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EFFECT OF DEEP PLOWING ON IMPROVING SOME SOIL PHYSICAL AND CHIMICAL PROPERTIES OF COMPACTED CLAYEY SOILS.

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ABSTRACT: *Two successive cultivation seasons were conducted in a field experiment at El-Gemmeiza Agricultural Research Station (El-Gharbia Governorate) to evaluate the suitability of deep plowing at 30 and 60 cm depth, in two mole patterns (parallel or cross moles) at three spacings (2, 4 and 6 m) for improving soil physical, hydro physical and chemical properties of compacted clayey soils.*

The results indicated that almost all mole treatments led to a significant decrease in soil bulk density, settling percentage, soil moisture content and water consumption, and significant increase in total soil porosity, hydraulic conductivity and water use efficiency comparing with the control (without moling), where deep tillage either 30 or 60 cm plow depth lower soil bulk density, settling percentage, soil moisture content and water consumption and increase total soil porosity, hydraulic conductivity and water use efficiency.

The mean values of the data obtained in all seasons under study showed that the moles at 2, 4 and 6 m spacing clearly decrease bulk density, settling percentage, soil moisture content and water consumption, and magnified total porosity, hydraulic conductivity and water use efficiency. Furthermore all treatments increased leaching the soluble salts and decrease EC and SAR values.

The crossed moles were better during the two seasons since they decreased bulk density, settling percentage, soil moisture content, water consumption, EC, SAR and total soluble salts and increased total porosity, hydraulic conductivity and water use efficiency as compared with the achieved by parallel ones.

The superiority of treatment was 60 cm plow depth with crossed moles at 2 m spacing since it gave the lowest values of bulk density, settling percentage, soil moisture content, water consumption, EC, SAR and total soluble salts and it gave the highest values of total porosity, hydraulic conductivity and water use efficiency.

Key Words: *Deep plow, mole pattern, compacted clayey, physical properties.*

INTRODUCTION

In Egypt, there are about 2 million feddans of heavy textured soils in Nile Delta which suffer from the presence of a dense layers and clay pan (El-Mowelhi *et al.* 1982 and Hamdi *et al.* 1968).

In the Middle Delta, at El-Gemmeiza Agricultural Research Station, soil leveling operations as well as the agromechanical practices starting from seeding until harvesting the crops are in progress. Yet a poor and stunted plants are observed in the area. The reduction in crop yields could possibly be ascribed to the soil compaction that can be induced by adapting the heavier vehicles and agro mechanical operations for long periods.

The improvement of heavy clay soils can be achieved by drainage and sub-soiling technique (Bailey, 1978 and Takahashi *et al.* 1978). It is important to detect the optimum drainage spacing, depth and distance between sub-soiling channels.

On the other hand, drainage installation for leaching purpose will only be fully successful if they permit the uniform leaching of soluble salts from the whole soil profile.

Cassel (1980) reported that deep ploughing improved the physical properties of compacted alluvial soils at 39-70 cm depth such as bulk density, maximum water capacity and the distribution of water reserves in the soil profile.

Burghardt and Hugenbusch (1982) showed that deep ploughing of the soil up to 70-100 cm, results in the formation of soil cracks which greatly improve aeration of the soil facilitating shrinkage of the clods and therefore settlement of the bog. They added that with increasing shrinkage, the both soil shear resistance and hydraulic conductivity of the soil increased.

Kaoud (1994) compared two tillage practices namely conventional (up to 30 cm) and deep plough (up to 60 cm). He showed that the changes in soil property especially bulk density within the surface soil layer (30 cm) were prominent in response to the two tillage practices. He added that the overall decrease in bulk density of that layer was 7.8 and 3.4% as a result of deep and conventional tillage when compared to the initial bulk density value. He concluded that changes in bulk density within the soil layer (30-60cm) showed a pronounced effect as a result of both tested tillage treatments. Since the reduction in bulk density in comparison with the initial value was estimated by 12.5 and 11.8% for deep and conventional tillage respectively.

Abou-El-Soud *et al.* (1996) reported that in the majority of cases, decreasing the mole spacing to 2 m doubled basic infiltration rate and obviously promoted salt leaching from soil profile under different crops. The mean values of the data obtained in all seasons under this study showed that installation of moles at 2, 4, and 6 m spacing clearly magnified basic infiltration rate in soil by 167.5, 135.0 and 52.5%, respectively comparing to the control. They added that the crossed moles were better during all seasons since they increased water infiltration rate of soil by 33% as compared with that achieved by the parallel ones.

Shetawy (2001) evaluated the effect of the machine design feature, the drain depth and the drain space parameters on moisture distribution, the soil strength, the crop yields and the coast of the deep plowing operations. He reported that following the moisture content distribution showed that the soil between 150 cm drain space which tilled by (S_2) subsoilr at 60 cm depth exhibited the higher drain factor values, as well as exhibited more homogeneously moisture distribution through the soil profile.

Hamdi *et al.* (1963) showed that deep ploughing generally increased the infiltration rate more than shallow ploughing. They cleared that, this may be due to the higher soil porosity and less soil compactness obtained by deep ploughing.

Nitant *et al.* (1995) reported that tillage operations (under 40 cm depth) reduced water and nutrient losses through weed uptake, enhanced profile water storage improved soil properties and suppressed weed growth. They compared some deep tillage operations (under 40 depth) with other shallow tillage operations (up to 20 cm depth). They found that deep tillage operations were superior to shallow tillage treatments, and deep tillage with sub-soiling Chisel also induced deeper root penetration by 34 and 39 cm more than the shallow tillage treatment.

Richard (1990) reported that salt balance in irrigated areas is maintained by applying enough water in excess of crop needs to leach soluble salts. Hence subsurface drainage (0.6 m depth in mineral soils) may be adequate to permit the necessary leaching and to hold the water table to a sufficient depth, preventing the upward movement of salty capillary water from reaching the crop root zone.

El-Sabry *et al.* (1992) found that the superiority of treatment was 3m spacing comparing with the other treatments (6, 8 and 12 m spacing). Furthermore all treatments increased leaching of soluble salts and decreased SAR values comparing with the control (without moling).

Abou-El-Soud *et al.*(1996) reported that the data obtained in all seasons under this study that installation of moles at 2, 4 and 6 m spacing decreased ECe values by 40.5, 41.1 and 33%, respectively comparing to the control. The crossed moles were better during all seasons since they decreased ECe by about 8% as compared with that achieved by the parallel ones.

The objective of this investigation is to find out the best effective practice for management of compacted clayey soil. This practice is to use deep plowing at 30 and 60 cm depth in two patterns (parallel and crossed moles) with different spacing apart (2, 4 and 6 m) along with the control (without moling), in relation to there effects on improving soil physical, hydro physical and chemical properties.

MATERIALS AND METHODS

Two successive field experiments were carried out at an area of 3 feddans of compacted clayey soils at El-Gemmeiza Agricultural Research Station (El-Gharbia Governorate) for two seasons, summer season 2001 using maize plants (*Zea mays*) and winter season 2001/2002 using barley plants (*Hordum vulgare*) to study the effect of deep tillage at 30 and 60 cm depth, in two mole patterns (parallel and cross) at three spacings (2, 4 and 6 m) as well as the control (untreated soil) on improving soil physical, hydro physical and chemical properties of the soil. Soil properties of the experimental soil are presented in Table (1).

The studied soil is very slowly permeable mainly because of a dense clayey layer at 30- 60 cm depth, which contains more than 40% clay and has a higher bulk density of 1.57 g cm^{-3} and a lower hydraulic conductivity of 0.25 cm hr^{-1}. The soil have ECe 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 area of the experiment was divided into 39 plots using a randomized complete block design with three replicates. The area of each plot was 323 m^2.

