J.Soil Sci. and Agric. Eng., Mansoura Univ., Vol. 6 (4): 501 - 521, 2015

EFFECT OF DIGGING DEPTHS OF SUGAR BEET'S HARVESTER ON SOME PROPERITIES OF SALT-AFFECTED SOILS AND RICE YIELD

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ABSTRACT

A field experiment was conducted in a farmer's field at South of El-Husainia plain, Al-Sharqia Governorate, Egypt during winter season of 2012/2013 and extended to the winter season of 2013/2014.Tha aim of the study was to assess the effect of mechanized sugar beet harvesting at different digging depths on some properties of salt affected soils and its productivity of rice crop. A split plot design with three replicates was used to conduct the field experiment. The main plots represented the harvesting depths (D1: conventional harvesting (farmer's method) using hoes, D2: mechanized harvesting with digging depth of 20-25cm, and D3: mechanized harvesting with digging depth of 35-40cm). The subplots represented sampling distance from the tile drain (A: 7.5 - 5.0m, B: 5.0 - 2.5m, and C: 2.5 – 0.0m). Salt contents at different layers were evaluated. The soil physical parameters determined included bulk density (*ρb*), saturated hydraulic conductivity (Ks) and soil penetration resistances (SPR). Rice grain yield, yield component and growth parameters (panicles length (cm), number of panicles/m^2, 1000-grain weight, plant height, leaf area index (LAI), and crop growth rate (CGR)) were determined. Results indicated in general that, salt contents at different layers decreased significantly with increasing digging depth, while the salts removed had an opposite trend. Removed salts with D3 treatment were 5 and 3.5 times more than those of D1 and D2 treatments, respectively. Similarly, values of *ρb* and SPR were reversely responded to the increase of digging depth. Reduction in average *ρb* values as compared with its initial value were 5.1, 3.1, and 0.11% for the D3, D2 and D1 treatments, respectively. Decreasing the distance from tile drain, increased both SPR and Ks values. The Ks values close to the tile drain increased by about 1.5 times than its initial values. Increasing digging depth from D2 to D3 resulted in increasing Ks value by about 49%. The enhancement in soil physiochemical properties, due to deep digging, significantly stimulated rice productivity (rice grain yield increased by about 16%) as well as all other yield components and growth parameters.

INTRODUCTION

Sugar beet is not only a winter crop involved in the Egyptian cropping pattern, which is grown under widely soils conditions, or an important source of animal feed or one of the excellent farmers cash crops, but also is considered the most important strategic source of sugar production in the country grown to minimize the national sugar gap, which reached 1.208 million tons in 2013/2014 (FAO, 2013). To decrease the production/consumption gap, the government’s strategies and policies encourage farmers to grow sugar beet over sugarcane to overcome the expected sugar shortage of 1.220 million tons in year 2014/2015 (USAD, May

2014). Besides, maximize water economic value (El-Gafy *et al.,* 2013) as well as improve land utilization efficiency (Jian *et al.,* 2014). Consequently, the target planted area is forecasted to be increased by 5% or roughly by 183 thousand feddans (≈76,891 ha) in May 2014/2015, as compared to 2013/2014 year (USAD, April 2014).

In spite of the positive impact of using advanced agricultural technology such as mechanized harvesting on yield and quality of sugar beet crop (Khalifa *et al.,* 2010; Jian, 2014), fully mechanized sugar beet harvesting is reported to be uneconomically and inconveniently to smallholdings characterization of Egyptian agricultural. Therefore, sugar beet is still manually harvested by hand digging or pulling the roots out of the soil by shovel and hoe, or sometime by chisel plow (FAO, 2009 and Salman *et al.,* 2014). Consequently, Egyptian researchers, recently, has developed and introduced different types of partially mechanized technique to minimize operation time, costs and total root losses, beside it is considered as an alternative technology for the traditional and fully mechanized sugar beet harvesting methods. Most of these researches focused on evaluating machine performance such as harvesting efficiencies, optimum speed, mechanical damage loss and its economic aspect's on the obtained yield (Morad *et al.,* 2007b; Tayel *et al.,* 2009 and Salman et al., 2014).

Few researchers studied the impact of mechanized harvesting on soil moisture content and lifting depths. Morad *et al.,* (2007) evaluated three sugar beet harvesting methods namely: traditional, chisel plow and sugar beet harvester equipment (one row harvesting machine), at Kafr El-Sheikh Governorate, as a function of change in harvesting speed and soil moisture content. They figured out that, soil moisture content of 24% is considered the optimum value during sugar beet harvesting. They stated that, the maximum lifting efficiency and minimum total losses were 93.98% and 8.31%, respectively obtained under mechanical planting and sugar beet harvester, compared with manual method which recorded 92.73% and 10.39%. They added that, decreasing or increasing soil moisture content less or more than 24% leads to increase the un-lifted beets and decrease the lifted beets under all experimental conditions.

Nejad *et al.,* (2013) indicated that, all exploitation practices from the soil that create better condition for water penetration, and improve soil structure, will be effective in soil salinity control. In the salt affected soil at Port-Said Research Station, Salman *et al.,* (2014) studied the possibility of using peanut digger machine for lifting sugar beet and investigated two digging depths (15 & 25cm) and vibrating fork and the effect on the performance of digger machine. They found that, increasing digging depth from 15 to 25cm tends to decrease the average of roots losses percentage from 3.8 to 2.7% and from 3.8 to 2.9% for vibrating and non-vibrating fork, respectively. They also added that, the use of a digger machine not only reduces the cost and time of the lifting operation, but also improved the soil properties as the result of deep digging as well as increasing productivity of the next crop.

