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### **DRAINAGE IN HEAVY CLAY SOIL AND SUGAR BEET YIELD IN EASTERN NORTH DELTA**

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**ABSTRACT** Sugar beet (Tribal variety) was cultivated in the winter season of 2004/05 in a previously established experimental drainage field at El-Serw Farm, Agricultural Research Station northeastern delta of Egypt near El-Manzala Lake. The experiment included three drain spacing treatments 15, 30, and 60m. The aim was to assess and evaluate the effects of drainage treatments and soil conditions and the extent of their impact on sugar beet yield. The results reveal that, five days after irrigation, the water table levels were 69, 44 and 39 cm and reached 110, 92 and 75 cm before the next irrigation for 15, 30 and 60 m drain spacing treatments, respectively. The water table depth varies depending on the drain spacing. In all layers, the hydraulic conductivity values were higher in 15 m drain spacing treatment than those in 30 or 60 m drain spacing treatments. Soil salinity ( $EC_e$ ) values were relatively affected by drain spacing treatments. In surface layer, the soil salinity value was 3.4, 4.1 and 5.3 dS/m for 15 m, 30 m and 60 m drain spacing treatments, respectively. Results indicate that spacing treatments highly affect sugar beet root diameters and lengths and consequently crop yield. Root diameters increased with decreasing drain spacing; average maximum root diameter was 32 cm, 26 cm and 20 cm for 15 m, 30 m and 60 m drain spacing treatments, respectively. There was an increment in sugar beet production with narrow drains spacing treatments; the yield being 34, 30 and 25 ton/feddan for 15 m, 30 m and 60 m drain spacing, respectively. (1 feddan= 4200m<sup>2</sup>)

**Keywords:** Drainage, Water table fluctuation, Soil properties, Sugar beet yield.

**INTRODUCTION** Nowadays, sugar beet is an important crop for manufacturing sugar for complementary national provisions of sugar in Egyptian market. Sugar beet provides about 40% of the world's sugar production (Abd-el-Hadi et al., 2002). Many investigators studied factors related to sugar beet yield such as Eara (1990), Hammond (1992) and el-Sayed (1997). Sugar beet in Egypt has a considerably higher sugar content and short growth period compared with sugar cane. Furthermore, consumed water by sugar beet to produce one ton of sucrose is about 1300 m<sup>3</sup>, whereas sugar cane needs about 4000 m<sup>3</sup> of water to produce the same quantity of sucrose. Sugar beet is widely grown in areas with salinity problems. Sugar beet could be grown in new reclaimed areas in north delta of

Egypt. Recently, great attention was paid to increase sugar beet productivity in these areas (Eisa, 1997).

Drainage plays a vital role in low permeable clay soils in order to prevent soil degradation. In Egypt, northern part of the Nile Delta represents large area of heavy clay soils with low permeability that might have a potential production. These soils are always threatened by a shallow saline groundwater, which is a permanent source of soil salinization that causes poor productivity. The present study is conducted in a drainage experimental field, northeastern Nile Delta, where previous studies were fulfilled to improve crop production under saline groundwater. The obtained results through ten years in consecutive research phases realized soil improvement leading to soil health and they have been summarized by Moukhtar and El-Hakim (2004). Although sugar beet is considered a salt tolerant crop, it is important to evaluate its behavior under more favorable soil conditions.

The present study aims to assess and evaluate the effects of drainage treatments and soil conditions and the extent of their impact on sugar beet yield.

**MATERIALS AND METHODS** A research site (20 feddens) was established at El-Serw Research Station Farm near lake El-Manzalla, El-Dakahlia Governorate. The soil profile represents the alluvium marine deposits. The clay content varies between 42 and 66 %. The soil is low permeable ( $K=0.0669$  m/day). The average of water table depth before constructed the tile drainage was 65 cm with an EC of 25 dS/m and SAR of 33. In 1995, this research area was provided by tile drainage system at 150 cm drain depth with three different drain spacing. Before installing the tile drainage system, a soil profile was dug down to 150 cm and defined its morphological description in details by Abd El-Aal, (1995) and it presented in table (1). Ten year later (2005) form installing the tile drainage system including three drain spacing treatments 15, 30, and 60m., three soil profiles representing the drain spacing treatments were described morphologically according to FAO (1990) and soil taxonomy were carried according to Soil Survey Staff (1996). Sugar beet (Tribal variety) was cultivated in the winter season of 2004/05; the normal agricultural practices for sugar beet were used. Water table position through an irrigation interval was measured in piezometers placed midway between drains according to Ritzema (1994). The hydraulic conductivity in consecutive layers was measured by inversed auger-hole method according to Van Beers (1979). Soil samples were collected every 30 cm up to 120 cm soil depth in each drain spacing treatment. Soil salinity and soluble ions were determined in soil saturation extract according to Page et al. (1982). At the end of the season, sugar root yield was determined in each treatment. The Average sugar beet yield was calculated for each treatment.