Table (1): Some physical and chemical properties of the used soil.

Properties	Values		
Soil depth, cm	0-20	20-40	40-60
PH, 1 :2.5 (suspension)	7.86	7.89	7.92
EC_e, dSm^{-1}	6.62	6.75	6.89
Soluble cations, meq l^{-1}			
Ca^{2+}	12.91	13.79	13.35
Mg^{2+}	20.83	21.54	21.13
Na^{+}	40.67	43.27	44.61
K^{+}	0.15	0.13	0.10
Soluble anions, meq l^{-1}			
CO_3^{2-}	0.75	0.75	0.79
HCO_3^{-}	4.01	5.26	6.76
Cl^{-}	48.00	49.13	50.19
SO_4^{2-}	21.80	23.59	21.45
Particle size distribution			
Sand, %	26.55	26.29	30.74
Silt, %	30.13	29.56	28.83
Clay, %	43.32	44.15	40.43
Texture class	clayey	clayey	clayey
Bulk density (Db) g/cm^3	1.45	1.57	1.52
Total porosity	45.28	40.75	42.64
Kh, cm hr^{-1}	0.27	0.25	0.23
$CaCO_3$, %	3.35	3.21	2.97
O.M., %	2.17	1.76	1.66

In summer season 2001 seeds 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 2001/2002 seeds of barley (*Hordum vulgare 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.

Undisturbed soil samples at (0 - 20 cm), (20 - 40 cm) and (40 - 60 cm) depths were collected from each plot at the end of each growing season to determine some physical and hydrophysical properties of soil. Soil bulk density (Db) was determined using the core method (Vomocil, 1986). Total porosity (E, %) was calculated for the different treatments according to the equation:

$$E = \left(1 - \frac{Db}{Dr}\right) \times 100$$, where Dr is the real density, taken as 2.65 g/cm^3.

Three replicates of hydraulic conductivity (Kh, cm hr^{-1}) were determined using a constant water head (Black, 1965). Soil moisture content (θw, %) was determined according to Richards (1954). Settling percentage of the soil aggregates was determined in soil aggregates of 2-5 mm size at the same depths by the method described by Willams and Cook (1961) and Harteg (1969).

Soil samples for determining the water consumptive use were taken just before and 2 days after of each irrigation and at the harvesting time from three replicates of each treatment at 0-20, 20-40 and 40-60 cm depths for soil moisture determination (Garcia, 1978). Water consumption (CU) and water use efficiency (WUE) for a given irrigation cycle for every layer of the soil profile were calculated for the different treatments using the following formula:

$$\text{Water consumption (cm)} = \frac{\theta a - \theta b}{100} \times Db \times D$$ (Israelson and Hansen,1962)

where: θa = Soil moisture percentage on weight basis after irrigation.

θb = Soil moisture percentage on weight basis before irrigation.

Db = Bulk density (g cm^{-3})

D = Soil depth (cm)

$$\text{Water use efficiency}(\text{kg fed}^{-1}\text{cm}^{-1}) = \frac{\textit{Seed yield } (kg/fed)}{\textit{Water consumption } (cm)}$$ (Jensen, 1983)

Soil samples (0-30cm) and (30-60cm) were collected from each field treatment plot in each season after crop harvesting. The collected soil samples were air-dried, ground and passed through 2 mm sieve and stored for chemical analysis.

Soil electrical conductivity (EC) in soil paste extract and soil pH in soil water suspension (1: 2.5) were measured. Soluble cations and anions were determined in soil paste extract using the methods described by Page *et al.* (1982).

Sodium Adsorption Ratio (SAR) was calculated as:

$$SAR = \frac{Na\ meq/l}{\sqrt{\frac{Ca+Mg\ meq/l}{2}}}$$

Total soluble salts, % were calculated according to the following equation:

$$T.S.S.,\% = \frac{EC\ dSm^{-1} \times 0.064 \times SP}{100}$$

where: SP = Saturation percentage

The collected data were statistically analyzed based on the method of Snedecor and Cochran (1981).

RESULTS AND DISCUSSION

I- Effects on some physical and hydrophysical properties of soil.

1- Soil bulk density (Db) and total soil porosity (E)

Data in Tables (2 and 3) and Figs. (1 and 2) show that almost all mole treatments led to a significant decrease in soil bulk density and significant increase in total soil porosity of the three sequence soil depths (0-20, 20-40 and 40-60 cm) at the end of the two seasons comparing to the control (untreated soil).

Deep tillage tended to lower soil bulk density and increase total soil porosity. The 60 cm plow depth decreases (Db) by 11.72, 13.38 and 7.89%, respectively over the control (untreated soil) for the three depths in the first season while it was decreased by 10.35, 12.74 and 7.84%, respectively at the same depths in the second one, while the 30cm plow depth decreases (Db) by 10.34, 11.46 and 1.32%, respectively for the three depths in the first season and it was decreased by 9.66, 10.83 and 1.31%, respectively for the same depths in the second one.

Total porosity take the opposite direction, where it was increased by 14.57, 19.61 and 10.34%, respectively over the control for the three depths in the first season and by 12.90, 18.85 and 10.44%, respectively at the same depths at the second one for 60 cm plow depth. The 30cm plow depth increased it by 10.35, 11.47 and 1.32 %, respectively for the three depths in the first season and by 11.37, 15.46 and 1.94 %, respectively for the same depths in the second one.

Concerning the mole pattern, data show that the crossed moles were significantly better than parallel ones in the two seasons on decreasing soil bulk density and increasing total soil porosity. The decrease in bulk density was 13.10, 14.01 and 5.26%, respectively over the control for the three depths

Table (2) : Effect of different mole treatments on some soil physical and hydrophysical properties in the first season (summer season 2001)

