant height, cm	Spike length, cm	No. of kernels per spike	No. of spikes per m^2	Dry matter yield, g/plant	
													straw	Grain
30	P*	2	7.61	2.21	5.40	33.94	38.47	29.08	85.80	7.30	41.70	289.42	2.21	2.22
		4	6.52	2.05	4.47	24.24	38.12	31.71	83.50	6.84	35.80	254.57	2.05	2.09
		6	6.27	1.86	4.41	12.73	37.92	29.85	76.50	6.56	35.40	228.27	1.95	1.76
	C**	2	7.78	2.25	5.53	36.36	40.43	29.07	86.30	7.48	42.30	292.43	2.28	2.23
		4	7.61	2.21	5.40	33.94	38.21	29.46	85.40	7.19	41.40	286.27	2.18	2.20
		6	7.15	2.10	5.05	27.27	39.72	29.57	84.20	7.13	39.20	262.53	2.12	2.17
60	P*	2	8.39	2.96	5.43	79.39	47.69	35.50	98.40	8.45	50.20	345.21	2.78	2.67
		4	7.27	2.40	4.87	45.45	43.28	33.11	92.20	7.53	45.60	298.31	2.60	2.33
		6	7.21	2.30	4.91	39.39	41.65	32.02	90.40	7.53	44.40	294.14	2.44	2.24
	C**	2	8.97	3.38	5.59	104.85	47.53	38.94	100.60	9.43	54.60	358.74	3.08	2.84
		4	8.41	2.97	5.44	80.00	47.60	35.36	96.70	8.22	49.80	344.41	2.72	2.67
		6	7.65	2.53	5.12	53.33	45.23	33.30	93.80	7.82	48.40	315.36	2.62	2.48
Control			6.01	1.65	4.36	0.00	37.19	27.45	70.50	5.12	34.80	219.68	1.77	1.30
A . Plow depth	30 cm		7.16	2.11	5.04	28.08	38.81	29.79	83.62	7.08	39.30	268.92	2.13	2.11
	60 cm		7.98	2.76	5.23	67.07	45.50	34.71	95.35	8.18	48.83	326.03	2.71	2.54
	F - test		5.77*	38.93**	0.35NS	34.68**	709.10**	11.77**	595.91**	91.58**	521.33**	766.94**	2243.69**	693.60**
	L.S.D $_{0.05}$		0.71	0.21	0.63	13.66	0.52	2.96	0.99	0.23	0.86	4.26	0.03	0.03
B . Mole pattern	P*		7.21	2.30	4.92	39.19	41.19	31.88	87.80	7.37	42.18	284.99	2.34	2.22
	C**		7.93	2.57	5.36	55.96	43.12	32.62	91.17	7.88	45.95	309.96	2.50	2.43
	F - test		4.30*	7.25*	2.04NS	6.42*	59.21**	0.27NS	49.18**	20.42**	81.38**	146.59**	478.92**	173.40**
	L.S.D $_{0.05}$		0.71	0.21	0.63	13.66	0.52	2.96	0.99	0.23	0.86	4.26	0.03	0.03
C . Mole space	2		8.19	2.70	5.49	63.64	43.53	33.15	92.78	8.17	47.20	321.45	2.59	2.49
	4		7.45	2.41	5.05	45.91	41.80	32.41	89.45	7.45	43.15	295.89	2.39	2.32
	6		7.07	2.20	4.87	33.18	41.13	31.19	86.23	7.26	41.85	275.08	2.28	2.16
	F - test		3.63*	7.87**	1.42NS	7.12**	32.43**	0.64NS	61.85**	23.93**	59.65**	169.14**	217.89**	136.24**
	L.S.D $_{0.05}$		0.87	0.26	0.78	16.74	0.63	3.62	1.22	0.29	1.06	5.21	0.03	0.04

P* = Parallel mole pattern.
C** = Cross mole pattern.

