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Effect of Deep Ploughing on Some Physical Properties and Corn Yield in Calcareous Sandy Clay Loam Soil

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FIELD experiment was conducted in the summer season of 1999 on Nubaria sandy clay loam soil using shallow and deep plows. The tillage treatments used in this study were rest; chisel plow at 20 cm depth, subsoiler plow at 80 cm depth with one share and subtiller plow at 70 cm depth with 5 chares. All plows were followed by a disk harrow to refine the soil surface.

Data of soil strength showed an original subsurface compacted layer at 29-50 cm depth. No significant differences in physical properties for applied treatments were found down to 20 cm depth. Loosening of the compacted layer by the deep tillage treatments, either by subsoiler or subtiller, resulted in significantly lower soil strength and bulk density and higher porosity, macropore volume accompanied by higher hydraulic conductivity with superiority for subtiller plow as compared to shallow tillage (chisel plow) as control.

Concerning the impact of tillage treatments after harvest on soil physical properties the data indicated that the average values of the surface layer for such properties varies within a very narrow range and nearly similar to the initial soil. As for the compacted layer, it could be concluded that subsoiling plows especially subtiller plow alleviate the compacted layer for more than one season. It is noticed that subsoiling plows provide a high crop yield as compared with surface plows. The increase in grain yield is 15.45% and 25.46% for subsoiler and subtiller plows relative to chisel plow, respectively.

Keywords :Soil compaction, deep plowing, penetration resistance, calcareous soil.

It is needless to state that human- induced soil degradation is now recognized as a wide-spread problem. It includes several aspects, e.g. physical, chemical and biological degradation processes. By far, soil compaction is the most important type of the physical soil degradation (Soane and Van Ouwerker, 1994).

In irrigated agriculture, the problem of soil compaction seems to have worsened in recent decades along with using intensive large machines in crop production. Moreover, with the intensive use of fertilizers, irrigation water and other interrelated inputs in many places, soil compaction and its ecological consequences have becomea major limiting factor to the attainment of maximal productivity Hillel (1998). This is because soil compaction influences soil strength, bulk density, distribution and continuity of pores with consequent adverse effect on drainage, root penetration, aeration, biological processes, nutrient uptake, all of which can have a direct bearing on crop production (Van Noordwijk and DeWilligen, 1991; Ball,1987; Ankeny *et al.,* 1990; and Blackwell *et al.*, 1990).

In Egypt, considerable evidences exists to show that soil compaction exerts an enormous impact on crop productivity. The Egyptian Executive Agency of Soil Improvement Project (1998, unpublished data) determined these problems due to the presence of a dense tillage pan, occur on more than 90% of total irrigated area in the Nile Valley and Delta. Moreover, Said (1998) mentioned that both naturally and machinery- induced compacted layers are commonly found in relatively-old reclaimed soils in West Delta region.

Soil compaction can be ameliorated or alleviated through machinery, agronomic and organic matter management technique. The efficiency of the tools depends on soil conditions, plant species and weather conditions. Therefore, the current study intends to evaluate the effectiveness of chisel, subsoiler and subtiller plows on loosening the compacted subsoil layers and consequently on corn yield under the conditions of sandy clay loam calcareous soil in West Nubaria region.

Material and Methods

The study was carried out in the mechanized farm at West Nubaria area, where the primary and secondary tillage operations are commonly undertaken with large and heavy field equipments. So, soil compaction, especially below the depth of normal tillage zone, has recently been identified in this area (Said, 1998).

To evaluate the relative effectiveness of the primary tillage tools in mitigating the compaction problems that were encountered in such area, randomized complete block experiment was designed. The experimental variables included three tillage treatments, namely:-

1- Chisel plow (CH) with 7 shares for two perpendicular passes at 20cm plowing depth.

2. Subsoiler plow (SS) with one share to break down the compacted layer down to 80 cm depth, followed by two passes of chisel plow.

3. Subtiller plow (ST) with S shares for one pass to create a deep loosening and disturbance in the soil mass down to 70 cm depth followed by two passes of chisel plow.

In all cases, disc harrow was used to refine the soil surface. Three replicats were applied for each treatment.

Corn (*Zea mays*) was planted on 25 June, 1999 at row spacing of 70 cm and planting depth of 5 cm below the soil surface using seeder.