Plow depth, cm	Mole pattern	Mole space, m	Db, gm/cm^3			E, %			Settling, %			Kh cm/hr			Soil moisture content (Θw),%, just before harvesting			Water consumption, cm	Water use efficiency, kg fed^{-1} cm^{-1}
			0-20cm	20-40cm	40-60cm	0-20cm	20-40cm	40-60cm	0-20cm	20-40cm	40-60cm	0-20cm	20-40cm	40-60cm	0-20cm	20-40cm	40-60cm		
30	P*	2	1.26	1.36	1.50	52.45	48.68	43.39	16.92	17.64	18.35	0.45	0.44	0.42	20.87	23.04	25.47	105.64	28.37
		4	1.31	1.43	1.51	50.57	46.04	43.02	19.86	20.90	21.94	0.39	0.38	0.36	21.15	24.88	28.23	103.90	27.41
		6	1.39	1.45	1.51	47.55	45.29	43.02	21.97	22.55	23.13	0.27	0.26	0.25	21.38	25.05	28.74	105.88	26.22
	C**	2	1.24	1.34	1.49	53.21	49.43	43.77	14.85	15.80	16.74	0.47	0.46	0.45	20.12	22.82	24.06	102.32	29.81
		4	1.27	1.37	1.50	52.07	48.30	43.40	15.12	16.75	18.37	0.46	0.45	0.43	20.74	22.91	24.45	104.32	28.27
		6	1.30	1.39	1.50	50.94	47.55	43.40	18.88	19.77	20.65	0.36	0.35	0.33	20.97	24.82	28.15	102.79	27.94
60	P*	2	1.25	1.33	1.37	52.83	49.81	48.30	8.36	8.83	9.29	0.68	0.66	0.64	12.87	19.24	23.34	88.10	39.12
		4	1.30	1.39	1.44	50.94	47.54	45.66	11.04	12.14	13.24	0.58	0.56	0.54	13.09	19.99	24.11	93.67	34.46
		6	1.33	1.42	1.47	49.81	46.42	44.53	12.95	14.42	15.89	0.49	0.47	0.45	16.75	20.23	24.13	103.11	30.56
	C**	2	1.22	1.29	1.34	53.96	51.32	49.44	4.19	5.07	5.94	0.94	0.92	0.90	12.71	18.92	22.97	82.81	43.15
		4	1.26	1.36	1.39	52.45	48.68	47.55	6.31	6.79	7.27	0.69	0.67	0.65	12.75	19.23	23.11	88.91	38.31
		6	1.29	1.36	1.41	51.32	48.68	46.79	10.25	10.69	11.13	0.56	0.54	0.52	12.94	19.58	23.87	86.95	38.27
Control			1.45	1.57	1.52	45.29	40.75	42.64	23.17	23.64	24.11	0.27	0.25	0.22	23.03	19.56	31.77	114.84	21.86
A. Plow depth	30 cm		1.30	1.39	1.50	51.13	47.55	43.33	17.93	18.90	19.86	0.40	0.39	0.37	20.87	23.92	26.52	104.14	28.00
	60 cm		1.28	1.36	1.40	51.89	48.74	47.05	8.85	9.66	10.46	0.66	0.64	0.62	13.52	19.53	23.59	90 59	37.31
	F - test		4.51*	11.56**	112.66**	4.50*	11.56**	112.74**	1138.75**	2405.34**	1399.72**	691.27**	1464.99**	877.85**	581.18**	160.65**	88.19**	232.88**	191.50**
	L.S.D $_{0.05}$		0.02	0.02	0.02	0.73	0.71	0.73	0.56	0.39	0.52	0.02	0.01	0.02	0.63	0.71	0.64	1.83	1.39
B. Mole pattern	P*		1.31	1.40	1.47	50.69	47.30	44.65	15.18	16.08	16.97	0.48	0.46	0.44	17.69	22.07	25.67	100.05	31.02
	C**		1.26	1.35	1.44	52.33	48.99	45.73	11.60	12.48	13.35	0.58	0.57	0.55	16.71	21.38	24.44	94.68	34.29
	F - test		21.16**	23.34**	9.35**	21.17**	23.35**	9.39**	177.22**	365.53**	207.82**	112.04**	252.53**	158.31**	10.32**	3.99^{NS}	15.69**	36.53**	23.57**
	L.S.D $_{0.05}$		0.02	0.02	0.02	0.73	0.71	0.73	0.56	0.39	0.52	0.02	0.01	0.02	0.63	0.71	0.64	1.83	1.39
C. Mole space	2		1.24	1.33	1.43	53.11	49.81	46.23	11.08	11.84	12.58	0.64	0.62	0.60	16.64	21.01	23.96	94.72	35.11
	4		1.29	1.39	1.46	51.51	47.64	44.91	13.08	14.15	15.21	0.53	0.52	0.50	16.93	21.75	24.98	97.70	32.11
	6		1.33	1.41	1.47	49.91	46.99	44.44	16.01	16.86	17.70	0.42	0.41	0.39	18.01	22.42	26.22	99.68	30.75
	F - test		27.14**	23.66**	9.42**	27.14**	23.67**	9.42**	113.25**	237.61**	138.35**	161.71**	361.63**	228.44**	7.44**	5.57*	17.61**	10.56**	14.69**
	L.S.D $_{0.05}$		0.02	0.02	0.02	0.90	0.87	0.90	0.68	0.48	0.64	0.02	0.02	0.02	0.77	0.88	0.79	2.24	1.70

P* = Parallel mole pattern

C** = Cross mole pattern

Table (3) : Effect of different mole treatments on some soil physical and hydrophysical properties in the second season (winter season 2001/2002)

Plow depth, cm	Mole pattern	Mole space, m	Db, gm/cm³			E, %			Settling, %			Kh cm/hr			Soil moisture content (Θw),%, just before harvesting			Water consumption, cm	Water use efficiency, kg fed⁻¹ cm⁻¹
			0-20cm	20-40cm	40-60cm	0-20cm	20-40cm	40-60cm	0-20cm	20-40cm	40-60cm	0-20cm	20-40cm	40-60cm	0-20cm	20-40cm	40-60cm		
30	P*	2	1.28	1.39	1.50	51.70	47.55	43.40	17.54	18.21	18.87	0.41	0.40	0.39	26.17	28.37	32.12	16.43	134.69
		4	1.34	1.42	1.52	49.43	46.41	42.64	20.06	18.12	22.17	0.34	0.33	0.31	28.59	29.09	33.44	17.43	117.61
		6	1.41	1.46	1.53	46.79	44.91	42.26	22.30	22.88	23.46	0.24	0.23	0.22	28.01	31.56	33.62	23.08	81.24
	C**	2	1.26	1.36	1.49	52.45	48.68	43.77	15.20	16.28	17.35	0.45	0.43	0.41	25.66	28.19	29.12	13.94	161.41
		4	1.28	1.39	1.50	51.70	47.55	43.40	15.47	17.13	18.78	0.42	0.41	0.40	26.15	28.23	30.86	16.36	134.78
		6	1.31	1.40	1.51	50.57	47.17	43.02	19.23	20.27	21.31	0.31	0.30	0.29	26.54	29.07	32.73	16.83	124.90
60	P*	2	1.27	1.34	1.38	52.08	49.43	47.92	8.62	9.09	9.55	0.63	0.62	0.61	18.73	22.15	27.19	12.84	227.03
		4	1.33	1.40	1.45	49.81	47.17	45.28	11.14	12.40	13.65	0.52	0.51	0.50	22.75	27.45	28.75	13.27	181.01
		6	1.35	1.44	1.48	49.06	45.66	44.15	13.26	14.84	16.41	0.44	0.43	0.42	23.70	28.18	29.07	13.34	172.19
	C**	2	1.23	1.30	1.36	53.58	50.94	48.68	4.51	5.32	6.12	0.89	0.88	0.87	16.98	21.62	22.15	8.58	360.71
		4	1.27	1.35	1.39	52.08	49.06	47.55	6.53	6.98	7.42	0.64	0.63	0.62	17.98	21.98	19.23	11.25	255.38
		6	1.32	1.37	1.42	50.19	48.30	46.42	10.86	11.16	11.46	0.50	0.49	0.47	20.74	27.28	28.72	13.24	201.44
Control			1.45	1.57	1.53	45.29	40.75	42.26	23.69	24.26	24.62	0.27	0.25	0.23	28.58	21.97	33.86	24.40	67.66
A. Plow depth	30 cm		1.31	1.40	1.51	50.44	47.05	43.08	18.30	18.62	20.32	0.36	0.35	0.34	26.52	29.09	31.98	17.35	125.77
	60 cm		1.30	1.37	1.41	51.13	48.43	46.67	9.15	9.97	10.77	0.60	0.59	0.58	20.15	24.78	25.85	12.09	232.96
	F - test		4.27*	11.84**	105.07**	4.26*	11.86**	104.97**	1493.73**	303.73**	1976.93**	802.87**	1397.45**	1223.15**	403.20**	181.50**	547.37**	123.39**	160.88**
	L.S.D 0.05		0.02	0.02	0.02	0.69	0.82	0.72	0.49	1.05	0.54	0.02	0.01	0.02	0.66	0.66	0.54	0.98	17.44
B. Mole pattern	P*		1.33	1.41	1.48	49.81	46.86	44.28	15.49	15.92	17.35	0.43	0.42	0.41	24.33	27.80	30.70	16.07	152.30
	C**		1.28	1.36	1.45	51.76	48.62	45.47	11.97	12.86	13.74	0.54	0.52	0.51	22.34	26.06	27.14	13.37	206.44
	F - test		33.89**	19.18**	11.67**	33.91**	19.19**	11.66**	221.22**	36.44**	282.35**	149.28**	249.72**	210.62**	39.14**	29.55**	184.96**	32.49**	41.05**
	L.S.D 0.05		0.02	0.02	0.02	0.69	0.82	0.72	0.49	1.05	0.44	0.02	0.01	0.02	0.66	0.66	0.54	0.98	17.44
C. Mole space	2		1.26	1.35	1.43	52.45	49.15	45.94	11.47	12.23	12.97	0.60	0.58	0.57	21.89	25.08	27.65	12.95	220.96
	4		1.31	1.39	1.47	50.76	47.55	44.72	13.30	13.66	15.51	0.48	0.47	0.46	23.37	26.69	28.07	14.58	172.20
	6		1.35	1.42	1.49	49.15	46.51	43.96	16.41	17.29	18.16	0.37	0.36	0.35	24.75	29.02	31.04	16.62	144.94
	F - test		32.41**	14.61**	10.90**	32.41**	14.58**	10.89**	148.78**	35.26**	194.32**	224.20**	377.36**	328.81**	27.19**	51.18**	66.24**	20.18**	27.69**
	L.S.D 0.05		0.02	0.03	0.02	0.85	1.01	0.89	0.60	1.28	0.54	0.02	0.02	0.02	0.80	0.81	0.66	1.20	21.36