## **RESULTS AND DISCUSSIONS**

**Morphological Watertable Depth Zone Description** For the area before installation drainage treatments, a morphological study is shown in table (1). The morphological features change depending on the depth of water table, soil parent material, soil texture, soil salinity and drainage conditions. The soil profiles are rich in shell fragments, many forms of gypsum crystals especially in subsurface and deep layers. The gleyed pockets are common in the water table fluctuation zone. The mottle color differs in value and chroma than the soil matrix color. Gleyization process and mottles is common features water table fluctuation zone due to the effect of shallow water table depth, free iron and

manganese oxides and soil texture. Under ineffective shallow open drainage conditions before installation deep tile drainage, the gleyization process started in the capillary fringe above the water table near the subsurface layers at 50 cm soil depth. The obtained results indicated that the morphological water table depth and its fluctuation vary depending on the long-term water table depths in the different treatments. For this condition, the boundaries of morphological distinct zone were shallow and narrow ranging between 50 and 60 cm (Abdel-Aal, 1995)

**Table 1: Soil Morphological studies for site without drainage**

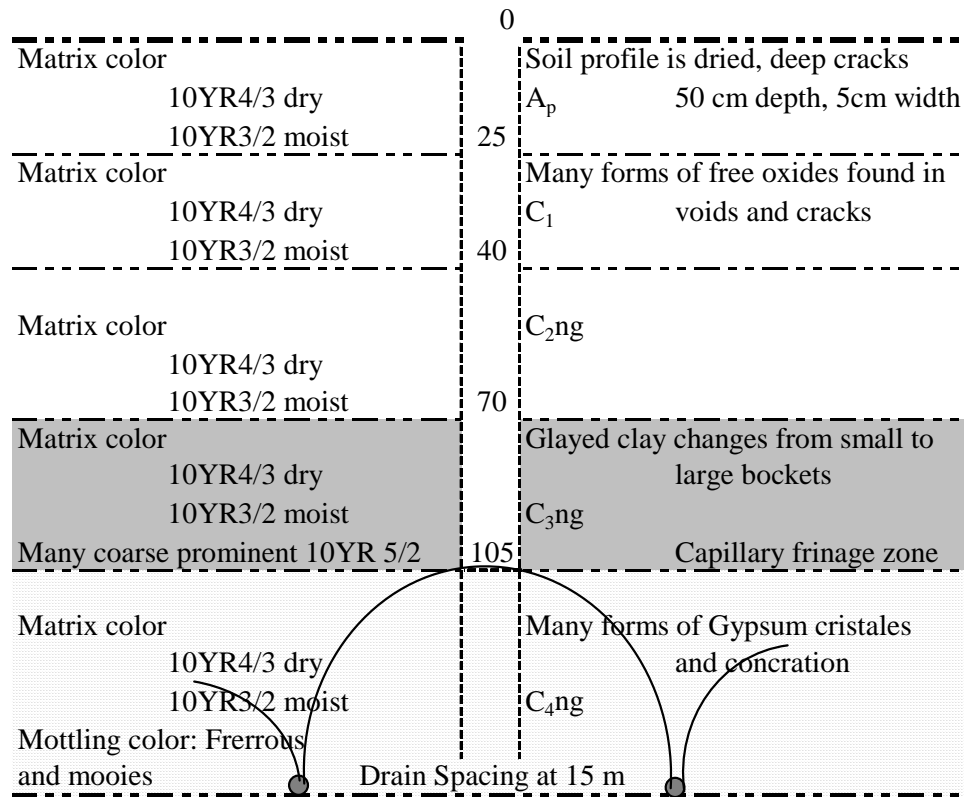
Soil classification	Aquic chromuderts, fine, montmorillonitic, thermic.
<b>Land form</b>	El-Serw Agriculture Station Farm, El-Gamalia, Dakahlia.
I-Physiographic Position.	Plain.
II-Land form of surrounding	Almost flat
III-Microtopography	Gilgai
Slope	Flat
Elevation	Zero level.
Land use	Arable land with Barseem.
Soil climate	Aquic and thermic.
Parent material	Alluvium and marine deposits.
Watertable depth	60 cm. after equilibrium.
Drainage class	Poorly drained
Human influence	Good farm management with good open drainage systems