All experimental plots were fertilized at rates of 150 kg N, 100 kg P_2O_5 and 50 kg K_2O per feddan in forms of ammonium sulphate, super phosphate and potassium sulphate in the same sequence. Surface irrigation was applied at 12 days irrigation intervals.

Penetration resistance was measured after 15 days from plantation and after harvest to a depth of 80 cm using penetrologger. The apparatus has a cone with 2 cm^2 base area - 60° angle cone and standard set of probing rod (10 mm dia.). In as much as soil strength is strongly affected by soil water content, soil samples were taken very close to the place of resistance test in each treatment; at depth intervals of; 0-20, 20-29, 29-50, 50-70 and 70-80 cm. Also, undisturbed soil cores were taken from these depths to determine bulk density, saturated hydraulic conductivity, porosity and pore size distribution.

Soil samples collected from the different applied treatments and the original soil samples were subjected to the following analysis:

1- Particle size distribution using the international pipette method.

2- Bulk density was determined and total porosity, and pore - size distribution were calculated following De Leenheer and De Boodt (1965).

3- Saturated soil hydraulic conductivity was measured under constant head of water after Klute (1986).

4-Total soluble salts as well as soluble cations and anions were determined in the saturated soil extract following the methods described by Richards (1954).

5- Soil pH was measured in the saturation extract using Beckman type pH meter (Richard 1954).

At the end of the growth season, corn grain yield was determined. Statistical analysis was carried out according to Steel and Torrie (1980).

Results and Discussion

Characteristics of the experimental site

The morphological study of the soil profile representing the experimental site point out that there are two dense layers at 29-50 and 50-80 cm depths, characterized by massive strongly cemented, hard to extremely hard structure and have abundant white powders and crystals of gypsum.

Descrition sheet

Location : West Nubaria, km 62 from Alexandria, East of the desert road.

Topography : Nearly level.

Parent material : Calcareous sediments.

Vegetation : Plowed field.

Depth	Description
0-29	Pale brown (10YR 6/3 dry), yellowish brown (l0YR 5/4, moist); sandy clay, loam; massive hard; sticky, plastic; clear smooth boundary.
29-50	Brown (l0YR 5/3, dry), dark brown (l0YR 4/3, moist) sandy clay loam; massive; strongly cemented; very hard to extremely hard; sticky, plastic; abundant white powders and crystals of gypsum; gradual smooth boundary.
50-80	Yellowish brown (10YR 5/4, moist) sandy clay loam mottled with brown (7.5YR 5/4) and olive gray (5Y 5/2) of clay patches, hard; sticky, plastic; many fine gypsum crystals; abrupt smooth boundary.

The relevant physical and chemical properties of the different layers of the studied profile, given in Table 1 reveal that the soil is sandy clay loam, calcareous, marginally saline and non-alkali throughout the studied depth of the soil profile. It is also evident that the bulk density of the subsurface soil layer (29-50cm) is remarkably higher (1.56 Mg/m^3) than those of the surface and the bottom soil layers. Consequently the penetration resistance of such layer is relatively large compared to the other layers of the soil profile.

Effect of tillage on soil properties

Soil strength

Due to the fact that soil strength is strongly affected by soil moisturc content, soil samples were taken from each of the studied soil depths in each tillage treatment at the time of measuring its penetration resistance (PR). Soil moisture content was determined, then a mathematical relationship between PR and soil moisture content was established (Fig. 1).

To evaluate the effectiveness of the employed tillage implements in loosening the compacted soil and at the same time eliminating the influence of soil moisture content, the obtained equations given in Fig.1 were used for estimating the strength of soil layers at a constant value of soil moisture, *i.e.*, 20% of the available soil moisture range of each soil layer. Such value was

TABLE 1. (a) Particle size distribution, calcium carbonate, gypsum and organic matter percentage of the investigated soil.