P* = Parallel mole pattern

C** = Cross mole pattern

in the first season, while it was 11.72, 13.38 and 5.23%, respectively at the same depths in the second one. The parallel moles decreased bulk density by 9.66, 10.83 and 3.29%, respectively for the three depths in the first season while it was 8.28, 10.19 and 3.27%, respectively at the same depths in the second one.

Total porosity take the opposite trend, where it was increased by 15.54, 20.22 and 7.25%, respectively over the control for the three depths in the first season and by 14.29, 19.31 and 7.60%, respectively at the same depths in the second one, for crossed moles. while the parallel ones increased it by 11.92, 16.07 and 4.71%, respectively for the three depths in the first season and by 9.98, 14.99 and 4.78 %, respectively for the same depths in the second one.

In regard to mole spacings, data clear that the superiority was with closer mole spacing on decreasing soil bulk density and increasing total soil porosity. Bulk density were obviously decreased by decreasing the mole spacing from 6 to 2 m in the two seasons. It was decreased by 13.10, 15.29 and 5.92%, respectively for the three depths in the first season while it was decreased by 13.10, 14.01 and 6.54%, respectively at the same depths in the second one for 2 m spacing. Also, it was decreased by 11.03, 11.47 and 3.95%, respectively for the three depths in the first season while it was 9.66, 11.46 and 3.92%, respectively at the same depths in the second one for 4 m spacing. In case of 6 m spacing the decrease was 8.28, 10.19 and 3.29%, respectively for the three depths in the first season and it was 3.45, 9.55 and 2.61%, respectively at the same depths in the second one.

Total porosity tended to take the opposite trend where it was increased by 17.27, 22.23 and 8.42 %, respectively over the control for the three depths in the first season and by 15.81, 20.61 and 8.71%, respectively at the same depths in the second one for 2 m spacing. In case of 4 and 6 m spacings the increases of total porosity take the same trend.

Regarding the combined effect the results revealed that the 60 cm plow depth with crossed moles at 2 m spacing was the best treatments since it induced the lowest value of bulk density 1.22, 1.29 and 1.34 g cm^{-3}, respectively for the three depths in the first season while it was 1.23, 1.30 and 1.36 g cm^{-3}, respectively at the same depths in the second one.

Total porosity take the opposite, where the highest value was 53.96, 51.32 and 49.44%, respectively for the three depths in the first season while it was 53.58, 50.94 and 48.68%, respectively at the same depths in the second one.

These results agree with that obtained by Cassel (1980), Kaoud (1994), Laddha and Totawat (1997) and Meharban *et al.*(1998). They reported that deep tillage decreased soil bulk density and penetration resistance up to the tilled depth of 40 cm and encourage water extraction more from deeper soil layers.

2- Structural stability (Settling percentage)

As an aspect of structural stability, the percentage of settling of the soil aggregates were determined. The low value of settling % indicates high degree of structure stability and vice versa. Results in Tables (2 and 3) indicate that the effect of all mole treatments on soil structure stability was obvious. The lowest value of settling % (i.e. higher degree of soil structure stability) was resulted under deep tillage, where the 60 cm plow depth treatments gave the lowest value which were 8.85, 9.66 and 10.46%, respectively for the three sequence layer depths (0-20, 20-40 and 40-60 cm) in the first season, while it was 9.15, 9.97 and 10.77%, respectively at the same depths in the second one. Using the 30 cm plow depth gave the mean values 17.93, 18.90 and 19.86%, respectively for the three depths in the first season, while it was 18.30, 18.82 and 20.32%, respectively at the same depths in the second one. The highest value of settling % (i.e. lower degree of soil structure stability) was obtained from the control (untreated soil) where the mean value was 23.17, 23.64 and 24.11%, respectively for the three depths in the first season, while it was 23.69, 24.26 and 28.58%, respectively at the same depths in the second one.

With regard to the mole pattern, data reveal that the crossed moles were significantly better than parallel ones in the two seasons. The mean values were 11.60, 12.48 and 13.35%, respectively for the three depths in the first season, while it was 11.97, 12.86 and 13.74%, respectively at the same depths in the second one. The parallel moles mean values were 15.18, 16.08 and 16.97%, respectively for the three depths in the first season while it was 15.49, 15.92 and 17.35%, respectively at the same depths in the second one.

Concerning the mole spacings, data show that by decreasing the mole spacing from 6 to 2 m the values of settling were decreased in the two seasons at all layer depths. The mean values were 11.08, 12.58 and 12.58 %, respectively for the three depths in the first season while it was 11.47, 12.23 and 12.97 %, respectively at the same depths in the second one, for 2 m spacing. In case of 4 m spacing the mean values was 13.08, 14.15 and 16.93%, respectively for the three depths in the first season and it was 13.30, 13.66 and 15.51 %, respectively at the same depths in the second one. Also it was 16.01, 16.86 and 17.70 %, respectively in the first season and it was 16.41, 17.29 and 18.16%, respectively in the second one at the three depths for 6 m spacing.

With regard to the combined effect data indicate that the best treatment was 60 cm plow depth with crossed moles at 2 m spacing since it gave the lowest value of settling percentage where the mean values were 4.19, 5.07 and 5.94 %, respectively in the first season and it was 4.51, 5.32 and 6.12%, respectively in the second one at the three layer depths. The improvement effect of these treatments on soil structure as judged from decreasing settling percentage may be attributed to the formation of water stable aggregates as a result of root exudates, root growth and decay.