<b>Depth layer</b>	<b>Description</b>
0-30 cm	Dark brown (10YR3/3) dry, very dark greyish brown(10YR3/2) moist; few fine faint pale brown (10YR6/3)humus mottles, clay; strong medium sub angular blocky structure; cracks (3 cm in width and 30 cm depth); many fine to medium tubular pores; very sticky, very plastic, extremely firm, very hard, abundant fine and medium roots; few fine lime nodules; few concretion of gypsum; slight effervescence with HCl; pH 8.4; gradual smooth boundary.
Apn	
30-60 cm	Dark greyish brown (10YR4/2) dry, very dark greyish brown (10YR3/2) moist; many coarse prominent light brownish grey (10YR6/2) ferric mottles; small pockets of gleyed clay; clay; strong medium sub angular blocky structure; many fine and medium tubular pores; sticky, plastic, firm, hard; few fine lime nodules; few small shell fragments; few concretion of gypsum; slight effervescence with HCl; pH 8.3; gradual irregular boundary.
C1n	
60-90 cm	Brown (7.5YR5/4) dry, dark greyish brown (10YR4/2) moist; abundant coarse prominent greyish brown (10YR5/2) ferrous mottles, large pockets of gleyed clay, clay; sticky, slight plastic, firm, hard; few fine and very fine lime nodules coating by ferrous oxides; few fine soft concretion of iron and manganese; few small shell fragments; few concretion of gypsum; slight effervescence with HCl; pH 8.2; gradual irregular boundary.
C2ng	
90-120 cm	Brown (7.5YR5/4) dry, dark greyish brown (10YR4/2) moist; abundant coarse prominent greyish brown (10YR5/2) ferrous mottles, large pockets of gleyed clay; clay; sticky, plastic, firm, slightly hard; few very fine iron oxides nodules; few coarse goldish lens of mica crystals; few very fine nodules of lime; few small shell fragments; few gypsum crystals; slight effervescence with HCl; pH 8.2; gradual irregular boundary.
C3ng	
120-150cm	Brown (7.5YR5/4) dry, dark greyish brown (10YR4/2) moist; common medium prominent greyish brown (10YR5/2) ferrous mottles, large pockets of gleyed clay; clay; sticky, plastic, firm, slight hard; very few fine and very fine soft concretion of

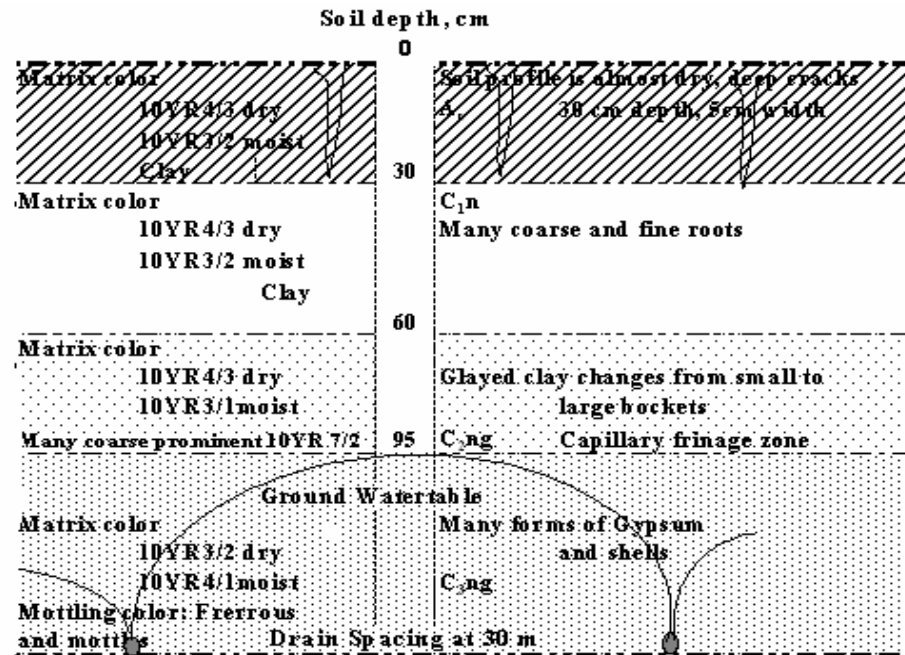
C4ng iron; many coarse goldish lens of mica crystals; very few lime nodules; very few small shell fragments; slight effervescence with HCl; pH 8.2.