Several investigators tried to identify the important factors that influence seedling emergence and crop yield. They stated that chemical factors (as EC and ESP) and physical factors as degree of soil compaction, soil bulk density, and soil moisture condition are the most effective factors affecting plant growth (Moor, 2001; Martı´nez *et al.,* 2008 and Mari *et al.,* 2011). According to Wolkowski and Lowery (2008), soil compaction occurs and develops from the normal practices of crop production. This was in consistency with the previous work of Duiker (2004) who observed the formation of plow pans on dairy farms that used the chisel plow. Ziyaee and Roshani (2012) conducted a survey to study the causes of soil compaction problems. They outlined that, soil compaction occurs in a wide range of soils and climates and is increasing for several reasons, i.e., earlier planting schedules, overgrazing & animal trampling which are directly affect the penetration resistance, besides, the impact of larger equipment uses and excessive tillage especially if soil is tilled when it is wet. They also reported that, repeated tillage over the years orients all of the soil particles in the same direction, causing a layer of compacted soil (a plow pan) to form directly beneath the area being tilled, particularly in high clay content soils.

Detrimental effects of soil compaction were well studied and found to be in association with different soil characteristics' mainly increases of soil penetration resistance (Lowery and Schuler 1994) and bulk density (Needham *et al.,* 2001). Whereas, soil total porosity and pore size, volume and pore continuity were decreased (Moore, 2001) resulting in reducing soil hydraulic properties (Green et al., 2003). Consequently, a lower salt leaching, particularly, during reclamation of salt affected soil (Azhar *et al.,* 2001) due to poor drainage efficiency (El-Shanawany *et al.,* 2000 and Gill, 2012), therefore, decreasing plant root penetration and density. Reduction in plants root, shoot growth, yield and yield parameters as well as changing in their physiological characteristic's were found in association with different plants grown in compacted soil, e.g. sorghum, cotton and *wheat (Gerik et al., 1987), barley (Mulholland et al., 1996 and Reintam et* al., 2005), tomato (Hussain *et al.,* 1999), sugarcane (Singh *et al.,* 2008), rice (Clermont-Dauphin *et al.,* 2010), maize (Lowery and Schuler, 1994 and Kobaissi *et al.,* 2013).

Since soil compaction is more likely to occur beneath the traffic path of farm machinery (Moore, 2001; Morad *et al.,* 2007a; Wolkowski and Lowery, 2008) and/or as dense layer generated in salt affected soils due to dispersion, translocation, and deposition of clay platelets in the conducting pores (Azhar *et al.,* 2001). It also involves poor physical condition created during pudding and flooding duration practices of continuous rice growing (Sur *et al.,* 1981). Thus, deep plowing (Ballantyne, 1983), beside amendments applications (Adeyemo and Agele, 2010), are considered the most effective mechanical manipulation methods to counter soil compaction and the unfavorable conditions of salt affected soils (El-Shanawany *et al.,* 2000; Azhar *et al.,* 2001 and Milani *et al.,* 2011).

Bulk density is considered one of the soil physical measurements that reflect soil quality governed crops productivity and found to be associated with soil texture, organic matter content and nutrients concentration (Martı´nez *et al.,* 2008 and Chaudhari *et al.,* 2013). Accordingly, bulk density tend to increase with increasing soil depth due to reduction in organic matter content, soil aggregation and root penetration densities along with less pore space with deep layers compared to surface layers. Subsurface layers are also subject to the compacting weight of the soil above them (Eluozo, 2013 and Islam *et al.,* 2015). Different researches indicated that fine clay soils usually have lower bulk densities of 1.0–1.6g/cm^3 than that of sandy soils of 1.2–1.8 g/cm^3 with a critical levels of 1.7 and 1.4g/cm^3 for sand and clay soils, respectively (Moore, 2001 and Eluozo, 2013). In addition, several investigations indicated that soil bulk density effectively affected by numerous factors, i.e. irrigation water quality, soil amendments applications, and tillage practices. Emdad *et al.,* (2006) found that water treatments of moderate and high EC-SAR (2.0 dSm^{-1} &10 and 6 dSm^{-1} &30, respectively) led to increase bulk density of the surface clay loam soil layer by about 4% and 7%, respectively. They also added that bulk density tended to increase linearly with increase exchangeable sodium percentage. Opposite trend was reported by Chaudhari *et al.,* (2013) who found strong negative correlation between soil bulk density and available Ca^{2+} and Mg^{2+} contents in soil.

In spite of decreasing bulk density of the surface soil layer, bulk density of the subsurface layers and compaction in crop root zone were induced under conventional tillage system. In this respect, Adeyemo and Agele (2010) reported that using mouldboard plough followed by harrowing at 10 and 20cm plowing depths promote soil compaction in 20-30cm depth. Also, results of ÇELİK (2011) in heavy clay soil under semi-arid conditions indicated that bulk density of the 20-30cm depth was greater compared to that of 0-10 cm and 10-20 cm depths. On other hand, Martı´nez *et al.,* (2008) found that soil bulk density was significantly affected by the interaction between soil depth and tillage system. Results of a 2-year field experiment by Abdelgawad *et al.,* (2004) showed that deep plowing of 50 cm depth breaks the hard pan and decreased the density of the soil, hence increasing the macro-pores of soil surface compared to normal plow of 25cm. Ji *et al.,* (2014) studied the effect of conventional tillage (CT) and deep tillage (DT) at depth of 20 and 30cm, respectively, at two sites of different texture on penetration resistance and soil bulk density. They stated that lower soil bulk density and higher soil water content were associated with DT as compared with CT tillage across the two years and depths. They also added that plowing sandy soil annually may be profitable at depth of 30cm deep, but in clay and clay loam soils plowing deeper than 20–25cm not recommended.

Rice cultivation is the major summer planted grain crop in northern Delta region. It occupied about 1.42 million feddans during 2011 (21.54% of the planted area of Egypt) and produced about 5.67 million tons of grains (Jian *et al.,* 2014). Because of the high water applications and submerged conditions within rice growing seasons, it helps in reducing soil salinity level and increasing depth of desalinized zone by the end of its growing seasons (Chaudhry *et al.,* 1989). Rice cultivation is most popular in the cropping pattern of the northern part of Egypt and is recommended to be involved in the crop rotations of salt affected soils (El-Mowelhi, 1993). Chaudhry *et al.,* (1998) found that, deep plowing (up to 45cm) concurrent with rice-wheat cropping practice led to reduce soil sodium adsorption ratio (SAR) of the surface layer (0-15cm) by 70% to be below safe limits (<13).