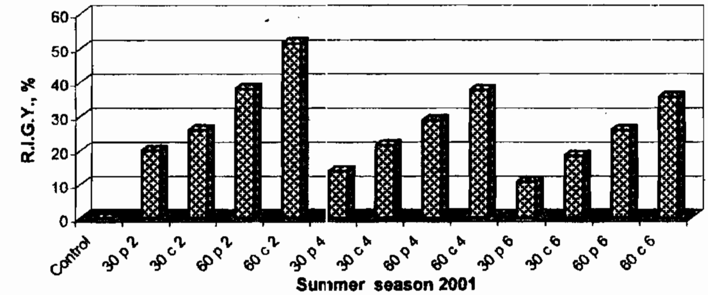

Fig.(1): Relative increasing grain yield % of maize as affected by different treatments.

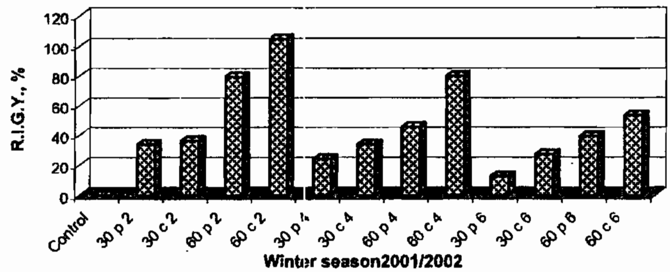

Fig.(2): Relative increasing grain yield % of barley as affected by different treatments.

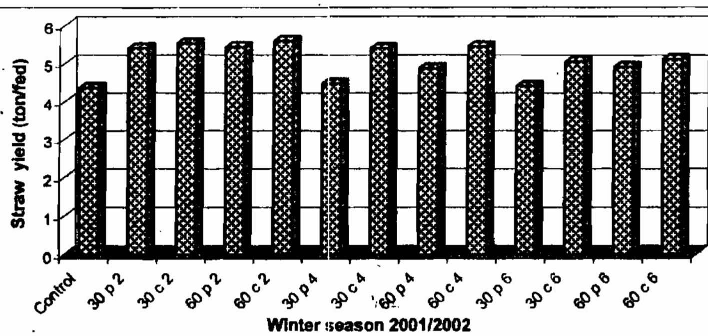

Fig.(3): Straw yield (ton/fed) of barley as affected by different treatments.

Concerning the effect of mole spacing, the data of the yield indicated that decreasing the mole spacing significantly increased the crop yield in the two growing seasons. This means that 2, 4 and 6 m mole spacings increased the yield by 34.0, 25.6 and 22.8% respectively for maize in the first season and by 63.64, 46.06 and 33.33% respectively for barley in the second season over that recorded with the control. It can be also seen a significant superiority of 2 m spacing since it produced the highest crop yields in the two growing seasons and there was no significant differences between the effect of 4 and 6 m mole spacings in the two growing seasons. These results may be attributed to that the construction of moles, especially at closer spacing improved the infiltration characteristic of the soil and consequently decreased its salinity content (Hamideh 1969). Also, the same treatments led to a significant increases in 100-seed weight and plant height for maize in the first season and in biological yield, 1000-seed weight and plant height for barley in the second season. These results are in agreement with those obtained by El-Gohary (1978), El-Sabry *et al.*(1992), El-Abaseri *et al.*(1996) and Shetawy (2001).

Regarding the combined effect of different treatments it could be observed that the highest yield of maize in the first season (3.79 tons/fed) and barley in the second season (3.38 tons/fed) were achieved by 60 cm plow depth with crossed moles at 2 m spacing treatment and in most of cases, the control gave the lowest yield. Also, the same treatment gave the highest values of 100-seed weight and plant height for maize in the first season and biological yield, 1000-seed weight, harvest index and plant height for barley in the second season, and the control gave the lowest values.

Concerning the other yield components, it was seen that deep tillage either in 30 or 60 cm led to a significant increase in ear length, ear diameter, number of rows per ear and number of kernels per rows for maize in the first season and in spike length, number of kernels per spike and number of spikes per m^2 for barley in the second season. These results trend may be attributed to the distribution of moisture, and soil strength magnitudes in the root growing zones resulted in a good growth of plant, which reflect on its components such as ear length, spike length, ear diameter...etc. Also, the same treatments led to highly significant increases in root, shoot and grains dry matter for maize in the first season and in straw and grains dry matter for barley in the second season. These results are in line with that obtained by El-Gohary (1978) who found that dry weight and seed cotton yield were significantly increased by using unfilled moles at 40 cm depth in clayey soil at Kafr El-Sheikh.