Whereas tile drain treatments installed, the morphological description showed that the depth of water table fluctuation zone was wider and deeper. In the arid circumstances, the upper boundaries of morphological water table fluctuation zone are 50, 60 and 75 cm, while the lowers boundaries are 80, 95 and 110 cm in 60, 30 and 15 m drain spacing treatments, respectively. Hence, morphological water table fluctuation zone ranges between 30 and 35 cm for all treatments. The morphological features due to iron and manganese oxides are the main component found in the water table fluctuation zone in the different treatments. These components with secondary formation of gypsum crystals affect the soil color, mottling and glieization phenomenon. The solubility of iron and manganese oxides is changeable and moving during fluctuation periods. In the dry conditions, they start to precipitate at the fluctuation zone through pores and cracks. Based on the aforementioned discussions, it could be concluded that the water table fluctuation zone is characterized by certain features differ from the other layers. The water table fluctuation zones are pedal, contain high amount of gypsum crystals and free iron oxides, found in different forms (concretions and coatings). The soil is characterized by low chroma ped interiors due to migration of iron and manganese oxides and filled air planner voids and pores. The morphological water table depth and its fluctuation zone form a gray and clear smooth boundary (Figure 1).

**(a) Drain Spaced at 15 m.**



(b) Drain Spaced at 30 m.



(c) Drain Spaced at 60 m.

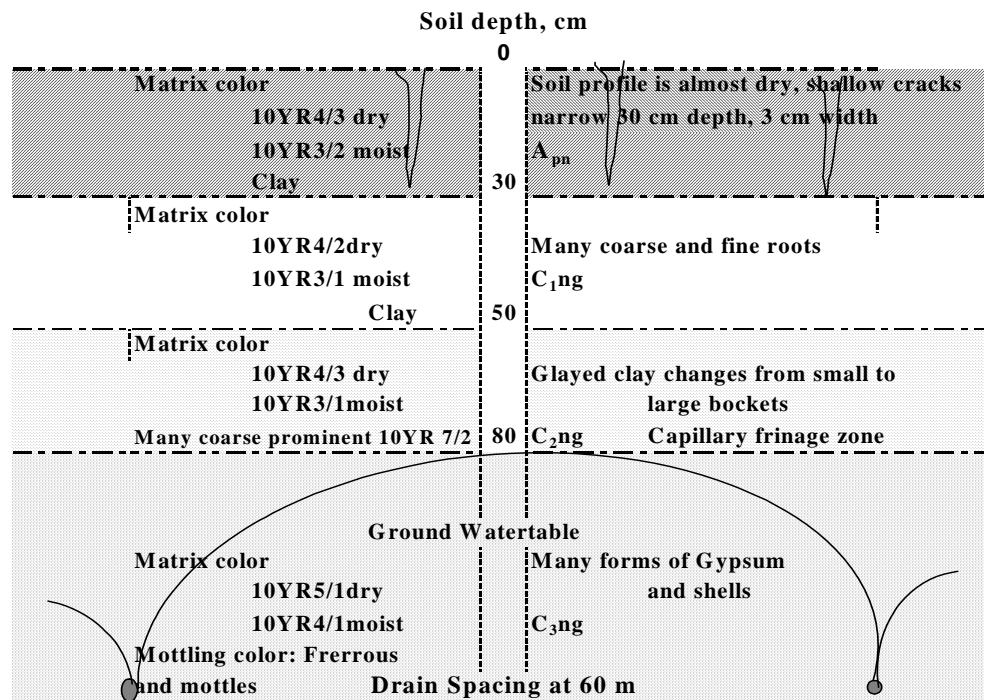


Figure 1. Watertable zone inspection and morphological profile description for different tile drains spacing: (a) for 15 m, (b) for 30 m and (c) for 60 m drain spacing .