The present work was attempted to identify the effect of two digging depths using a sugar beet harvester (digger machine) equipped by couple straight shanks on the productivity of the following rice yield and its components, salt content in the soil profile, and some soil physical properties.

MATERIALS AND METHODS

A field experiment was conducted in a farmer's field at South of El-Husainia plain, Al-Sharqia Governorate during two successive years (winter season 2012/2013, summer season 2013 and winter season 2013/2014). The main aim of the study was to assess the effect of mechanized sugar beet harvesting at different digging depths on the productivity of rice crop, salt content, and some soil physical properties.

Experimental site and cultural practices:

The experimental site, as a part of South of El-Husainia plain, was first planted on the winter season of 2007 with continuous barley – rice – sugar beet cropping pattern. The field received irregular amounts of gypsum applications under open drainage system. Land productivity was low during its early planting stages and progressively increased up to about 2.5 and 20 ton/fed for rice and sugar beet crops, respectively. In winter season 2010/2011, a tile-drain system (0.80m depth and 15m apart) was installed. Before planting the sugar beet, 5 ton/fed compost and 2 ton/fed gypsum, were applied. Sugar beet seeds were conventionally planted (rows spacing ≈ 0.65m) on 19 September 2012 and was harvested on 21 March, 2013. The plot area was $50m^2$ and the total experimental area was about $3000m^2$. After harvesting the sugar beet (winter season 2012/13) using the proposed harvesting machine, experimental area was prepared conventionally for the rice crop grown during the summer season of 2013 (without puddling). Rice crop (Giza-178 cultivar) was sown in June and was harvested in September, 2013. During the winter season of 2013/14, sugar beet crop was planted in the same experimental area. All agronomic practices to cultivate rice and sugar beet crops at south El-Hussainia area were followed.

Soil sampling and analysis.

To achieve the objectives of current study, initial soil samples from the experimental site were collected before harvesting sugar beet crop, cultivated during the 2012/2013 winter season, at 15cm layer interval up to 60cm depth to determine the main soil physical and chemical characters according to Richards (1954). The analysis of the collected soil samples is presented in Table 1.

An evaluation to the soil physical properties was performed before harvesting sugar beet crop cultivated during the winter season of 2013/2014 (e.g., one year of using the digger machine to harvest the sugar beet). The following soil physical parameters were determined:

1-Bulk density (ρb) values were measured in middle of each layer, 15cm, to 60cm depth by the core method as described by USDA (1999).
2-Saturated hydraulic conductivity (Ks) values were determined with inverse auger-hole method according to Van Hoorn (1979).
3-Soil Penetration Resistances (SPR) values were measured at 7.5cm increment along the soil up to 60cm depth. Five locations per each plot were recorded by using hand-pushing penetrometer (Mark: BESTOOL KANON, Model: Daiki) with penetration speed of 1 cm s^{-1}.

Also, salt content (measured by electrical conductivity meter) in the different soil layers were determined.

Table 1. Mean values of the analysis of some chemical and physical properties of the initial soil samples collected from the experimental site.

Depth cm	Clay %	Silt %	Sand %	Texture	ρb g cm^{-3}	PR MPa	K (cm/day)
0-15	58.75	24.10	17.15	clay	1.41±0.02*	1.44±0.26	3.09±0.39
15-30	57.80	26.52	15.67	clay	1.44±0.01	2.24±0.52	
30-45	54.47	24.85	20.68	clay	1.45±0.01	2.99±0.42	
45-60	62.25	21.74	16.00	clay	1.39±0.01	2.96±0.39	
Depth cm	**OM %**	**$CaCo_3$ %**	**CEC $cmol_c$ kg^{-1}**	**pH (1: 2.5)**	**EC_e (dSm^{-1})**	**SAR**	**Moisture content**
0-15	1.40	7.47	43.40	8.42	8.48±1.26	17.21±2.09	29.80±4.64
15-30	0.95	8.89	42.12	8.35	10.92±2.25	19.60±2.80	33.71±4.83
30-45	0.87	5.56	40.16	8.15	8.39±1.61	17.70±3.08	33.90±4.48
45-60	0.34	7.22	45.22	7.97	13.69±1.61	23.14±2.50	40.05±3.28

***The numbers following ± indicate stander deviation. ρb : bulk density g cm^{-3}, PR : penetration resistance MPa, K : hydraulic conductivity cm/day, OM % : organic matter percent, $CaCo_3$ % : calcium carbonate percent, CEC : cation exchange capacity $cmol_c$ kg^{-1}**

Experimental design and tested treatments:

A split plot experimental design with three replicates was used to conduct the field experiment. The tested treatments were as follows:

Main plots represented mechanized harvesting depths:

D1: Conventional harvesting (farmer's method) using hoes.
D2: Mechanized harvesting with digging depth of 20-25cm.
D3: Mechanized harvesting with digging depth of 35-40cm.

Treatments were separated by 7m buffer zone to avoid overlapping during harvesting applications.

Subplots represented sampling distance from the tile drain:
A: 5.0-7.5m. B: 2.5-5m. C: 0.0-2.5m

Equipment specification:

Two types of tractors (Table 2) were used to operate and dragging the harvesting machine during the experimental period. *NEWHOLLAND* tractor was used for operating digger (lifter and cleaner) machine while

PELARUS tractor was used to perform all the conventional farm tillage practices.

