J. Agric. Sci. Mansoura Univ., 29 (8): 4357 - 4373, 2004

QUANTITATIVE EVALUATION OF SUGARCANE DRAINAGE-REQUIREMENT, CONTRIBUTIONS TO CONSUMPTIVE USE AND WATER USE EFFICIENCY.

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ABSTRACT

Due to over-irrigation and seepage from unlined canals, problems of raising the soil water-table (SWT) on some crops are evident. Thus the crop-drainage requirement, seasonal consumptive use (SCU) and its components, and water use efficiency (WUE) for sugarcane as related to SWT depth were undertaken in a lysimeter study. Water-tables were statically maintained at 40, 70, 100, 130 and 160 cm from soil surface. Two sugarcane varieties namely; G.T.54-9 (C9) and F.153 were grown during 2001/2002 and 2002/2003 seasons as plant cane and first ratoon crops. A water budget model was used to evaluate the capillary upward water flux as influenced by the different SWT depths.

The general performance of sugarcane yield components and sugar yield showed that C9 and F153 were significantly higher at 70 cm depth; the shallower or deeper are the lower the plant cane, stalk, bagasse, juice and sugar yields. Both varieties were not significantly different at different depths regarding to cane and sugar yields of both plant cane and first ratoon crops; and for tops plant crop as well as, for juice of first ratoon crop. Stalk cane and bagasse means showed that the two varieties acted significantly different with water-table levels.

An exponential equation describing the water-table contribution (WTc) to the SCU in relation to the SWT depths was reported. The values of WTc were reduced by 44.83 and 81.48 % as SWT was increased from 40 to 70 and 160 cm, respectively. As for irrigation contribution (Ic), a polynomial regression model was reported to identify Ic as a function of SWT depth. Ic values were significantly compounded by 146.55 and 470.40% as SWT increased from 40 to70 and 160 cm, respectively. The dependence of moisture depletion on SWT revealed a significant regression model where the depletion contribution augmented as SWT increased.

The general trend for SCU was that the deeper the SWT, the larger is the SCU. However, SCU at 70 cm depth was lower than that of 40 cm. Increasing SWT from 70 cm to 100, 130 and 160 increased the SCU by 15.84, 34.20 and 49.07 %, respectively. The behavior of the monthly and accumulated consumptive use was described during the entire growth periods where four stages of plant growth may be recognized.

It is suggested that, at 70 cm depth, maximum sugarcane yield may be obtained with less water consumption and efficiency of water utilization might be expected. The amounts of consumed water as related to sugarcane yield were given and showed that at 70 cm depth the highest efficiency occurred. Shallower or deeper exhibited larger amounts of water that need to produce the same quantity of yield.

INTRODUCTION

"Optimum crop drainage-requirement" is basically decided by the minimum depth to soil water-table (SWT) that must be sustained to provide optimum crop yield (Benz *et al.*, 1984). Suchlike requirement depends upon many factors, which include plant root system, soil hydrodynamic properties and evapotranspiration demand (Raats and Gardner, 1974 and Van Bakel, 1981).

Significant sugarcane yield losses are attributed to over-irrigation and seepage from unlined canals in the presence of insufficient and inefficient drainage systems. This is a serious problem in Egypt's agriculture which has resulted mainly from inadequate depth to the (SWT). Under such posture, a proper water management schedule considering water-table fluctuation and contribution to crop evapotranspiration may prove helpful in increasing water-use efficiency bearing in mind the cost of irrigation and the price of cane. Thereupon, the capillary up-ward flux and the extent of the SWT status need to be precisely evaluated for exploiting the situation for the maximum benefit of the sugarcane crop.

Among the important considerations in this regard is the necessity of having information on maximum crop water-use as a function of SWT depth in order to predict the capillary upward water flux to the plant root zone. Theoretical presentation have been documented by (Malik *et al.*, 1989; Prathapar *et al.*, 1992 and Thorburn *et al.*, 1992) based on numerical or analytical solutions of the flow equations.