**Water Table Fluctuation** The water table depth through irrigation interval is shown in Figure 2. Five days after irrigation, the water table levels were 69, 44 and 39 cm and reached 110, 92 and 75 cm before the next irrigation for 15, 30 and 60 m drain spacing treatments, respectively. The water table depth varies depending on the drain spacing. According to the morphological features, Abdel-Aal (1995) defined the boundaries of water table fluctuation zone in the same field. He stated that there were two boundaries of water table fluctuation zone between irrigation cycles. The upper boundary is at the highest level of water table and the lower one is at the deepest level. Also, he stated that the distance between the two boundaries varied according to drain spacing, being wider and deeper in the narrow spacing. Its width was 45 cm under 15 m drain spacing and 30 cm under 30 or 60 m drain spacing.

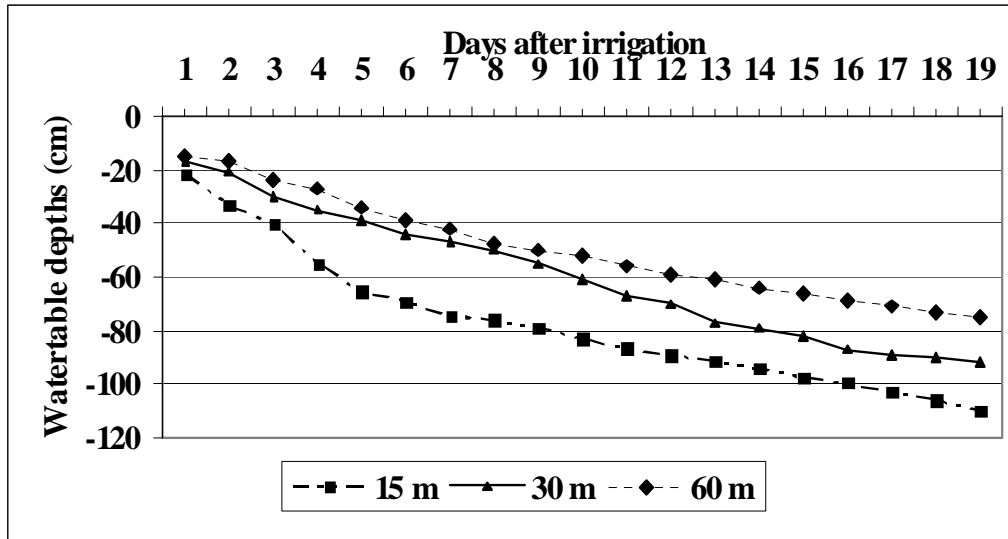


Figure 2 Fluctuations of water table depth through irrigation interval under different drain spacing treatments.

**Soil salinity** Salinity and chemical compositions in the root zone are shown in Table 1. Soil salinity ( $EC_e$ ) values were relatively affected by drain spacing treatments. In surface layer, the soil salinity value was 3.4, 4.1 and 5.3 dS/m for 15 m, 30 m and 60 m drain spacing treatments, respectively. There was no change in soil salinity between surface (0-20 cm) and subsurface layer (20-40 cm). Regarding soil chemical analysis, data in figure (3) indicated that chloride ions exceed sulphate and bicarbonate was the least ions; for cations ions, it was noticed that sodium was the dominant ions in soil solution; magnesium exceeds calcium ions and potassium was the least ions in soil solution.

Table 1. Soil chemical analysis in the root zone under different drainage treatments.

Drain spacing	Depth, cm	SP	EC dS/m	Anions (meq/L)				Cations (meq/L)			
				CO <sub>3</sub>	HCO <sub>3</sub>	CL	SO <sub>4</sub>	Ca	Mg	Na	K
15 m	0-20	97	3.4	....	2.2	20.1	14.4	3.2	6.0	27.1	0.4
	20-40	98	3.5	....	2.3	20.5	15.0	3.7	6.2	27.5	0.4
30 m	0-20	81	4.1	....	3.2	26.3	12.8	4.2	8.1	29.5	0.5
	20-40	78	4.2	....	3.3	28.6	12.8	4.6	10.2	29.4	0.5
60 m	0-20	98	5.3	....	4.5	38.3	12.5	6.4	12.1	36.2	0.6
	20-40	98	5.5	....	4.6	41.2	13.8	7.8	14.4	36.8	0.6