Layer Depth (cm)	Particle size distribution (%)				Texture Class	Calcium carbonate %	Gypsum %	Organic Matter %
	C. sand	F. sand	Silt	Clay				
0-29	19.43	45.30	11.47	22.10	SCL	27.58	0.82	1.31
29-50	13.65	38.82	21.57	27.96	SCL	41.23	1.98	0.67
50-80	11.34	40358	25.69	25.69	SCL	32.05	1.27	0.27

(b) Some physical properties of the investigated soil:

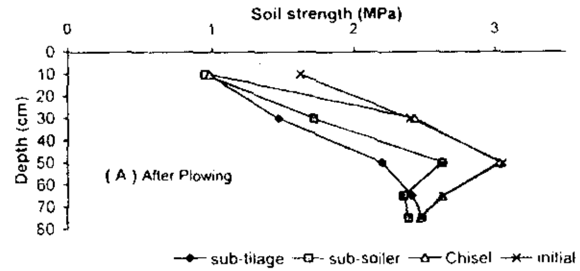
Layer depth (cm)	Particle density ($Mg\ m^{-3}$)	Soil strength at 20% AV MPa	Bulk density ($Mg\ m^{-3}$)	Total porosity (%)	Pore size Distribution (%)		Sat. Hyd. Conductivity ($cm\ hr^{-1}$)	Moisture content V/V (%) At moisture tension	
					Macro	Micro		0.33 atm	15.0
0-29	2.62	1.98	1.41	46.18	11.45	18.15	0.37	24.63	12.87
29-50	2.61	3.08	1.56	40.23	0.76	23.94	0.06	29.18	15.21
50-80	2.62	2.51	1.44	44.81	5.05	19.67	0.22	27.61	13.66

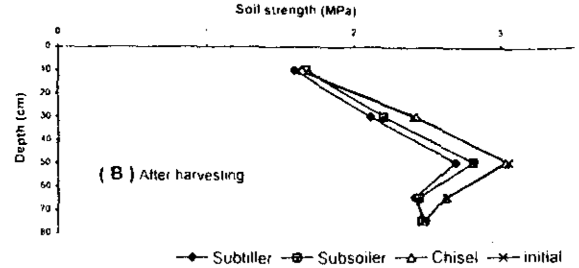
c) Some chemical properties of the investigated soil:

Layer Depth (cm)	PH	EC $dS\ m^{-1}$	Soluble cations and anions (me/L)							
			Na	K	Ca	Mg	Cl	HCO_3	CO_3	SO_4
0-29	7.90	2.35	12.13	0.71	7.14	3.31	14.25	2.79	-	5.71
29-50	8.15	3.90	20.52	0.34	13.78	5.07	23.86	2.95	-	12.90
50-80	8.05	3.52	18.93	0.26	11.42	4.69	22.54	3.02	-	9.74

selected on the premise that it could represent the minimum permissible moisture for growing plant and at this value irrigation becomes a must. These equations show highly negative correlation coefficients between penetration resistance and moisture content for all depths of the soil treatments. Figure 1 shows that PR values of the compacted subsurface layers (29-50 and 50-80 cm) of the untilled soil control reach 3.22 and 2.651 MPa. These values were considered by many investigators to cause detrimental effects on root growth, water and nutrient uptake and thus crop yield (Taylor *et al.*, 1964; Quessible *et al.*, 1992 and Poach and Verplanke, 1997).

Regarding the effect of tillage treatment on soil loosening, it is evident that PR of the surface layer (0-20 cm) is, more or less, the same under all the applied treatments (Fig. 1A). However, below this layer, the influence of chisel plow





LSD (0.05) Depth 0.0462 Tillage 0.0393

Treatment	Depth	Equation Model	r	n = 10
	00 - 20	Y = 2.0629 - 0.0735 X	-0.9274	
	20 - 29	Y = 4.2021 - 0.1071 X	-0.9670	
Chisel	29 - 50	Y = 5.6417 - 0.1438 X	-0.9183	
	50 - 70	Y = 4.6534 - 0.1208 X	-0.9637	
	70 - 80	Y = 4.3892 - 0.1136 X	-0.9241	
	00 - 20	Y = 2.5322 - 0.1067 X	0.9439	
	20 - 29	Y = 4.2163 - 0.1444 X	-0.9654	
Subsoiler	29 - 50	Y = 5.6251 - 0.1623 X	-0.9709	
	50 - 70	Y = 4.6739 - 0.1378 X	-0.9223	
	70 - 80	Y = 4.4208 - 0.1182 X	-0.9013	
	00 - 20	Y = 2.4468 - 0.0982 X	-0.9837	
	20 - 29	Y = 3.8782 - 0.1349 X	-0.9683	
Subtiller	29 - 50	Y = 4.5961 - 0.1282 X	-0.9665	
	50 - 70	Y = 4.8911 - 0.1434 X	-0.9147	
	70 - 80	Y = 4.7250 - 0.1310 X	-0.9622	
	00 - 20	Y = 3.3885 - 0.1099 X	-0.9923	
	20 - 29	Y = 5.0440 - 0.1541 X	-0.9905	
Initial	29 - 50	Y = 6.2161 - 0.1737 X	-0.9792	
	50 - 70	= 5.1522 - 0.14462	-0.9899	
	70 - 80	Y = 4.8886 - 0.1386 X	-0.9940	