Many field and lysimeter studies have been devoted to the relationship between sugarcane yield response and water-table conditions. Wilson (1985) examined the yield losses resulting from high water tables; he outlined a negative relationship between yield and SWT depth. An optimum SWT level deeper than one meter was mentioned by Gosnel (1971) for optimum cane growth production while Juang and Uehara (1979) obtained the best cane yield when the water table was at 80 cm.

Artificial shallow water-table has been recognized as a potential source for sugarcane irrigation to fulfill water crop use. The observations of Tripath and Mishra (1986) indicated that about 70% of the total crop evapotranspiration may be met from a water-table at 60 cm depth. The results outlined by Mohamed and Aboushal (1999) indicated that 78.3 % of the corn consumptive use can be provided from a 40 cm water-table and the smaller amount was the deeper the water-table. The results of Pitts *et al.* (1990) showed that plant growth, root density and sugar content were not statistically different between 45 and 75 cm SWT depth. The accepted figure by (Dick, 1982) for SWT depth to minimize yield losses is 50 cm below the soil surface. Rudd and Chardon (1977) reported a reduction in cane yield of 0.46 t/ha for every day the water table was less than 50 cm. Nevertheless, results of (El-Ghamrey *et al.*, 1990) suggested only 40 cm depth for best cane growth. Some other studies have tried to correlate between SWT level and N deficiency. Woodruff *et al.*, (1983) concluded that N deficiency is a major cause of yield depression under shallow SWT conditions. Their results showed that soils with SWT within 70 cm deep required more N to reach maximum corn yield than soils with deeper depths. Some studies tried to correlate between the crop damage at specific growth stages and the soil water-tables status (Kanwar *et al.*, 1988; Evanes *et al.*, 1990 and Mohamed *et al.*, 1996).

The question remains whether the sugarcane yield will be affected by having shallow fluctuated water-table conditions. Thereupon, the objectives of this study were to evaluate quantitatively the response of two local sugarcane varieties to depth to the soil water-table accounting for the critical crop drainage-requirement. The seasonal and monthly water consumption and its constituents, as well as their efficiency on growth yield and sugar content were also of the ultimate goal of the present study.

MATERIALS AND METHODS

Experimental complex:

A two-year lysimeter experiment was conducted in reinforced double wall concrete tanks during 2001/2002 and 2002/2003 seasons at the Soil Salinity Laboratory at Alexandria, Egypt. Each lysimeter, 4 m^2 surface area and 2 m deep, was provided with a 5.0 cm inside diameter tile drain with a side outlet at a specific depth, by which the soil water-table depth (SWTD) is determined, and a feeding tube that connects the lysimeter bottom to a water supply tank placed above the soil surface.

The lysimeters were uniformly packed with clay loam soil, which was classified as Vertic Terrifluvents and represents the up-northern Nile Delta area. Prior to planting, all lysimeters were washed free from any residual soil salts. A representing soil sample was then collected and analyzed for main characterization. The soil contains 8.95 % $CaCO_3$ with a pH of 7.4 and the EC of its saturated paste extract is 1.2 dSm^{-1}, 40.5 % clay, 28.0 % silt and 32.5 % sand.

The experimental layout permits to run a randomized complete block design with four replicates. Two sugarcane *(Saccharum officinarum L.)* varieties, i. e. G.T. 54 – 9 (C9) and F.153 were examined under five water-table depths of 40, 70, 100, 130; and 160 cm. measured from the soil surface. The developed soil water-table was controlled constant during the growing seasons (static ground water-table) by daily water feeding from the supply tank through the feeding tube. Irrigation water was metered as needed to all lysimeters at the same time in amounts sufficient to saturate the whole soil profile down to the ground water-table level. The effluent drainage water was then evacuated and measured. Data about precipitation was collected from the rainfall meter on the spot, where the net values were estimated after collecting its effluent drainage.

Cropping pattern:

One and half rows of cane cuttings of the tested varieties were raised in ridges of 50 cm apart, with row and half method, in accordance with standard grower practices, on the10th of November for both plant cane and the first ratoon crops. At planting, the lysimeters were fertilized with 60 kg P_2O_5/fed as superphosphate (15.5%), in addition to N- fertilizer as ammonium nitrate (33.5 %) which was added at a rate of 250 kg N/fed, in two split applications; two months after planting and 60 days later.While, K-fertilizer was applied at a rate of 48 Kg K_2O/fed as one dose with the second split of nitrogen.