**Hydraulic Conductivity** Data of hydraulic conductivity are shown in Figure 3. Generally, results indicated that the hydraulic conductivity values in the surface layers (0-30 cm) are relatively higher than those in the subsurface layers. Results could be attributed mainly to the different tillage practices in root zone. In all layers, the hydraulic conductivity values were higher in 15 m drain spacing treatment than those in 30 or 60 m drain spacing treatments

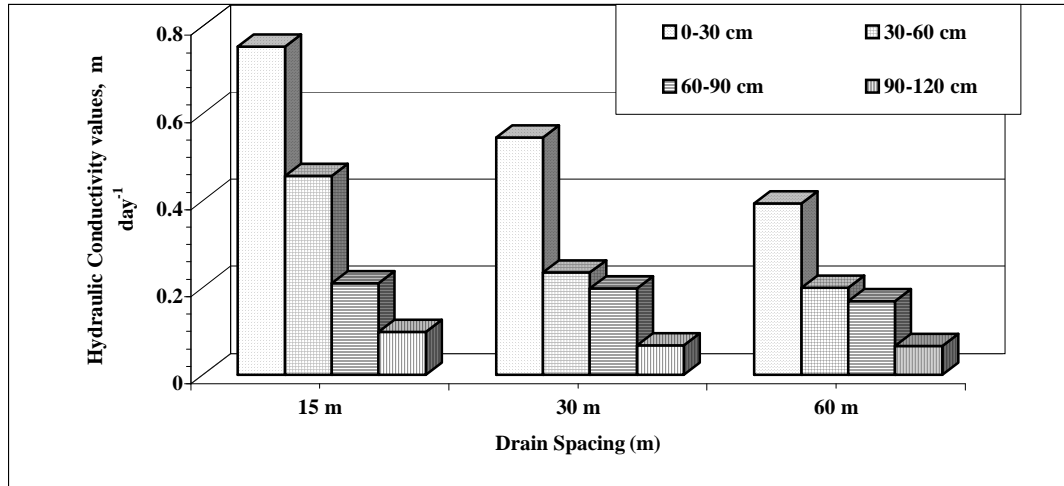


Figure 3a. Hydraulic conductivity in different soil layers in relation to drain spacing.

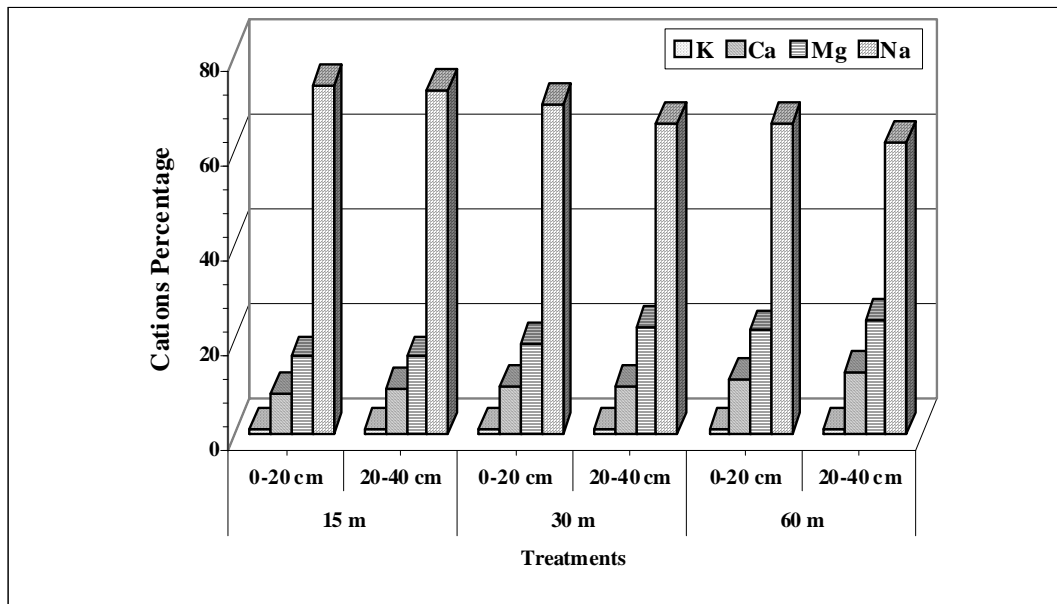


Figure 3b. Cations percentage in soil saturation extracts under different drain spacing treatments in the root zone.