Regarding the effect of mole pattern, data showed a significant increases with cross moles than parallel ones in ear length, number of rows per ear and number of kernels per row for maize in the first season, while the ear diameter was non significant. On the other hand, data showed a significant increases in spike length, number of kernels per spike and number of spike per m^2 for barley in the second season. Also, the same treatment led to highly significant increases in maize dry matter for root, shoot and grains in the first season and in straw and grains dry matter of barley in the second season. These results may be attributed to the fact that the crossed pattern had a number of moles per unit area is twice as with the parallel one at the same spacing.

With regard to the effect of mole spacing, data showed that by decreasing the mole spacing there was a significant increase in ear length, number of rows per ear and number of kernels per row for maize in the first season while the ear diameter was non significant. While in the second season there was a significant increase in spike length, number of kernels per spike and number of spikes per m^2 for barley. It can be concluded that the superiority was of 2 m spacing since it produced the highest values of these characters, and there were no significant differences between the effect of 4 and 6 m mole spacing in most of those characters in the two growing seasons. Also, the same treatment led to a significant increases in dry matter of maize for root, shoot and grains in the first season and in straw and grains dry matter of barley in the second one, as shown in Tables (4 and 5).

Concerning the combined effect of different treatments it could be seen that all mole treatments increased these characters comparing to the control in the two growing seasons. The best treatment was found to be 60 cm plow depth with crossed moles at 2 m spacing during the two studied seasons, since it recorded the highest values of ear length, ear diameter, number of rows per ear and number of kernels per row 25.90cm,4.90cm, 14.60 rows and 50.20 kernels respectively for maize in the first season and 9.43cm, 54.60 kernels and 358.74 spikes respectively for spike length, number of kernels per spike and number of spikes per m^2 for barley in the second season, while the control detected the lowest values 21.40cm, 3.90cm, 12.30 rows and 43.40 kernels respectively in the first season and 5.12cm, 34.8 kernels and 219.68 spikes, respectively in the second season.

Thus, the present study could confirm that adapting deep tillage in combination with crossed moles at 2 m spacing is an important practice for fighting and lossening the compacted underlying layers, and accordingly increasing crop production comparable to conventional tillage.

IV- Estimation of the net deep plowing cost:

Cost evaluation was performed for tractor and plow considering conventional method of estimating both fixed and variable coasts. The plough cost was 1.35 LE/h, tractor cost was 34.45 LE/h and total costs were 35.8 LE/h.

The averages of total deep plowing cost and net profit as affected by different plowing conditions are shown in Table (6). It can be concluded that, although, the total cost of deep plowing for 2 m mole space recorded higher values than of the other mole spacings (4 and 6 m), the net profit of this mole space was in general lower than that of the other spaces. Thus, it can be concluded that, it is better economy to decrease the mole space down to 2 m to decrease the deep plowing cost.

Table (6): The net revenue*** (LE/fed) due to different mole treatments through the two growing seasons under study.

Plow depth, cm	Mole pattern	Mole space, m	Actual field capacity, fed/hr	Total deep plowing cost, LE/fed	Total yield price, LE/fed			Net revenue
					Maize grain	Barley grain	Barley straw	
30	P*	2	1.25	28.64	225.00	420.00	208.00	824.36
		4	2.49	14.38	157.50	300.00	22.00	465.12
		6	3.74	9.57	121.50	157.50	10.00	279.43
	C**	2	0.58	61.72	292.50	450.00	234.00	914.78
		4	1.16	30.86	238.50	420.00	208.00	835.64
		6	1.74	20.57	207.00	337.50	138.00	661.93
60	P*	2	1.12	31.96	427.50	982.50	214.00	1592.04
		4	2.33	15.36	324.00	562.50	102.00	973.14
		6	3.51	10.20	292.50	487.50	110.00	879.80
	C**	2	0.50	71.60	580.50	1297.50	246.00	2052.40
		4	1.11	32.25	423.00	990.00	216.00	1596.75
		6	1.68	21.31	400.00	660.00	152.00	1190.69

P* = Parallel mole pattern.
C** = Cross mole pattern.
*** = (yield of the treatment - control) - the cost of the treatment
The price of the yield and the cost of different treatments were calculated as subsidized price of 2001 and 2002.