3- Soil hydraulic conductivity:

Water movement in soils is a sensitive soil property to the measure of subsoil compactness. That is because soil saturated hydraulic conductivity and soil infiltration characteristics are supposed to be increased with the presence of wide and continuous pores. Thus their values are affected by any factors that affected the soil porosity such as deep tillage operations. Results in Tables (2 and 3) and Figs. (3 and 4) show that all mole treatments indicated progressive increase in soil hydraulic conductivity (Kh) of the three sequence depths (0-20, 20-40 and 40-60 cm) at the end of the two seasons comparing to the control (untreated soil). Deep tillage caused a gradual increase in hydraulic conductivity where the 60 cm plow depth increase it by 144.44, 156.00 and 181.82%, respectively for the three depths in the first season while it was 122.22, 136.00 and 152.17%, respectively at the same depths in the second one. The 30 cm plow depth increased it by 48.15, 56.00 and 68.18%, respectively for the three depths in the first season and by 33.33, 40.00 and 47.83%, respectively at the same depths in the second one.

Regarding mole pattern, data presented in Tables (2 and 3) and Figs. (3 and 4) indicate that the crossed moles significantly increased hydraulic conductivity more than the parallel ones in the two seasons at the three layer depths. The increases were 114.81, 128.00 and 150.00%, respectively for the three depths in the first season and were 100.00, 108.00 and 121.74%, respectively at the same depths in the second one. The parallel moles increased hydraulic conductivity by 77.78, 84.00 and 100.00%, respectively in the first season and by 59.26, 68.00 and 78.26%, respectively in the second one for the three layer depths.

Concerning the mole spacings, it can be noticed that decreasing the distance between the moles lead to an increase in soil hydraulic conductivity where the 2 m spacing increased it by 137.04, 148.00 and 172.73 %, respectively at the three layer depths in the first season and by 122.22, 132.00 and 147.83%, respectively at the same depths in the second one. Also it was increased by 96.30, 108.00 and 127.27%, respectively in the first season, while it was 77.78, 88.00 and 100.00%, respectively in the second one in the three layer depths for 4 m spacing. In case of 6 m spacing the increase was 55.56, 64.00 and 77.27%, respectively at the three depths in the first season and by 37.04, 44.00 and 52.17%, respectively at the same depths in the second one.

With regard to the combined effect, data showed that the 60 cm plow depth with crossed moles at 2 m spacing was the best treatment since it gave the highest value of hydraulic conductivity 0.94, 0.92 and 0.90 cm hr^{-1} respectively at the three depths in the first season while it was 0.89, 0.88 and 0.87 cm hr^{-1} respectively at the same depths in the second one.

These results show that the adequate moling and/ or effective drainage system enhances removing the excess free water and salts from the soil profile and also in a such a way to led the swelling and shrinkage processes,

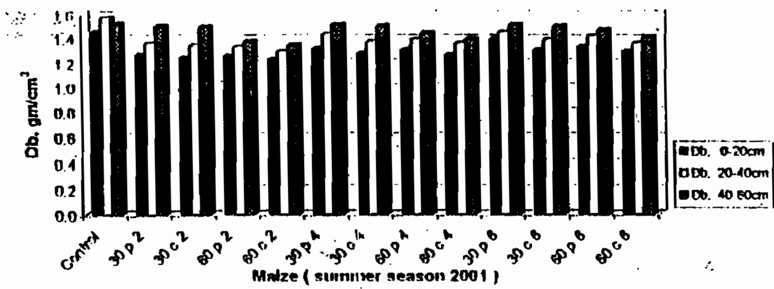

Fig.(1): Bulk density (Db, gm/cm3) in the first season as affected by different treatments.

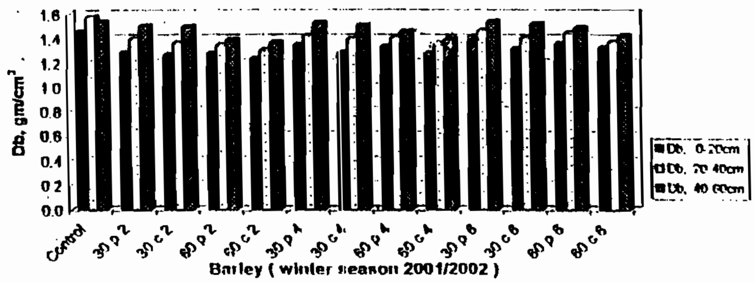

Fig.(2): Bulk density (Db, gm/cm3) in the second season as affected by different treatments.

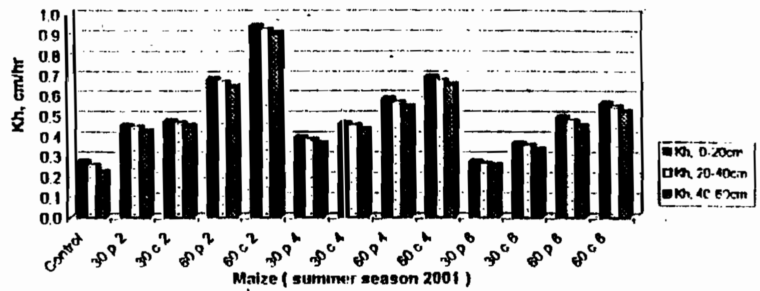

Fig.(3): Hydraulic conductivity (Kh, cm/hr) in the first season as affected by different treatments.

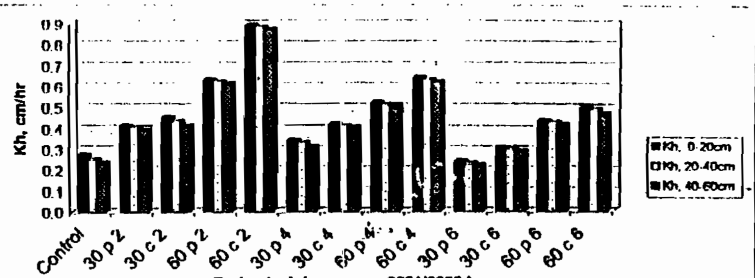

Fig.(4): Hydraulic conductivity (Kh, cm/hr) in the second season as affected by different treatments.

the cracks were formed and consequently the hydraulic conductivity of soil increased (El-Sabry *et al.*, 1992).

These results are in general agreement with those reported by Burghadt and Hugenbuch (1982) and Mielk *et al.* (1984) who pointed out that hydraulic conductivity for sub-tillage at 229 - 305 mm depth was almost from 2 to 4 times greater than no sub-tillage treatment. Also, similar results had been obtained by El-Sabry *et al.* (1992) who stated that the superiority of treatment was 3 m spacing comparing with the other treatments (6, 8 and 12 m) on increasing hydraulic conductivity comparing with the control (without moling).

4- Soil moisture content (θw, %):

The moisture content distribution data provided strong evidence for both lateral and deeply movement of drain water in each tilled sector.

Moreover the recorded data in Tables (2 and 3) were compared with respect to the effect of mole depth parameter. It can be seen that, as the mole depth increase, the moisture content decrease, where the 60 cm plow depth treatment gave the lowest value which were 13.52, 19.53 and 23.59%, respectively for the three sequence layer depths (0-20, 20-40 and 40-60 cm) in the first season, while it was 20.15, 24.78 and 25.85%, respectively at the same depths in the second one. In case of 30 cm plow depth, the mean values were 20.87, 23.92 and 26.52%, respectively for the three depths in the first season, while it was 26.52, 29.09 and 31.98%, respectively at the same depths in the second one.

With respect to mole pattern, it can be seen that the crossed moles were better than the parallel ones in decreasing soil moisture content in the two seasons, where the mean values were 16.71, 21.38 and 22.44%, respectively in the first season and 22.34, 26.06 and 27.14%, respectively in the second one at the three depths. The parallel moles mean values were 17.69, 22.07 and 25.67%, respectively in the first season and were 24.33, 27.80 and 30.70%, respectively in the second one at the three depths.