**Sugar Beet Plant Characteristics and Yield** Root shape of sugar beet and its length and diameter as affected by drain spacing treatments is presented in Figure 4. Results indicate that spacing treatments highly affect sugar beet root diameters and lengths and consequently crop yield. Root diameters increased by decreasing drain spacing; average maximum root diameter was 32 cm, 26 cm and 20 cm for 15 m, 30 m and 60 m drain

spacing treatments, respectively. For main root, the average maximum lengths were 42, 30 cm and 21 cm for the same previous mentioned treatments. Regarding root tails, it is noticed that the average maximum root tails increased with decreasing the spacing between tile drains; the average maximum root tails reached 90 cm depth for drain spacing 15 m, 75 cm depth for 30 m spacing and 45 cm depth for 60 m drain spacing.

Regarding sugar beet crop yield, data indicated that drain spacing treatments affect clearly sugar beet production. Data in Figure 5 shows the average sugar beet yields in relation to soil salinity and water table depth in the different treatments. Results showed that there was an increment in sugar beet production with narrow drains spacing treatments; the yield being 34, 30 and 25 ton/feddan for 15 m, 30 m and 60 m drain spacing, respectively. These increments of yield production with narrow drain spacing are the result of deeper water table depth, which prevents salinization (figure 5). Since the average soil salinity was 3.4, 4.1 and 5.3 dS/m; the average water table depth was 78 cm, 60 cm and 50 m for the above mentioned treatments.

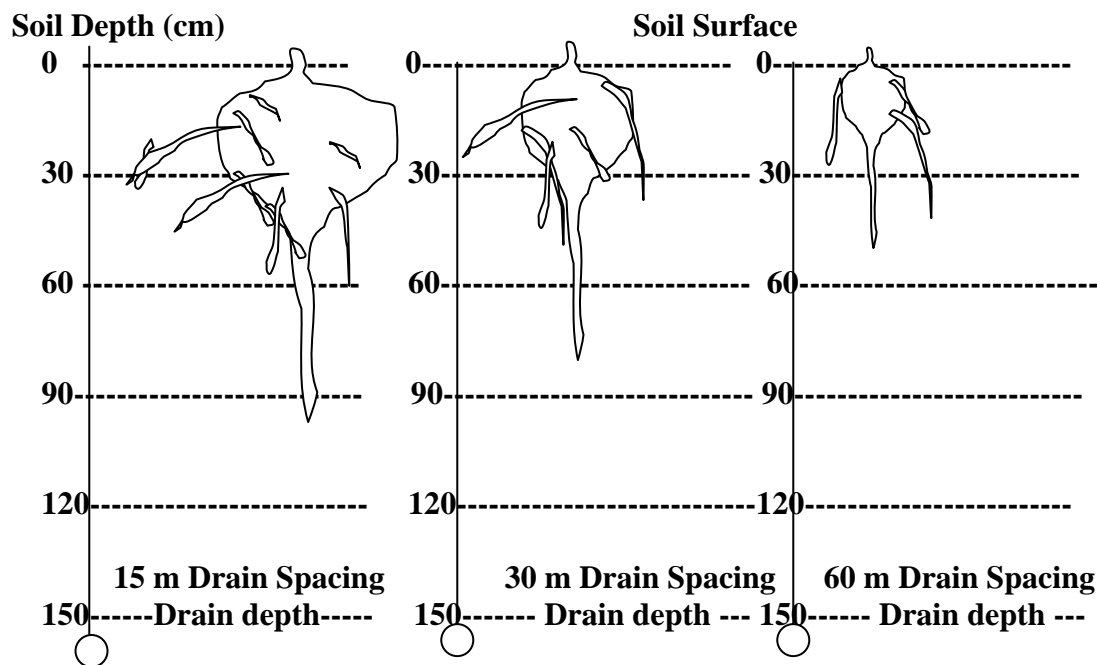


Figure 4. Sketch Diagram of sugar beet root shape, length and diameter under different drain spacing treatments.