Table 2. The main specifications of the used tractor:

Items	**Specifications**	
Model:	**NEWHOLLAND, 110-90**	**PELARUS, MTZ-80**
Power, kW:	89.55	59.70
Type:	4 - wheel drive	4 - wheel drive
Engine:	6 - Cylinder, Diesel.	4 - Cylinder, Diesel.
Mass, kg	4280	3370

SIMON digger machine equipped by couple straight shanks was used as beet harvester as shown in Figs. (1a &1b). As described by Salman *et al.,* (2014), SIMON digger (lifter and cleaner) includes a share of 140 cm long and 20 cm width and a vibrating fork fixed at the rear of the share containing two shafts on the straight line. On each shaft six iron bars (28 cm long) were fixed on the shape of fork. The vibrating fork moves up and down, it takes the motion from the tractor rear PTO of 540 rpm. Straight shank is fixed on each digger edges (behind centered of tires) on the same share level and the overall mass of machine is 320 kg.

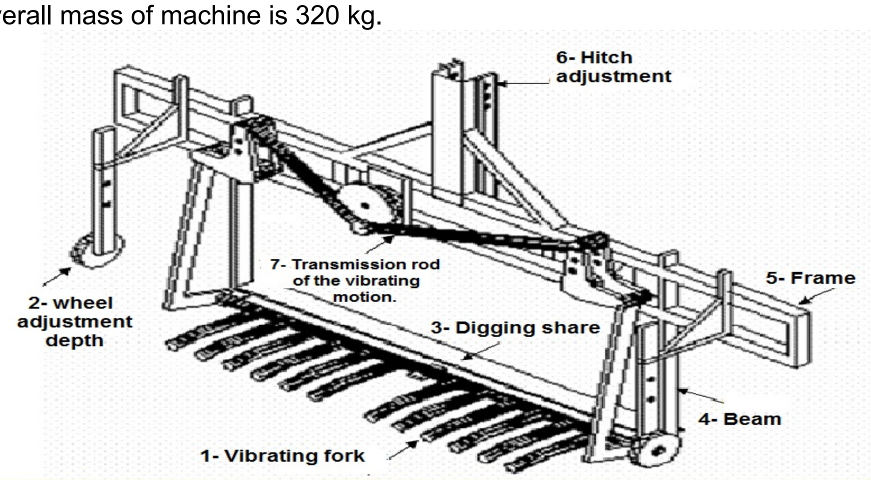

Figure 1a. Schematic diagram of the sugar beet digger.

Figure 1b. Sugar beet digger machine equipped by couple straight shanks.

Plant sampling and analysis.

For rice growth parameters analysis, 3 hills were sampled from each plot at 65, 80 and 95 days after sowing to measure plant height (from the plant base to the tip of the highest leaf), leaf area index, crop growth rate (CGR), and the aboveground total dry weight. At the harvest, panicles length (cm), number of panicles/m^2, 1000-grain weight, and grain yield were determined. The method of growth analysis was used to detect and calculate mean rate of change in plant weights (W_2 and W_1) observed at two sampling periods (t_2 and t_1) as affected by the studied treatments. The leaf area index (LAI) and crop growth rate (CGR) are calculated according to Nogueira *et al.,* (1994) as follows:

$$LAI = \frac{\text{Leaf area}}{\text{crop land area}}$$

$$CGR = \frac{(\text{w2} - \text{w1})}{(\text{t2} - \text{t1})}$$

Statistical analysis:

All the collected data for the rice grain yield, its components and growth parameters, and the soil physical parameters were subjected to the statistics analysis according to Snedecor and Cochran (1989) and the mean value were compared by LSD test at 5% probability level.

RESULTS AND DISCUSSION

Effect of treatments on salt contents in the soil profile

The effect of tested treatments on salt contents at different soil layers (0-60cm) as compared with the initial state is illustrated in Figs. (2&3). Results indicated that salt contents decreased significantly with increasing digging depth. For the D3 (digging depth of 35-40cm) treatment, salt contents decreased by 62.7, 58.4, 54.5, and 47.2% for the 2nd, 1st, 3rd and 4th layers, respectively as compared with the initial values Fig.(2). The corresponding values for D2 treatment were 50.2, 46.4, 30, and 24% for the 1st, 2nd, 4th and 3rd layers, respectively. On the other hand, the lowest decrease in salt contents were obtained with the D1 (conventional harvesting) treatment which reached to 19.9, 17.8, 0, and 7.1% for the 1st, 2nd, 3rd and 4th layers, respectively. These findings were in agreement with those obtained by Ali and Khater (2009), who reported that EC_e values decreased significantly below control treatment with different rates of decrease according to tillage system.

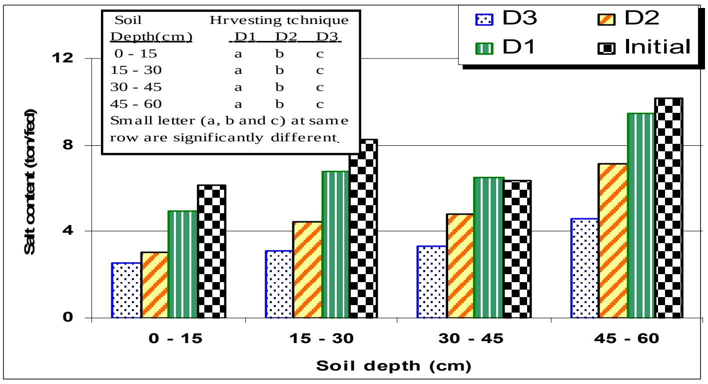

Fig. 2.Effect of digging treatments on salt contents at different soillayers.

Regarding the effect of distance from tile drain A, B, and C, Fig.(3) on salt contents in different layers (0-30 &30-60cm), results indicated a significant decrease in salt contents with decreasing the distance from the tile drain after implementing the harvesting digging treatments. Results revealed also that, salt contents at different layers were less than the initial state with an average of 43 and 28 % for the concerned layers, respectively.