Measurements:

Water consumptive use (CU) for each lysimeter was computed based on the following water budget equations:

$CU = Ic + R_c - WTc - Dc$ ....(1)

Where:

Ic = contribution from surface application water,
R_c = contribution due to precipitation,
WTc = contribution from soil water-table (capillary rise supply) and
Dc = contribution due to compensation of soil water depletion for the period between the last irrigation and the harvest date.

Under the experimental conditions, the Ic and WTc may be determined as follow:

$Ic = Ir - Ed$..(2)
$WTc = Fw - Ef$ ....(3)

Where:

Ir = irrigation water metered to the system
Ed = Outgoing effluent of drainage water during the entire season.
Fw = amount of water fed to the water-table and
Ef = excess feeding water released from the system.

The amount of R_c was determined on the spot where the net rainfall during the winter season was determined to be 8.93, 8.57, 7.86, 5.72 and 2.32 cm for 40, 70, 100, 130 and 160 cm SWT lysimeters, respectively. These amounts were treated as surface application and added, by proceeding to Ic values. Thus, the seasonal CU and its components were computed from the daily change in water level at the water supply tank and the net of surface application water during the entire 2002-2003 season. The CU for sugarcane production was, thus estimated based on two-time intervals, i.e., monthly and the entire growth season (360 days).

At harvest, the above ground millable canes from each lysimeters were harvested and stalk and top were weighed. Bagasse and Juice yields and sugar percentage were evaluated on randomized stalk cane samples.

Significant differences among all the experimental means were statistically identified at 0.05 probability for a complete randomized block design using SAS-GLM procedure (SAS, 1989).

Water-use efficiency:

Water-use efficiency was evaluated using both the water-to-stalk cane yield and water-to-sugar yield ratios (Shih, 1986). In this case, water-use efficiency is defined as the amount of water required producing 1 kg of stalk cane or 1 kg of sugar yield. The larger ratio implies lower water-use efficiency.

RESULTS AND DISCUSSION

Growth and yield performance:

Soil water-table (SWT) depths, sugarcane varieties and their interactions significantly affected yield components as shown in Table 1 for plant cane and Table 2 for first ratoon crops. Whole plant, stalk cane, bagasse, juice and sugar yields were significantly the highest at 70 cm SWT depth. The general performance was that the deeper or shallower SWT, the lower is the growth and yield production. Top yield, on the other hand, was not affected by SWT level for plant cane crop but it showed significant impact in the first ratoon season where the highest yield was markedly recorded at 100 cm SWT depth.

Table (1): Yield components of the plant cane crop as influenced by soil water-table depths and crop varieties.

Variety (V)	Soil water-table (SWT) depth, cm.					Means	LSD SWT x V
	40	70	100	130	160		
			Whole plant, kg / lys.				
C9	84.81 c	95.21 a	89.10 b	76.89 d	66.44 e	82.49 a	
F153	70.42 c	88.85 a	76.81 b	62.63 d	54.22 e	70.58 b	3.63
Means	77.62 c	92.03 a	82.95 b	69.76 d	60.33 e		
			Stalk, kg / lys.				
C9	75.06 b	86.32 a	78.64 b	67.51 c	57.56 d	73.02 a	
F153	61.64 c	79.92 a	68.18 b	54.62 d	45.57 e	61.98 b	N.S.
Means	68.35 c	83.12 a	73.41 b	61.07 d	51.57 e		
			Top, kg / lys.				
C9	9.75 a	8.89 a	10.46 a	9.38 a	8.88 a	9.47 a	
F153	8.78 a	8.93 a	8.63 a	8.01 a	8.65 a	8.60 b	N.S.
Means	9.26 a	8.91 a	9.55 a	8.69 a	8.76 a		
			Bagasse, kg / lys.				
C9	42.12 b	48.79 a	44.68 b	35.61 c	29.44 d	40.13 a	
F153	36.54 b	46.16 a	38.54 b	29.72 c	23.97 d	34.99 b	N.S.
Means	39.33 c	47.48 a	41.61 b	32.66 d	26.71 e		
			Juice, kg / lys.				
C9	32.94 b	37.52 a	33.96 b	31.91 b	28.12 c	32.89 a	
F153	26.43 c	33.75 a	29.64 b	24.90 c	21.60 d	27.26 b	N.S.
Means	29.69 c	35.64 a	31.80 b	28.40 c	24.86 d		
			Sugar, kg / lys.				
C9	12.56 b	15.20 a	12.79 b	10.04 c	8.20 d	11.76 a	
F153	10.41 b	13.61 a	10.76 b	6.92 c	6.54 c	9.65 b	N.S.
Means	11.48 b	14.40 a	11.78 b	8.48 c	7.37 d		