With regard to the mole spacings data show that the lowest moisture content values are in favor with the narrow mole spaces, where the 2 m spacing show the lowest values. The mean values were 16.64, 21.01 and 22.96%, respectively at the three depths in the first season, while it was 21.89, 25.08 and 27.65%, respectively at the same depths in the second one. By increasing mole spacings from 2 to 6 m, the values were increased where it reached to 18.01, 22.42 and 26.22%, respectively in the first season and 24.75, 29.02 and 31.04 %, respectively in the second one at the three depths.

Concerning the combined effect, data cleared that the best treatment was 60 cm plow depth with crossed moles at 2 m spacing since it gave the lowest value of moisture content where the mean values were 12.71, 18.92 and 82.81%, respectively in the first season and were 16.98, 21.62 and 22.15%, respectively in the second one at the three layer depths. These results may be due to sub-soiling has substantially improved water and root penetration (Michael and Ojha 1981). Also, these results are confirmed with Setawy (2001).

5- Consumptive use of water (CU) and water use efficiency (WUE):

It is clear from data presented in Tables (2 and 3) that CU values for zea mays and barley were increased by decreasing plow depth. The 30 cm plow depth significantly increased CU values over the other plow depths (60 cm plow depth). The increase percentages due to plow depth comprised 14.96 and 43.51% for maize and barley respectively. These increases in CU values may be attributed to that the soil moisture under 30 cm plow depth is more subjected to crop transpiration and evaporation from the soil.

Water use efficiency is defined in the present work, as Kilograms of maize or barley seeds produced by one cm of the consumed water by maize or barley plants per feddan. Data in Tables (2 and 3) reveal that the different mole treatments significantly affected WUE for maize and barley during the two growing seasons of study, Deep tillage tended to increase WUE in the two growing seasons where the 60 cm plow depth increased it by 33.25 and 84.42% over the 30 cm plow depth in the first and second seasons, respectively. These results are in line with those reported by Meharban *et al.* (1998) who reported that deep tillage increased soil water use efficiency, and resulted in saving of 1 to 3 irrigations depending on soil texture and water stress condition. Thus, it is obvious that water use efficiency tended to decrease with the increase in water retained in the root zone.

Regarding the influence of mole pattern on CU for maize and barley, it seems that parallel moles significantly increased CU values over the crossed moles by 5.67 and 20.19% for maize and barley respectively. These increases in CU values may be attributed to that soil moisture under parallel moles is more than crossed ones as discussed before.

However, the values of WUE for maize and barley significantly increased with crossed moles over the parallel ones. The increase percentages amounted to 10.54 and 35.55% for maize and barley respectively. The most probable explanation for these above mentioned results is that the yield in all seasons positively responded to the crossed moles more than the parallel moles and the differences ranged between 11 and 15 %, (El-Abaseri *et al.*1996).

With regard to the effect of mole spacings on CU for maize and barley It noticed that increasing the mole spacings from 2 to 6 m caused a significant increase in the values of CU in the two seasons. The increase percentages due to mole spacings comprised 3.17 and 5.24%, respectively in the first season and 12.59 and 28.34%, respectively in the second one. This increase can be attributed to the increases of soil moisture content with increasing mole spacings as mentioned before.

Regarding to the effect of mole spacings on WUE for maize and barley, it seems that WUE was significantly increased by decreasing mole spacings. The increase percentages amounted to be 14.18 and 4.42 %, respectively for maize and 52.45 and 18.81%, respectively for barley. The increase in WUE by decreasing mole spacings may be attributed to the significantly increases in the yield caused by installation of moles at 2, 4 and 6 m spacing which obviously increased the relative yield, (El-Abaseri *et al.* 1996).

With regard to the combined effect, the results reveal that the 60 cm plow depth with crossed moles at 2 m spacing was the best treatment since it indicate the lowest values of CU 82.81 and 8.58 cm for maize and barley respectively and gave the highest values of WUE 43.15 and 360.71 kg fed^{-1} cm^{-1} for maize and barley, respectively as shown in Tables (2 and 3).

II- Effects on some chemical properties:

Soil reaction (pH) and soil salinity (EC):

Results in Tables (4 and 5) show that all mole treatments lead to a favorable decrease in soil reaction (pH) of the two sequence soil depths (0-30 and 30-60 cm) at the end of the two seasons comparing to the control (untreated soil). By increasing tilling depth the soil pH decrease, where the 60 cm plow depth decreased it more than the 30 cm one.

On the other hand, it is obvious that mole pattern also affects soil pH where crossed moles were better than parallel ones on decreasing soil pH of the two sequence soil depths at the end of the two seasons.

The effect of different spacings on decreasing soil pH during the two seasons at the two soil depths can be arranged in the following descending order: 2m > 4m > 6m > the control.

Concerning the combined effect of different treatments on soil pH, it could be observed that all mole treatments decreased soil pH comparing to the control. 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 lowest values of soil pH 7.64 and 7.68 respectively for the two soil layer depths in the first season and 7.40 and 7.54 respectively for the two layer depths in the second one. While the control gave the highest values 7.87 and 7.92 respectively in the first season and 7.66 and 7.71 respectively in the second one at the two layer depths.

The mole treatments in this study differed quietly in their effects on electrical conductivity of soil paste extract dSm^{-1} (EC), sodium adsorption ratio (SAR) and total soluble salts % (TSS, %) of the soil with different crops. From the data in Tables (4 and 5) and Figs.(5-8), it could be concluded that a general reduction in electrical conductivity, sodium adsorption ratio and total soluble salts concentration by increasing plow depth, and by increasing the number of mole drains per unite area. This reduction can be explained by the fact that the mole drains allow water percolated and down ward moved taking with high amount of soluble salts. It can be noticed also that the effect of

Table (4): Some soil chemical properties at surface and subsurface layers (0-30 and 30-60cm) in the first season (summer season 2001) as affected by different mole treatments .