The results indicated also that the net profit of the cross moles were in general higher than those of parallel ones.

Also, it can be seen that, it is better economy to increase the plow depth up to 60 cm to increase the net profit.

Thus, according to the economic evaluation in Table (6) it could be concluded that the combined treatment of 60 cm plow depth with crossed pattern at 2 m spacing was the best treatment and should be recommended due to a relative high net income comparing to the other mole treatments.

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تأثير الحرث العميق علي إنتاجية الأراضي الطينية المندمجة.

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الملخص العربي

أجريت تجربة حقلية في أراضي طينية مندمجة في محطة البحوث الزراعية بالجميزة محافظة الغربية وذلك لتقييم كفاءة استخدام الحرث العميق للتربة علي عمقي ٣٠ ، ٦٠ سم بإنشاء أنفاق متوازية أو شبكية علي أبعاد مختلفة (٢ ، ٤ ، ٦ متر) كوسيلة لحل مشاكل هذه الأراضي وزيادة إنتاجيتها خلال موسمين زراعيين متتاليين .

أوضحت النتائج المتحصل عليها زيادة معدل استهلاك الوقود بنسبة ٢٣% بزيادة عمق الحرث، كما زاد استهلاك الطاقة من ٤١,٣١ إلي ٤٩,٣٦ كيلووات بزيادة عمق الحرث من ٣٠ إلي ٦٠ سم، كما أدت هذه المعاملات إلي زيادة نسبة الانزلاق. وانخفضت قيم مقاومة الأرض للاختراق بزيادة عمق الحرث ونقص المسافة بين الأنفاق وكذلك في حالة الأنفاق الشبكية.

ولقد أدت معظم المعاملات إلي زيادة المحصول ومكوناته معنويا في موسمي الدراسة مقارنة بالأراضي غير المعاملة حيث أدي الحرث العميق إلي زيادة محصول الذرة الشامية في الموسم الأول بحوالي ١٨,٤ و ٣٦,٤% على التوالي ومحصول الشعير في الموسم الثاني بحوالي ٢٧,٨٨ و ٦٧,٢٧% على التوالي لمعاملتي الحرث علي عمق ٣٠ ، ٦٠ سم .

وتفوقت الأنفاق الشبكية علي الأنفاق المتوازية في موسمي الدراسة ولكن إذا تساوي عدد الأنفاق في وحدة المساحة فإنه لا توجد فروق محسوسة بين كلا من الأنفاق الشبكية والأنفاق المتوازية من حيث تأثيرها علي المحصول ومكوناته.

كما أدى إنشاء الأنفاق علي أبعاد ٢ ، ٤ ، ٦ متر إلي زيادة المحصول ومكوناته حيث كانت الزيادة في محصول حبوب الذرة الشامية في الموسم الأول ٣٤,٠٠ ، ٢٥,٦٠ ، ٢٢,٨٠% على التوالي، ومحصول الشعير في الموسم الثاني ٦٣,٦٤ ، ٦٤,٠٦ ، ٣٣,٣٣ % على التوالي .

وأوضحت النتائج أن معاملة الحرث على عمق ٦٠ سم بإنشاء أنفاق شبكية علي مسافة ٢ متر قد أعطت أفضل النتائج من حيث المحصول ومكوناته.

ويشير التحليل الاقتصادي إلي تفوق معاملة الحرث علي عمق ٦٠ سم بإنشاء أنفاق شبكية علي مسافة ٢ متر مقارنة بالأنواع الأخرى حيث أنها أعطت اكبر عائد اقتصادي .