LSD (0.05) Depth 0.01208 Tillage 0.0149

Treatment	Depth	Equation Model	r	n = 10
	00 - 20	Y = 3.3100 - 0.1028 X	-0.9828	
	20 - 29	Y = 5.1987 - 0.1624 X	-0.9950	
Chisel	29 - 50	Y = 6.3692 - 0.1839 X	-0.9913	
	50 - 70	Y = 4.8549 - 0.1234 X	-0.9838	
	70 - 80	Y = 4.7739 - 0.1324 X	-0.9771	
	00 - 20	Y = 3.1734 - 0.0902 X	-0.9824	
	20 - 29	Y = 4.5124 - 0.1328 X	-0.9530	
Subsoiler	29 - 50	Y = 6.0035 - 0.1739 X	-0.9841	
	50 - 70	Y = 4.8560 - 0.1346 X	-0.9778	
	70 - 80	Y = 4.3310 - 0.1092 X	-0.9102	
	00 - 20	Y = 3.4810 - 0.1193 X	-0.9808	
	20 - 29	Y = 5.0060 - 0.1710 X	-0.9911	
Subtiller	29 - 50	Y = 5.2819 - 0.1442 X	-0.9489	
	50 - 70	Y = 5.2757 - 0.1650 X	-0.9049	
	70 - 80	Y = 4.6856 - 0.1267 X	-0.9295	

Where Y is the soil strength (MPa) and X is the soil moisture content (W/W%)

Fig. 1. Effect of tillage treatments on soil strength (MPa) at 20% AW after two periods of the investigated soil.

(CH) on soil loosening is nil. For the subsurface layers (20-29 cm and 29-50 cm), it is clear that subsoiling using either subsoiler or subtiller substantially reduce the PR of such layers. The magnitude of such decreases approached 25.6% and 34.2% for (20-29 cm) depth and 21.7% and 37.7% for (29-50 cm) depth relative to chisel treatment, respectively. Evidently, the subtiller is superior relative to the subsoiler in breaking the compacted layer and loosening the soil. As for the bottom layer (50-80 cm), the data in Fig. 1 A elucidate that the effect of subsoiler and subtiller in reducing soil compactness sharply decreases. Similar findings were achieved by Barabosa *et al.* (1989).

The persistence of the applied tillage treatment on soil strength was determined after crop harvesting. Data in Fig. 1B show that the positive effect of tillage treatments in the surface layer (0-29 cm) disappeared entirely by the end of growth season. In this respect, Davies *et al.* (1993) postulated that recompaction of the loosened soil tend to take place because the lateral effect of traffic extends no deeper than 35 cm. In the compacted subsurface layer (29-50 cm), it is clearly noticed that the effect of subsoiler and subtiller plows seems to persist for more than one season as the reduction of the PR after corn harvesting reached 14% and 19.50%, compared to the control, in the same sequence. As for the bottom depth (50-80 cm), the data on Fig. 1B indicate that PR values of the treated soil remained the same like the chisel treatment, in consequence of the minute effect of the studied subsoiling plows at depth deeper than 50 cm.

Bulk density and the characteristics of soil pores

Due to the fact that the ability of plant roots to penetrate the soil is a function of its compressibility and consequently the characteristics of its pore- space, therefore, the impact of the applied tillage treatment on bulk density (BD), total porosity (TP) and pore size- distribution was taken into account.

Regarding soil bulk density, Table 2 shows that at the beginning of growth season the applied treatments have resulted in a remarkable decrease in the surface layer as compared to unplowed soil (Table l). Moreover, It is evident that the decrease in bulk density of the top soil layer (0-20 cm) in each stage, *i.e.*, plowing and harvesting was, more or less similar under all treatments. In the subsurface layer, (29-50 cm), the data reveal that chiseling treatment did not affect the bulk density. This is because the depth of such plowing treatment may not exceed 20 cm. Whereas, subtilling and subsoiling treatments caused appreciable decrease in soil bulk density. Nevertheless, the former is superior to the latter. As regard to the deeper layer (50-80 cm), it is evident that the variation in bulk density is very small indicating that beneficial effect of both subsoiler and subtiller on soil loosening disappeared below 50 cm depth. By the end of growth season, the obtained data reveal that subsoiling either with subtiller or subsoiler resulted in appreciable decrease in bulk density of the compacted subsurface layer (29-50 cm) compared to the control. This means that the beneficial effect of such treatment persists for more than one season. Obviously, subtiller seems to be more efficient in disruption of the deep compacted layers compared to subsoiler.