N.S= not significant **lys. =lysimeter**

The most important economic yield parameter is the sugar quantity which was significantly augmented, for the two studied varieties, by 25.54% and 25.60 % for plant cane and the first ratoon crops, respectively when the SWT depth increased from 40 to 70 cm. On the contrary, significant diminishing were determined by 18.19, 41.11 and 48.82% for plant cane crop and by 18.22, 37.64 and 49.66% for the first ratoon crop as a result of increasing SWT from 70 to 100, 130 and 160 cm depth, respectively.

Thus, the above results may suggest that the 70 cm SWT depth could be regarded as the optimum depth for sugarcane production. It has been suggested, in the literature, that the target water-table level for sugarcane lays between 23 and 30 inches. Due to the work reported by Dick (1982), sugarcane yield increased by 58.2 and 64.06% when the depth to the water-table increased from 43 to 52 and 65 cm, respectively, depends on the number of days water-table stayed at less than 50 cm. Studies by Izuno *et al.* (1989) shown both plant cane and ratoon sugarcane crops produced high yields at an average water table of 22 inches, while El-Ghamry *et al.*, (1990) indicated that only 40 cm water-table was the optimum depth for their tested varieties. This may be expected since the undesirable condition for the tested genotype resulting from shallower or deeper water-table may be considered. Both low oxygen and high carbon dioxide contents of soil air under shallower water-table create problems in absorption of water and nutrient by crops (Woodruff *et al.,* 1983).

Table (2): Yield components of the first ratoon crop as influenced by soil water-table depths and crop varieties.

Variety (V)	Soil water-table (SWT) depth, cm.					Means	LSD SWT x V
	40	70	100	130	160		
			Whole plant, kg / lys.				
C9	83.97 c	94.87 a	87.96 b	75.39 d	64.57 e	81.35 a	
F153	69.68 c	88.02 a	75.48 b	60.83 d	51.53 e	69.11 b	3.65
Means	76.83 c	91.45 a	81.72 b	68.11 d	58.05 e		
			Stalk, kg / lys.				
C9	64.82 c	77.91 a	68.49 b	56.34 d	48.74 e	63.26 a	
F153	54.68 b	71.63 a	57.64 b	46.93 c	37.51 d	53.68 b	N.S.
Means	59.75 c	74.77 a	63.07 b	51.63 d	43.13 e		
			Top, kg / lys.				
C9	19.15 a	16.96 b	19.47 a	19.05 a	15.83 b	18.09 a	
F153	15.00 b	16.39 ab	17.84 a	13.90 b	14.01 b	15.43 b	1.49
Means	17.08 b	16.68 b	18.65 a	16.48 b	14.92 c		
			Bagasse, kg / lys.				
C9	32.48 c	41.70 a	36.19 b	30.29 c	26.83 d	33.50 a	
F153	28.89 b	37.94 a	30.78 b	25.22 c	20.97 d	28.76 b	N.S.
Means	30.69 c	39.82 a	33.49 b	27.76 d	23.90 e		
			Juice, kg / lys.				
C9	32.34 b	36.21 a	32.31 b	26.04 c	21.91 d	29.76 a	
F153	25.78 b	33.69 a	26.86 b	21.70 c	16.54 d	24.92 b	1.23
Means	29.06 b	34.95 a	29.58 b	23.87 c	19.23 d		
			Sugar, kg / lys.				
C9	11.76 b	14.42 a	12.08 b	9.21 c	7.68 d	11.03 a	
F153	9.56 b	12.35 a	9.83 b	7.50 c	5.79 d	9.01 b	N.S.
Means	10.66 b	13.39 a	10.95 b	8.35 c	6.74 d		