0 - 30 cm layer														
Plow depth , cm	Mole pattern	Mole space, m	pH 1:2.5 susp.	EC dSm-1	Cations, meq/l				Anions, meq/l				SAR	TSS %
					Ca	Mg	Na	K	CO_3	HCO_3	Cl	SO_4		
30	P*	2	7.75	3.25	10.48	8.45	18.05	0.29	0.00	3.76	5.00	28.51	5.87	0.15
		4	7.80	6.22	17.66	19.72	33.87	0.29	0.00	2.26	37.50	31.78	7.83	0.26
		6	7.83	6.24	12.81	15.35	32.43	0.54	0.50	4.26	27.50	28.87	8.64	0.27
	C**	2	7.73	2.52	9.40	7.74	11.57	0.29	0.00	4.01	5.50	19.49	3.95	0.13
		4	7.64	3.16	8.70	9.08	15.26	0.36	0.00	3.51	8.13	21.76	5.12	0.15
		6	7.79	4.55	13.07	15.07	22.99	0.41	0.50	4.01	41.00	6.03	6.13	0.21
60	P*	2	7.64	1.75	7.84	3.83	7.70	0.26	0.00	4.26	4.00	11.37	3.19	0.07
		4	7.66	2.24	6.49	8.97	10.03	0.08	0.00	1.75	8.00	15.82	3.61	0.08
		6	7.83	2.41	6.65	9.06	10.79	0.27	0.75	3.76	2.25	20.01	3.85	0.09
	C**	2	7.79	1.51	5.30	4.25	6.65	0.56	0.00	5.26	3.25	8.25	3.04	0.06
		4	7.64	1.53	4.52	5.20	6.85	0.21	0.50	5.01	3.50	7.77	3.11	0.07
		6	7.66	1.77	4.52	3.94	6.63	0.67	0.00	2.26	5.75	7.75	3.22	0.08
Control			7.87	6.61	16.17	17.58	40.66	0.15	0.75	4.01	48.00	21.80	9.90	0.31
30 - 60 cm layer														
Plow depth , cm	Mole pattern	Mole space, m	pH 1:2.5 susp.	EC dSm-1	Cations, meq/l				Anions, meq/l				SAR	TSS %
					Ca	Mg	Na	K	CO_3	HCO_3	Cl	SO_4		
30	P*	2	7.76	4.78	17:35	14.30	18.85	0.94	0.00	5.91	4.13	41.40	4.74	0.17
		4	7.81	6.42	15.16	16.25	34.50	0.41	0.50	15.01	30.50	20.31	8.71	0.28
		6	7.90	6.65	17.12	15.00	35.38	0.35	0.50	4.14	37.75	25.46	8.83	0.30
	C**	2	7.75	2.84	9.40	8.00	13.02	0.36	0.00	4.91	9.75	16.12	4.41	0.15
		4	7.79	4.03	13.25	11.54	18.27	0.70	0.00	6.62	10.63	26.51	5.19	0.17
		6	7.80	5.68	19.58	14.00	25.69	0.53	0.50	5.67	13.13	40.50	6.27	0.26
60	P*	2	7.71	2.08	6.63	5.97	9.62	0.29	0.00	6.58	8.13	7.80	3.83	0.08
		4	7.73	2.33	6.52	7.31	10.44	0.72	0.00	9.58	6.25	9.16	3.97	0.11
		6	7.74	2.65	7.75	8.31	11.84	0.36	0.00	9.85	8.25	10.16	4.18	0.12
	C**	2	7.68	1.74	5.95	4.82	7.78	0.26	0.00	4.54	6.25	8.02	3.35	0.06
		4	7.69	1.87	6.36	5.87	9:10	0.26	0.00	10.74	6.88	3.97	3.68	0.07
		6	7.70	1.93	6.40	5.98	9.67	0.26	0.00	10.74	6.25	5.32	3.89	0.10
Control			7.92	6.89	14.43	15.36	40.62	0.15	0.50	5.26	43.00	21.80	10.52	0.29

P* = Parallel mole pattern

C** = Cross mole pattern

Table(5):Some soil chemical properties at surface and subsurface layers (0-30 and 30-60cm)in the second season (winter season 2001/2002) as affected by different mole treatments .

0 - 30 cm layer														
Plow depth , cm	Mole pattern	Mole space, m	pH 1:2.5 susp.	EC dSm-1	Cations, meq/l				Anions, meq/l				SAR	TSS %
					Ca	Mg	Na	K	CO_3	HCO_3	Cl	SO_4		
30	P*	2	7.61	2.53	9.00	8.32	11.60	0.36	0.00	8.32	8.13	12.73	3.91	0.07
		4	7.66	2.68	9.00	6.00	12.52	2.69	0.00	3.89	9.25	17.07	4.57	0.08
		6	7.66	3.16	11.75	8.75	15.17	0.38	0.00	6.80	13.13	16.12	4.74	0.09
	C**	2	7.57	2.06	7.35	6.25	9.70	0.29	0.00	6.80	6.25	10.54	3.72	0.06
		4	7.59	2.36	8.68	7.50	10.62	0.37	0.00	7.94	8.75	10.48	3.73	0.07
		6	7.66	2.54	9.06	7.30	12.55	0.38	0.00	7.56	8.75	12.98	4.39	0.08
60	P*	2	7.53	1.39	4.43	4.65	6.70	0.18	0.00	4.54	5.00	6.42	3.14	0.05
		4	7.56	1.81	6.23	5.80	8.64	0.31	0.00	7.58	9.13	4.27	3.52	0.06
		6	7.56	1.95	6.85	6.12	9.37	0.21	0.00	5.29	6.88	10.38	3.68	0.07
	C**	2	7.40	1.15	4.95	2.31	5.51	0.36	0.00	6.72	5.25	1.16	2.89	0.03
		4	7.50	1.50	4.74	5.35	6.83	0.18	0.00	5.29	4.75	7.06	3.04	0.04
		6	7.56	1.76	6.25	5.95	7.85	0.31	0.00	5.67	6.88	7.81	3.18	0.05
Control			7.66	5.60	12.93	11.52	34.27	0.26	0.00	10.67	24.38	23.93	9.80	0.15
30 - 60 cm layer														
Plow depth , cm	Mole pattern	Mole space, m	pH 1:2.5 susp.	EC dSm-1	Cations, meq/l				Anions, meq/l				SAR	TSS %
					Ca	Mg	Na	K	CO_3	HCO_3	Cl	SO_4		
30	P*	2	7.62	3.72	12.42	13.65	16.55	0.18	0.00	6.78	9.88	26.14	4.58	0.10
		4	7.67	3.98	14.23	12.25	18.57	0.36	0.00	6.05	10.00	29.36	5.10	0.11
		6	7.73	4.38	14.42	13.53	21.63	0.94	0.00	4.91	6.25	39.36	5.79	0.13
	C**	2	7.60	2.32	8.00	6.25	11.39	0.72	4.91	10.74	6.88	3.83	4.27	0.07
		4	7.62	3.01	9.50	10.75	14.15	0.36	0.00	5.67	10.00	19.09	4.45	0.09
		6	7.63	3.73	14.89	10.00	17.63	0.46	0.00	8.32	15.00	19.66	5.00	0.10
60	P*	2	7.57	1.83	6.03	5.05	7.86	0.15	0.00	6.80	7.13	5.16	3.34	0.06
		4	7.59	1.88	5.50	6.47	9.41	0.26	0.00	10.58	5.00	6.06	3.85	0.08
		6	7.60	2.14	7.45	6.32	10.80	0.21	0.00	5.67	6.25	12.86	4.12	0.09
	C**	2	7.50	1.48	5.55	4.50	6.50	0.53	0.00	6.43	5.00	5.65	2.90	0.03
		4	7.54	1.65	5.19	6.11	7.41	0.15	0.00	3.80	8.50	6.56	3.12	0.04
		6	7.58	1.82	6.30	5.24	8.78	0.26	0.00	4.54	8.50	7.54	3.66	0.05
Control			7.71	5.82	13.57	10.68	35.70	8.11	0.00	6.51	10.48	51.07	10.25	0.15

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

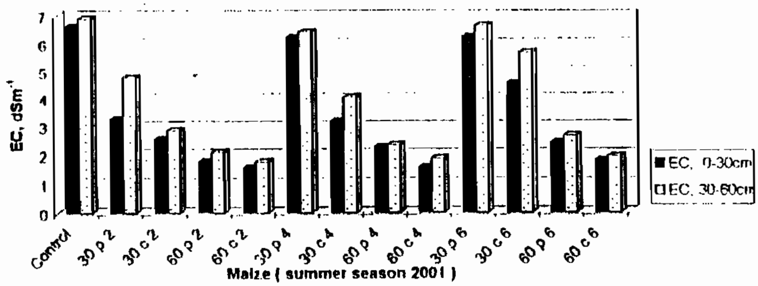

Fig.(5): Electrical conductivity (EC, dSm-1) in the first season as affected by different treatments.