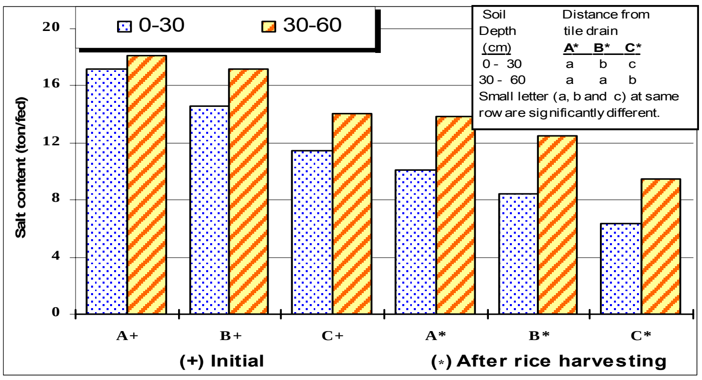

Fig. 3. Effect of the distance from tile drain treatments on salt contents at different soil layers.

The effect of treatments on the amounts of salt removed from the soil profile is illustrated in Fig.(4). Results indicated that the amounts of salts removed from soil profile significantly increased with increasing the digging depth (e.g. D3 treatment) and with increasing the distance from the tile drain (e.g. A treatment). For the deepest digging D3 treatment (35-40cm), amounts of salts removed were 5 and 3.5 times more than the conventional (D1) and D2 (20-25cm) treatments, respectively. These finding could be explained according to Unger (1979), Van Hoorn (1984), Chen et al., (2013), and Salman et al., (2014) on the basis of the management work of couple straight shanks fixed on both sides of digging share of the digger machine (sugar beet harvesting) and the vibration fork which may modified cracks regime in the soil. In addition, break down the plow pan layer (15-30cm) of relatively higher density and EC_e values (as compared with the tilled layer), besides, fracturing or smashing the soil blocks and lumps into small units. Therefore, such mechanism may cause greater soil aeration, insulation and more uniform distribution between plant residues and clay particles that led to better contact between water and soil during rice-flooded irrigation, consequently, considerable salt removals within 60cm depth of the digging treatments comparing with the conventional method (Fig. 4). These results are supported by findings of Unger (1979) and Bahner (1999) who reported that 40 and 60cm deep plowing loosened parts of slowly permeable soil layer, which resulted in a much greater leaching and faster reclamation of upper soil layers as result of modifying infiltration rate of a sub-soiled land than that of shallow plowed layer.

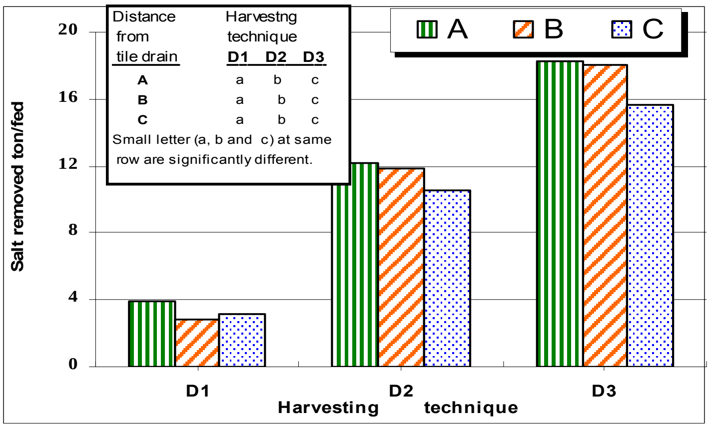

Fig. 4. Effect of the tested treatments on amounts of salts removed from the soil profile.

Effect of treatments on some soil physical properties

Soil bulk density (ρb).

Results showed that, soil *ρb* significantly decreased with increasing the depth of digging as well as decreasing the distance from tile drain (Table 3). Soil *ρ*b values measured under the tested treatments were less than the values of the initial conditions. For the surface layer (0 - 15cm), average of soil *ρ*b value for D2 treatment was significantly less than the values for D1 and D3 treatments indicating the limited effect of the shallow digging treatment to the surface 15cm. For the subsurface layers (15 - 60cm), soil *ρ*b values for the D3 were significantly less than the same values for the D1 and D2 treatments. Mean *ρ*b values were 1.420, 1.379, and 1.352 g/cm^3 for D1, D2, and D3 treatments, respectively. These values were 0.11, 3.1, and 5.1% less than the soil *ρ*b values at the initial conditions. The obtained results indicated that, the digging depth treatments usually loosens and inverts soil, thereby forming more macropores under the tested treatments than under the conventional harvesting system. These findings correspond directly with both saturated hydraulic conductivity values (Table 4) and soil penetration resistance values (Fig. 5), where Ks values were high and SPR values were less in D3 treatment than all other treatments because of greater soil loosening and manipulation under the deep digging system. Results in Table 3 indicated also that, soil *ρ*b values for the C plots were significantly less than the same values for the B and A treatments. Mean soil bulk density values were 1.399, 1.383, and 1.369 gcm^3 for the A, B, and C plots, respectively. These values were 2.3, 2.8, and 3.1% less than the corresponding soil *ρ*b values of 1.43, 1.383 and 1.369 at the initial conditions (data not shown). The interaction effect between digging depth and distance from the tile drain treatments indicated that the D3C had the best effect on decreasing the soil *ρ*b values. Overall, these findings widely agreed with results found by ÇELİK (2011), who indicated in heavy clay soil under semi-arid conditions that bulk density of the 20-30cm depth was greater compared to that of 0-10 cm and 10-20 cm depths. The results agreed also with those reported by Martı´nez et al., (2008). They found that soil bulk density was significantly affected by the interaction between soil depth and tillage system. The obtained results were in line with the results of a 2-year field experiment by Abdelgawad et al., (2004) which showed that deep plowing of 50 cm depth breaks the hard pan and decreased the density of the soil, hence increasing the macro-pores of soil surface compared to normal plow of 25cm.

Table 3. Effect of treatments on soil bulk density (g/cm^3).