N.S= not significant **lys. =lysimeter**

Tables 1 and 2 illustrated also that C9 and F.153 sugarcane varieties were not significantly different at different SWT depths regarding to plant cane and sugar yields for both plant cane and the first ratoon crops, top of plant cane as well as, for juice of the first ratoon crop. Nevertheless, stalk cane and bagasse means showed that the two verities acted significantly different with water-table levels. The work of Carter (1981) indicated the same performance of three sugarcane varieties where cane and sugar yields were not significantly different for both 2- and 4- feet SWT treatments. He explained this as the major portion of the cane roots appeared to be in the upper 38 inches of the soil profile. However, the variance among the studied genotypes revealed the superiority of C9 sugarcane variety over F.153, regardless of the existing level of water-table. The studied growth and yield parameters recorded higher significant averages of C9 than F 153. For instance, sugar and juice production exhibited significant increases of 21.86 and 20.92% for plant cane crop and 22.42 and 19.42% for the first ratoon crop, respectively.

As for the interaction effect, the results in Tables 1 showed insignificant differences of stalk cane, top, bagasse, juice and sugar yields due to interaction between SWT depth and sugarcane variety (V) in the plant cane crop season. Only the plant cane crop production revealed significant averages over both SWT depth and V. Sugarcane variety C9 that was subjected to 70 cm water-table depth showed the highest means as compared with others depths, followed by the variety F.153 grown at 70 cm depth. The lowest mean was recorded for the deepest SWT (160 cm). More significant performance was reported in Table 2 for the first ratoon crop. Plant cane crop, top and juice averages exhibited significant interaction effect, while, stalk cane, bagasse and sugar yields have affected insignificantly by (SWTD) X (V). Both C9 and F.153 varieties showed the highest values of plant cane crop yield when grown at 70 cm water-table depth. Top yield results indicated that C9 plants gave the highest means at 40, 100 and 130 cm whereas the lowest were for 70 and 160 cm depths. As for juice, C9 and F.153 varieties at 70 cm depth gave the highest means followed by 40 and 100 cm. The lowest means over all the experiment was assigned for the deepest SWT i.e., 160 cm depths. It may then be recommended that growing C9 variety at 70 cm SWT depth is the best for maximizing the sugarcane production. Both the tested varieties could be considered very sensitive to soil aeration or in other words to the SWT depth. The high water-tables no doubt resulted in poorer root systems and less water uptake than the deeper water tables (Gascho and Shih, 1979).

Water-table, irrigation, and depletion contributions to sugarcane consumptive use :

Water use performance of sugarcane crop as presented by seasonal consumptive use (SCU) and its constitutes were studied as functions of the soil water-table (SWT) depth. Average values of the sugarcane seasonal CU; contributions due to water-table, irrigation and depletion, over the two studied varieties, were evaluated and given in Table 3 and Fig.1. The contribution due to water-table or capillary rise flow WTc is being significantly lesser with increasing the SWT depth between 40 and 160 cm. The contribution was reduced by 44.83, 76.78, 77.24 and 81.48% as water-table increased from 40 to 70, 100, 130 and 160 cm, respectively (Table 3). Such functional relationship as depicted in Fig 1 may be expressed by an exponential equation in the form:

$WTc = a\ e^{-b\ (WTd)}$ .... (4)

Where:

WTd = the depth to the SWT, cm; a and b are coefficients which were estimated from the experimental data and reflex soil and weather parameters (Malik *et al.*, 1989).

Table (3): Water-table, irrigation and depletion contribution to seasonal consumptive use (SCU) as affected by soil water-table (SWT) depth.