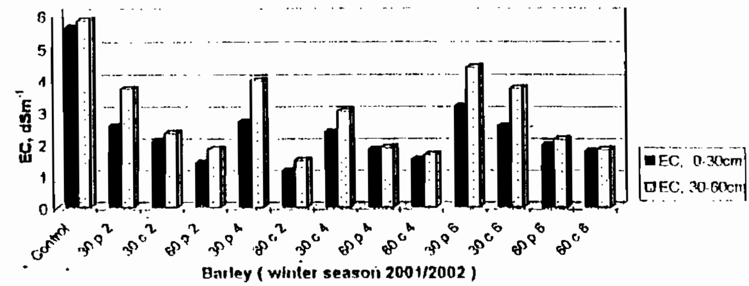

Fig.(6): Electrical conductivity (EC, dSm-1) in the second season as affected by different treatments.

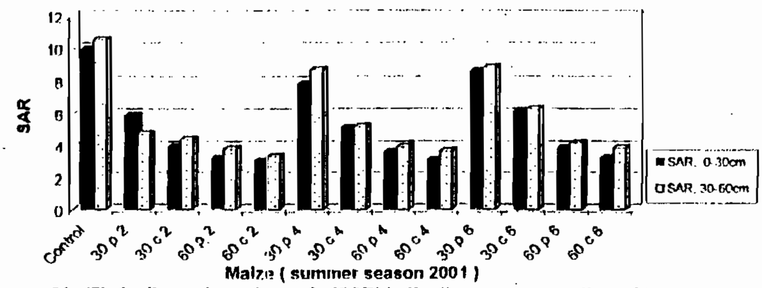

Fig.(7): Sodium adsorption ratio (SAR) in the first season as affected by different treatments.

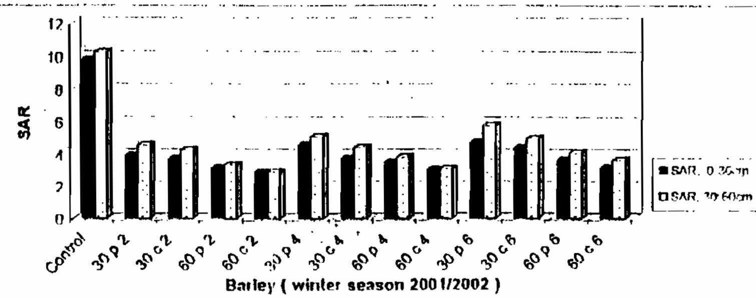

Fig.(8): Sodium adsorption ratio (SAR) in the second season as affected by different treatments.

mole treatments on reducing EC, total soluble salts and SAR values were more pronounced after cultivation of barley in the second season (2001-2002) and enhancing the leaching processes. These results are in harmony with those obtained by El-Sabrey *et al.* (1992) and Abou El-Soud *et al.* (1996).

As the superiority of crossed moles in improving the infiltration properties, they also promoted the leaching of salts greater than the parallel moles through the two seasons under study. This trend may be due to that the number of moles per unite area with crossed pattern are twice of that with parallel pattern at the same spacing. Therefore, the crossed moles increased the permeability of soil more than the parallel moles at the same spacing. Consequently, the crossed moles enhanced the leaching of salts from soil and decreased EC, SAR and TSS values greater than the parallel ones at the same spacing.

The effect of mole spacings on the leaching of salts during the two seasons can be arranged in the following descending order : 2m > 4m > 6m > the control. The previous results show that the leaching of salts was enhanced as the mole spacing decreased and vice versa. This trend is somewhat appropriate with the infiltration characteristic results, since the higher the basic infiltration rate, the lower are the EC, SAR and TSS values. These results are consistent with El-Sabry *et al.* (1992).

Regarding the combined effect of different treatments on EC, SAR and TSS, it could be observed that all mole treatments decreased salt content of soil comparing to the control in the two seasons at the two layer depths. 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 lowest values of EC, SAR and TSS 1.51 and 1.74 dSm^{-1}, 3.04 and 3.35, 0.06 and 0.06%, respectively for the two depths in the first season, and 1.15 and 1.48 dSm^{-1}, 2.89 and 2.90, 0.03 and 0.03%, respectively at the same depths in the second one. While the control detected the highest values 6.61 and 6.89 dSm^{-1}, 9.90 and 10.52, 0.31 and 0.29 %, respectively in the first season and 5.60 and 5.82 dSm^{-1}, 9.80 and 10.25, 0.15 and 0.15 %, respectively in the second one at the two layer depths.

Generally, it can be concluded that using the deep plow of 30 and 60 cm depth with crossed moles at 2 m spacing improved the physical, hydro physical and chemical properties of compacted clayey soils.

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تأثير الحرث العميق علي تحسين بعض الخواص الطبيعية والكيماوية للأراضي الطينية المندمجة.

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الملخص العربي

تم تنفيذ التجربة خلال موسمين متتالين (٢٠٠١ ، ٢٠٠١/٢٠٠٢) في محطة البحوث الزراعية بالجميزة، محافظة الغربية وذلك لتقييم كفاءة استخدام الحرث العميق للتربة علي عمق ٣٠، ٦٠ سم بإنشاء أنفاق متوازية أو شبكية علي أبعاد مختلفة (٢ ، ٤ ، ٦ متر) ومدى تأثيرها علي بعض الخواص الطبيعية والهيدروفيزيائية والكيماوية للتربة الطينية المندمجة خلال موسمين زراعيين متعاقبين (ذرة شامية ٢٠٠١ وشعير ٢٠٠١ / ٢٠٠٢) .

وبصفة عامة أوضحت النتائج أن أغلب المعاملات تؤدى إلي تحسن ملحوظ في الخواص الطبيعية والكيماوية للتربة حيث انخفضت الكثافة الظاهرية والمحتوى الرطوبي للتربة والاستهلاك المائي وزادت قيم المسامية الكلية والتوصيل الهيدروليكي وكفاءة استخدام المياة وكذلك زيادة في ثبات البناء مقارنة بالأراضي غير المعاملة حيث أدى الحرث العميق سواء علي عمق ٣٠ أو ٦٠ سم إلي النتائج السابقة.

ومن متوسط النتائج لموسمي الزراعة يتضح أن إنشاء ألمول علي أبعاد ٢، ٤، ٦ متر أدى إلي انخفاض قيم الكثافة الظاهرية والمحتوى الرطوبي والاستهلاك المائي وزيادة قيم المسامية الكلية والتوصيل الهيدروليكي وكفاءة استخدام المياه بالإضافة إلي زيادة ثبات البناء.

وكذلك أدت جميع المعاملات إلي زيادة غسيل الأملاح وانخفاض قيم التوصيل الكهربي لمستخلص عجينه التربة المشبعة ونسبة إدمصاص الصوديوم.

وأظهرت النتائج تفوق الأنفاق الشبكية علي الأنفاق المتوازية حيث انخفضت قيم الكثافة الظاهرية والمحتوى الرطوبي والاستهلاك المائي والتوصيل الكهربي بمستخلص عجينه التربة المشبعة ونسبة ادمصاص الصوديوم ونسبة الأملاح الكلية وزادت قيم المسامية الكلية والتوصيل الهيدروليكي وكفاءة استخدام المياه وكذلك زيادة ثبات البناء عن القيم المتحصل عليها في الأنفاق المتوازية .

وأوضحت النتائج أن معاملة الحرث علي عمق ٦٠ سم بإنشاء أنفاق شبكية علي مسافة ٢ متر أعطت أفضل النتائج من حيث تحسين الخواص الطبيعية والهيدروفيزيائية والكيماوية للتربة مقارنة بباقي المعاملات وخاصة معاملة المقارنة (الكنترول).