As for soil porosity, the results given in Table 2 show that at the beginning of growth season, subsoiling had a marked positive effect on soil porosity of the subsurface compacted layers. However, subtiller plow seems to be superior to the subsoiler in increasing porosity down the depth of 70 cm, whereas the improving effect of subsoiler was confined within 50 cm depth. Nevertheless, such effects on soil porosity disappeared by the end of growth season.

With respect to the pore-size distribution, the data given in Table 2 substantiate generally that plowing results in noticeable increase in macro-pores with consequent decrease in micro- pores compared to the unplowed soil (Table 1). In the surface layer (0-20 cm), such effects are quite similar under all of the applied plowing treatments. For the effect of deep plowing on pore-size distribution of compacted subsurface layer, (29-50 cm), it is obvious that subsoiling and subtilling treatments increased the macro - pores by 213 and 820% relative to chiseling treatment, respectively. The obtained data also point out that such beneficial effect lasts for more than one season as the increase of macro-pore volume in this layer by the end of the growth season, approached about 70 and 415% compared to chiseling, in the same sequence. Similar finding were achieved by Larson *et al.* (1994).

Saturated hydraulic conductivity (Ks)

Table 2 elucidates that plowing had resulted in remarkable increase in Ks of the tilled surface layer as compared to the unplowed soil (Table 1). As for the types of plows, the data clarify that deep plowing caused substantial increase in

Ks of the compacted subsurface (29-50 cm) layer, compared to chiseling treatment. Such increase approached 142.9% and 514.3% for subsoiler and subtiller, respectively. However by the end of growth season, the results point out that reducing effect on the values of Ks of the surface layer (0-20 cm) disappeared after one growth season. On the contrary the positive effect of deep plows on saturated hydraulic conductivity of the compacted subsurface layer (29-50 cm) seems to persist for more than one growing season where the increase of Ks of such layer by the end of the growing season reaches 83 and 200% for subsoiller and subtiller relative to the chisel, respectively.

TABLE 2. Effect of tillage treatments on some physical properties of the investigated soil at the two investigated periods.

Till-age Treat	Depth (cm)	BD Mg/m^3	TP %	Pore size Distribution (%)		Ks cm/hr	BD Mg/m^3	TP %	Pore size Distribution (%)		Ks cm/hr
				Macro	Micro				Macro	Micro	
		After plowing					After harvesting				
CH	0-20	1.33	49.24	14.76	15.16	1.91	1.41	46.18	11.37	18.28	0.34
	20-29	1.43	45.42	10.98	18.16	0.36	1.43	45.42	10.98	18.30	0.29
	29-50	1.56	42.23	0.69	23.87	0.07	1.57	39.85	0.53	23.70	0.06
	50-70	1.44	45.04	5.06	19.22	0.21	1.44	45.04	4.95	19.34	0.22
	70-80	1.44	45.04	5.14	19.54	0.23	1.44	45.04	4.85	19.50	0.24
SS	0-20	1.33	49.24	15.27	14.61	1.93	1.42	45.80	11.12	18.97	0.36
	20-29	1.39	46.95	12.15	13.39	0.68	1.43	45.42	10.18	18.85	0.32
	29-50	1.47	43.68	2.16	22.08	0.17	1.51	42.15	0.90	22.88	0.11
	50-70	1.42	45.80	5.59	16.84	0.29	1.44	45.04	4.88	18.53	0.27
	70-80	1.44	45.04	5.28	18.85	2.24	1.44	45.04	4.81	19.47	2.21
ST	0-20	1.32	49.62	15.85	13.34	1.97	1.42	45.80	11.05	18.13	0.37
	20-29	1.35	48.47	14.22	13.51	1.06	1.41	46.18	10.88	18.54	0.35
	29-50	1.40	46.36	6.35	20.86	0.43	1.46	44.06	2.73	21.12	0.18
	50-70	1.43	45.42	5.91	19.37	0.25	1.44	45.04	4.95	19.41	0.25
	70-80	1.44	45.04	4.98	19.85	0.21	1.44	45.04	4.78	20.69	0.20