Treatments	Soil depth (cm)				Mean
	0-15	15-30	30-45	45-60	
I. Effect of digging depths:					
D1	1.394^a	1.447^a	1.450^a	1.389^a	1.420
D2	1.318^c	1.367^b	1.442^b	1.388^a	1.379
D3	1.328^b	1.344^c	1.360^c	1.377^b	1.352
Π. Effect of distance from tile drain:					
A	1.364^a	1.407^a	1.431^a	1.393^a	1.399
B	1.344^b	1.385^b	1.418^b	1.385^b	1.383
C	1.331^c	1.365^c	1.404^c	1.377^c	1.369
ΠI. Interactions effects between digging depths & distance from tile drain:					
D1A	1.406a	1.459a	1.458a	1.396a	1.430
D1B	1.394b	1.449b	1.453a	1.390b	1.422
D1C	1.382c	1.433c	1.439cd	1.382c	1.409
D2A	1.339e	1.390d	1.451ab	1.395a	1.394
D2B	1.313g	1.362f	1.444bc	1.389b	1.377
D2C	1.303h	1.348g	1.432d	1.382c	1.366
D3A	1.348d	1.371e	1.383e	1.388b	1.373
D3B	1.327f	1.345g	1.358f	1.378d	1.352
D3C	1.308g	1.315h	1.339g	1.366e	1.332

Values in a same column followed by different letter are significantly different

Saturated hydraulic conductivity (Ks).

Soil Ks was significantly affected by the depth of digging and was greatest in D3 than in D2 and D1 (Table 4). Mean soil Ks values were 3.29, 4.26, and 6.34 cm/day for D1, D2, and D3 treatments, respectively. The significant increase in Ks values in the mechanized digging plots is related to soil loosening, greater porosity, and better pore continuity than in the traditional harvested plots. Results indicated significant effect to the space from tile drain on Ks values. The Ks values close to the tile drain were significantly different than those far from the drain. Mean soil Ks values of D3 were 5.04, 6.72, and 7.25 cm/day for A (far from tile drain), B, and C (close to the tile drain) treatments, respectively. Results showed also that, mean Ks values after one year of applying the treatments were 50% more than the mean Ks value at the initial conditions. The findings associate directly with the SPR results presented in Figure 5 where soil compaction values were less in D3 and D2 treatments (mechanized digging) than in D1 (traditional harvest) plots. These results agreed with those of Rao et al., (1960) and Mannering *et al.,* (1966).

Table 4. Soil hydraulic conductivity, Ks (cm/day) as affected by the tested treatments.

Treatments	A	B	C	Mean
D1	3.02 h	3.28 g	3.57 f	**3.29 c**
D2	3.64 f	4.29 e	4.83 d	**4.25 b**
D3	5.04 c	6.72 b	7.25 a	**6.34 a**
Mean	3.90 c	4.76 b	5.22 a	4.63
Initial	2.77	3.08	3.41	3.09

Soil Penetration Resistances (SPR).

The effect of treatments on soil SPR is illustrated in Figures 5, 6a, 6b, and 7. Results indicated that, there were no differences between SPR values at initial stage and the D1 traditional harvesting method (Figure 5). The deepest digging treatment (D3) showed the smallest SPR values especially in the 20 to 45cm depth. There was no effect of the tested treatment at 60cm depth from soil surface. Lower SPR with the D3 treatment in the 20 to 45cm depth is likely the result of digging-induced soil loosening caused by deeper penetration of digger implement.

Figures 6a and 6b showed soil penetration resistance values, measured at initial stage and at the end of the experiment, as affected by distance from the tile drain. Results indicated that, maximum SPR values at initial stage (2.5 to 3.5Mpa) were higher than the maximum values (2.5 to 3MPa) after implementing the treatments. It was clear that, SPR values close to the drain (drier conditions) were higher than those far from the drain (wetter conditions).

The interaction effect of digging depths and distance from the tile drain on soil penetration resistance values are presented in Figure 7. Results indicated, in general, that the SPR values increased with depth. There were no effects of the tested treatments on SPR values at 60cm depth. SPR in the A plots (far from tile drain) averaged 1.9, 1.97, 1.5, and 1.43MPa for initial, D1, D2, and D3 treatments, respectively. The respective values for the B plots (middle distance from the drain) averaged 2.41, 2.34, 2.03, and 1.64 MPa, whereas the mean SPR values in the C plots (close to the tile drain) were 2.7, 2.61, 2.26, and 1.93MPa. Similar trends were reported by Ballantyne (1983), El-Shanawany *et al.,* (2000), Azhar *et al.,* (2001), Adeyemo and Agele (2010) and Milani *et al.,* (2011). They indicated that, deep plowing beside amendments applications are considered the most effective mechanical manipulation methods to counter soil compaction and the unfavorable conditions of salt affected soils.

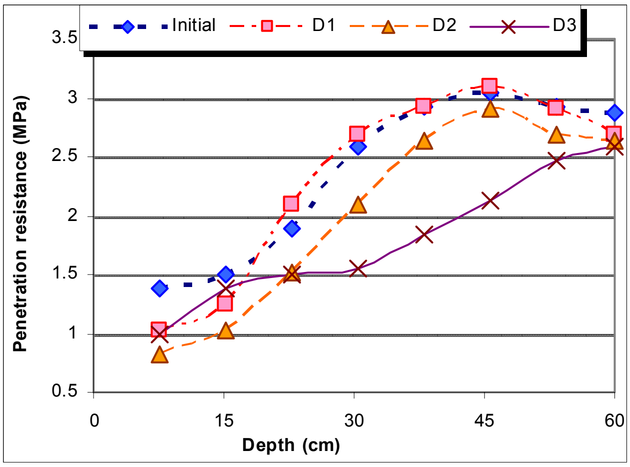

Figure 5. Effect of harvesting digging depths on soil penetration resistance.