It can be said that a clear response of sugar beet yield is obtained as more improvement in soil conditions is realized. This is due to the improvement that occurred in the root zone conditions, as a direct effect of soil desalinization and to the faster water table recession upon irrigation as a result of drainage. Beside drainage, improving poor permeability, and enhancing water movement is an important factor for salt leaching and for preventing water logging in the root zone. This must be based on an integrated approach to soil and water management, taking into account specific conditions leading to soil deterioration. It can be recommended that in newly reclaimed lands, if drainage conditions are not satisfactory additional measures could be taken for better soil water management.

Regarding watertable fluctuation, results showed that, five days after irrigation, the average values of water table level are 60, 65 and 70 cm depth and they reach to 80, 95



and 110 cm before next irrigation for 60, 30 and 15 m spacing treatments, respectively. The long-term water table monitoring gives high relation and confirmed the results obtained from morphological studies. The water table depth varies depending on the drain spacing and irrigation intervals. There are two boundaries of water table fluctuation zone between irrigation cycles. The upper boundary is at the highest level of water table; the lower boundary is at the deepest level of water table. The distance between upper and lower boundaries is the water table fluctuation zone. For tile drain treatments, the obtained data indicated that the width of water fluctuation zone was wider and deeper and its width was 35 cm for 15 and 30 m spacing treatments and it was 30 cm for 60 m spacing treatment.

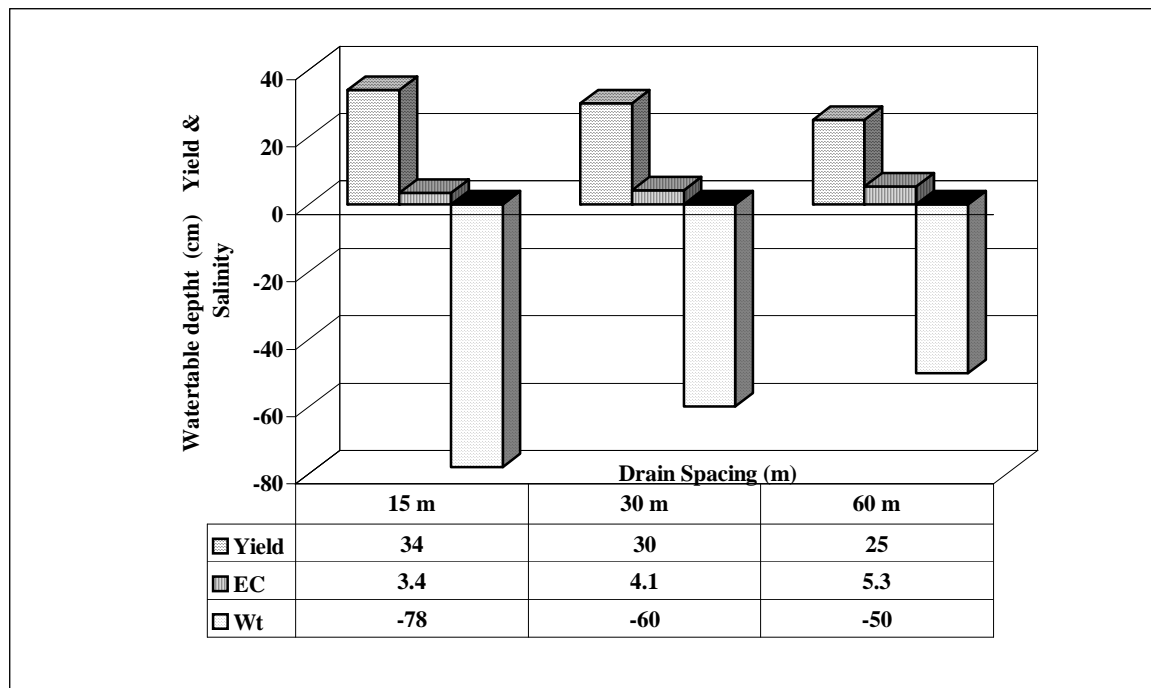


Figure 5. The sugar beet yield in relation to soil salinity and water table depth under different drain spacing treatments.

**CONCLUSIONS** It can be concluded that the morphological studies are related to long-term observation of water table. They are considered a simply way to predict the early problems in order to sustain the soil potentiality and increase crop productivity. The upper boundary of water table fluctuation zone should be kept at minimum depth of 70 cm better from soil surface to sustain a good condition for field crop. These are reflect on decreasing soil salinity and increasing sugar beet production with decreasing drain spacing.

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