Note: BD is the bulk density TP is the total porosity Ks is the hydraulic conductivity

LSD (0.05)	BD	PP	Macro	Micro	Ks
		Plowing			
Depth	0.0023	0.4321	0.437	0.5757	0.0026
Tillage	0.0018	0.3347	0.338	0.4459	0.002
		Harvest			
Depth	0.0039	0.1437	0.133	0.5752	0.0027
Tillage	0.003	0.1114	0.103	n.s.	0.0021
		Time of measurement			
	0.0029	0.6817	0.2828	0.0676	0.0024

Crop yield

The following data present the values of corn grain yield as affected by the applied tillage treatments in the experiment. Apparently, deep tillage significantly increases corn yield as compared to surface tillage, i.e., chiseling. The increase in grain yield approaches 18.06% and 24.08% relative to chisel treatment under subsoiling and subtilling treatments, respectively. Most probably, such positive effect of deep tillage may due to the disruption and loosening of the compacted subsurface layers which may cause appreciable improvement on the physical factors affecting root growth namely; soil mechanical impedance, soil aeration, soil water and soil temperature, there by crop productivity increases. This findings are quite in agreement with Carter (1990), Jourge *et al.,* 1992) and Barabosa *et al.,*1989).

Effect of tillage treatments on corn grain yield (Ardab/fed.).

	CH	SS	ST
	15.28	18.04	19.17
LSD(0.05)		0.7029	

From the above-mentioned results, it could be concluded that subsurface soil compaction can be considered one of the limiting factors for achieving optimum crop productivity in the studied area. Moreover, the study gives evidence for the importance of subsoiling plow which could persist more than one year, particularly under the modern agriculture practices.

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تأثير الحرث العميق على الخواص الطبيعية للتربة ومحصول الذرة فى أراضى جيرية مندمجة

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أقيمت تجربة حقلية بهدف دراسة وتقييم أثر عمليات الحرث المختلفة على الخواص الطبيعية للتربة وإنتاجية محصول الذرة فى الأراضى الجيرية المندمجة .

وقد أجريت هذه الدراسة في منطقة غرب النوبارية حيث الأراضى الجيرية ذات قوام ثقيل وسلتية طينية رملية ذات طبقة مندمجة تحت سطحية على عمق ٢٩ سم حيث استخدمت ثلاث طرق حرث وهى:

(أ) حرث سطحى لعمق ٢٠ سم بمحراث حفار ذو سبعة أسلحة.
(ب) حرث عميق لعمق ٨٠ سم بمحراث تحت تربة بسلاح واحد.
(جـ) حرث عميق لعمق ٧٠ سم بمحراث حفار عميق ذو خمسة أسلحة .

وقد أوضحت النتائج مايلى :

١- أدى استخدام الحرث العميق إلى نتائج معنوية بتقليل اندماج التربة حيث انعكس ذلك علي خفض الصلابة والكثافة الظاهرية للتربة مع زيادة النسبة المئوية للمسامية الكلية والمسام الواسعة مصحوبا بزيادة التوصيل الهيدروليكى، وقد كانت النتائج أكثر ايجابية باستخدام المحراث الحفار العميق متعدد الأسلحة، وذلك بالمقارنة مع معاملة الحرث السطحى .

٢- فى نهاية موسم النمو ، وجد أن الطبقة المندمجة أقل صلابة فى معاملات الحرث العميق خاصة معاملة المحراث الحفار العميق متعدد الأسلحة بالمقارنة مع معاملة الحرث السطحى مما يدل علي أن التأثير الإيجابى للحرث العميق علي تقليل اندماج التربة يمكن أن يمتد إلى أكثر من موسم زراعى.

٣- أدى استخدام الحرث العميق إلى زيادة معنوية في إنتاجية محصول الذرة بالمقارنة مع الحرث السطحى حيث بلغت الزيادة فى محصول الحبوب ٤٥و ١٥٪ و ٤٦ و٢٥٪ فى معاملات الحرث العميق وذلك باستخدام محراث تحت التربة ذو السلاح الواحد، المحراث الحفار العميق متعدد الأسلحة علي التوالى بالمقارنة مع الحرث السطحى .