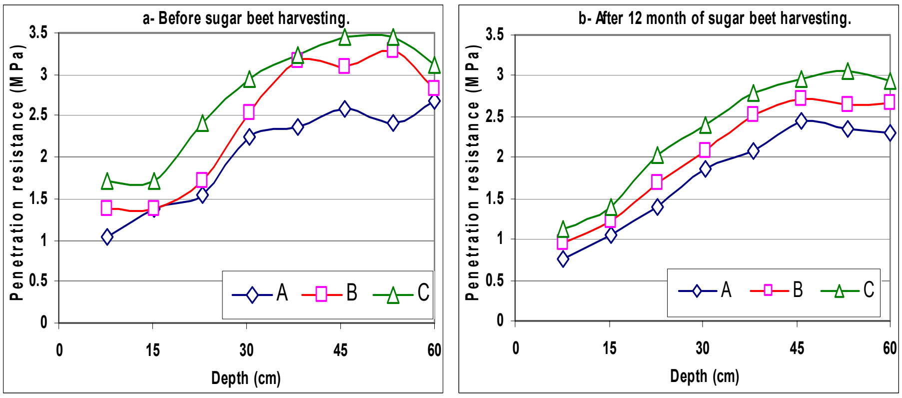

Figure 6(a & B). Soil penetration resistance values as affected by the distance from the tile drain (a- initial stage & b-final stage).

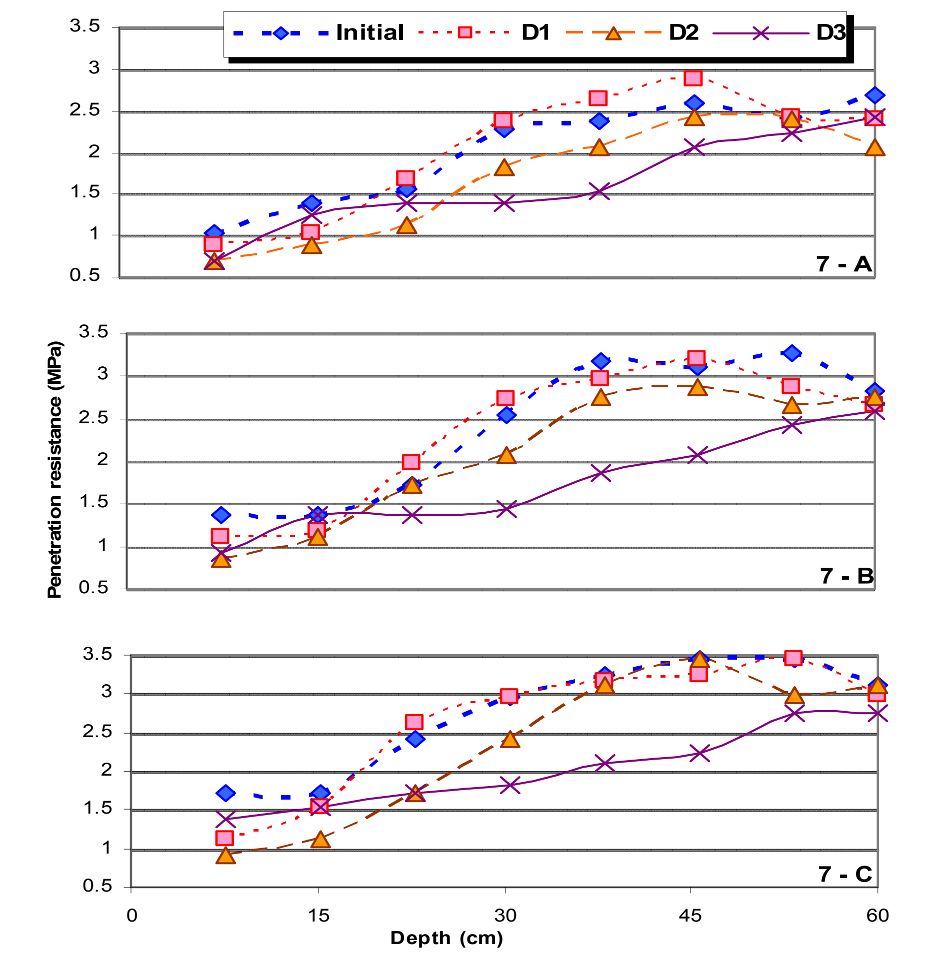

Figure 7. The interaction effect of the tested treatments on SPR values.

Effect of treatments on rice yield, its components, and growth parameters

Results indicated significant effect of the treatments on all measured parameters (Table 5). Increasing the digging depth from shallow depth (D1) to deep depth (D3) significantly increased the grain yield from 2.95 to 3.43 ton/fed. Also, rice plants close to the tile drain (C) produced rice grain yield of 3.27 ton/fed which is significantly higher than that produced in area far from the tile drain (3.08 ton/fed). The similar trend was also obtained for the crop growth rate, leaf area index, plant height, panicle length, no of panicle/m^2, and the 1000 grain weight. The interaction effect between the digging depths and the distance from tile drain indicated that the D3C treatment gave significantly higher values for rice grain yield, yield components, and growth parameters. These results may be attributed to deep loosening and soil modification occurred by the digging depths while harvesting the sugar beet crop that break down the compacted soil layer and fractured soil blocks into small particles, consequently, facilitated a better water interpenetration through disordered layers, due to flooding irrigation during rice season, which resulted in reducing salt contents of the plowed depth as result of improving the leaching process. The generated conditions stimulated both root proliferation and plant growth which had a direct effect on crop yield and its attributes (Alam *et al.,* 2013 and Zayed *et al.,* 2014).

Table (5). Effect of tested treatments on rice yield, its components, and growth parameters.

Treatment	Plant parameters						
	CGR	LAI	PLH	PAL (cm)	PAN /m^2	10^3 GW(g)	GY ton/fed
I. Effect of digging depths:							
D_1	29.63^b	4.27^c	90.44^c	18.21^c	468.11^c	18.54^c	2.954^c
D_2	29.68^b	4.35^b	93.33^b	19.31^b	488.78^b	19.53^b	3.124^b
D_3	31.32^a	4.40^a	95.33^a	20.66^a	512.22^a	21.62^a	3.434^a
Π. Effect of distance from tile drain:							
A	29.68^c	4. 29^c	91.33^c	18.99^c	479.78^c	18.84^c	3.078^c
B	30.28^b	4.34^b	92.89^b	19.37^b	489.56^b	19.97^b	3.161^b
C	30.67^a	4.38^a	94.89^a	19.82^a	499.78^a	20.88^a	3.273^a
ΠI. Interactions effects between digging depths & distance from tile drain:							
D_1A	29.22^h	4.18^f	88.33^{ns}	17.87^i	457.67^i	17.48^h	2.818^h
D_1B	29.81^e	4.28^e	90.00^{ns}	18.13^h	470.00^h	18.89^f	2.926^g
D_1C	29.87^e	4.33^d	93.00^{ns}	18.63^g	476.67^g	19.26^e	3.118^e
D_2A	29.36^g	4.32^d	92.00^{ns}	18.87^f	482.67^f	18.55^g	3.043^f
D_2B	29.67^f	4.36^c	93.00^{ns}	19.43^e	489.33^e	19.19^e	3.122^e
D_2C	30.00^d	4.38^b	95.00^{ns}	19.63^d	494.33^d	20.83^c	3.206^d
D_3A	30. 45^c	4.37^{bc}	93.67^{ns}	20.23^c	499.00^c	20.47^b	3.374^c
D_3B	31.35^b	4.39^b	95.67^{ns}	20.53^b	509.33^b	21.84^b	3.433^b
D_3C	32.15^a	4. 43^a	96.67^{ns}	21.20^a	528.33^a	22.55^a	3.495^a

*** CGR= Crop growth rate; LAI= Leaf area index; PLH= Plant height; PAL= Panicle length; PAN= no of panicle/m^2; GW= grain weight; GY= Grain yield.**

CONCLUSIONS

Sustainability and amelioration of salt affected as well as increasing its productivity could be attained by using considerable soil managements techniques. The obtained results suggested that using the harvester digger machine equipped with couple straight shanks had significant effects on improving soil characteristics and directly stimulated plant growth parameters which reflected on inducing soil and rice crop productivity.

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تأثير أعماق حصادة بنجر السكر على بعض خواص الأراضى المتـأثرة بـالأملاح ومحصول الأرز

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أجريت تجربة حقلية بحقل أحد المزارعين في جنوب سهل آلحسيينيه- محافظة الـشرقية - مـصر مـن الموسم الشتوى ٢٠١٢/٢٠١٣ وامتدت حتى الموسم الشتوى ٢٠١٣/ ٢٠١٤. وكان الهدف الرئيسي من هذه الدراسة هو تقييم تأثير الحصاد الالى لبنجر السكر بأعماق حفر مختلفة على بعض خواص الاراضى المتـأثره بـالاملاح (محتـوى الاملاح وبعض الخصائص الطبيعية للتربة) وكذلك على إنتاجية محصول الأرز. وقد استخدام لاجراء التجربة تـصميم قطع منشقة من الدرجة الاولى مع ثلاث مكرارت. حيث تمثل القطع الرئيسية أعماق الحصاد (D1: الحـصاد التقليـدي (طريقة المزارعين) باستخدام المعاول، D2: الحصاد الآلي مع عمق الحفر من(٠,٢٠-٠,٢٥ متر) وD3: الحصاد الآلي مع عمق الحفر من (٠,٣٥-٠,٤٠متر). وتمثل القطع المنشقة المسافة من الصرف المغطى (A: ٥,٠ -٧,٥متر، B: ٢,٥ - ٥متر و C: ٠,٠ - ٢,٥متر). وتضمنت قياسات الخصائص الطبيعية للتربة قياس الكثافة الظاهرية (*ρb*)، التوصـيل الهيدروليكي (Ks)، مقاومة التربة للاختراق (SPR). اما بالنسبة لمحصول الأرز، تم أخذ القياسات التالية: محصول الحبوب ، وطول السنابل (سم)، وعدد السنابل / م٢ ، ووزن ١٠٠٠ حبة، طول النبات، دليل مـساحة الورقـة (LAI)، معدل نموالمحصول (CGR). وقد أشارت النتائج الى أنخفاض معنوى لمحتوى الاملاح بطبقات التربة المختلفـة مـع زيادة عمق الحفر، بينما كان لكمية الأملاح المزالة اتجاه عكسى. كانت الأملاح إلمزاله بالمعاملة D3 ٥ و ٣,٥ ضعف من المعاملات D1 و D2 على التوالي. وبالمثل، أستجابة قيم الكثافة الظاهرية (ρb) ومقاومة التربة للاختراق (SPR) سلبيا مع زيادة عمق الحفر. وكان الانخفاض في متوسط قيم *ρb* مقارنة مع قيمتها الأولية يمثل ٥,١ ، ٣,١ ، و ٠,١١ ٪ للمعاملات D3، D2 وD1، على التوالي. كما تزداد قيم مقاومة التربه للاختراق مع تناقص المسافة مـن الـصرف المغطى ، بينما كانت هذه القيم تتناسب طرديا مع القيم التوصيل الهيدروليكى للتربة (Ks) التي ازادت بنحو ١,٥ ضعف قيمتها الاولية. أدى زيادة عمق الحصاد من المعاملة D2 إلى D3 الى زيادة قيمة (Ks) بنحو ٤٩٪. ولذلك فأن تحسين الخواص الكميائية والطبيعية للتربة نتيجة لزياده الحفر حفز معنويا إنتاجية الارز (زيادة إنتاجية محصول الحبوب الأرز بنحو ١٦٪) وكذلك مكونات المحصول وعوامل النمو.