SWT Depth, cm	SCU cm	Contribution to SCU, % due to		
		Irrigation	SWT	Depletion
40	157.96 d	21.90 e	76.73 a	1.40 e
70	155.87 e	54.72 d	42.90 b	2.38 d
100	180.56 c	74.83 c	21.58 c	3.59 c
130	209.17 b	82.27 b	13.15 d	4.59 b
160	232.35 a	84.92 a	9.66 e	5.42 a
Average	187.18	63.73	32.81	3.47

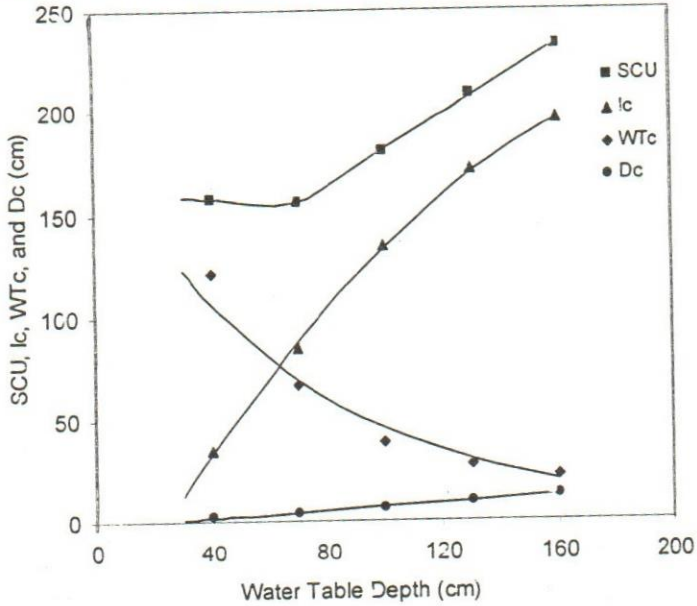

Fig.(1): Seasonal consumptive use (SCU) and the contribution due to water table (WTc), irrigation (Ic) and depletion (Dc) as functions to water-table depth.

The contribution due to water-table WTc may be defined as total head of water in cm per period of time. The experimental data shown in Fig. 1 could then be expressed by equations 5 as:

$WTc = 188.29\ e^{-0.0142\ (WTd)}$ ....(5)

The capillary upward water flux WTc was donated in cm over the 360 days of the growth season long. The correlation coefficient was 0.9831 indicating an extremely close fit. It may notice that at very shallow water-table (WTd = 0), capillary rise contribution (WTc) goes to its maximum, i.e., 188.29 cm., which is even more than the average of total water consumption over all the different, studied SWT, (Table 3 and Fig 1). This means that, the soil is overwhelmed and no need to any watering surface applications. On the contrary, for very deep SWT, i. e., (WTd = ∞) the value of $e^{-0.0142(\infty)}$ goes to zero and WTc reaches its minimum and can be considered null. Many investigators in accordance with these outline such trend. The analytical solution of upward vertical flow approved that the capillary rise flux was related exponentially with depth to water table (Stuff and Dale 1978) and recently Malik *et al.* (1989). The results given by Gayle, *et al.* (1985) indicated a very close relationship to that obtained in this study where an exponential function between WTc in mm/day and WTd was reported. Their a and b values were, respectively 43.73 and -0.0535 which are different than those given in equation 5 owing to different weather, soil and sugarcane genotype parameters. Similar findings have presented by Ragab and Amer (1986) on corn Giza 2 variety. Their a and b values were different since their equation was developed for shorter growth period (75 days only). The study conducted by Moustafa *et al.* (1977) showed that the contribution due to saline water-table reached its maximum (26.5 %) at 40 cm depth; whereas, that at 160 cm was only 4.8 %. Stuff and Dale (1978) reported that capillary water supplied an average of 27% of the ET in periods with little precipitation. Thus the significance of the shallow water-table as a valuable water resource must be considered, provided that soil salinity is controlled.

A polynomial regression model was found to identify the influence of SWT depth on irrigation contribution (Ic). The following regression equation was derived from the experimental data.

$Ic = 0.0051\ (WTd)^2 + 2.387\ (WTd) - 54.062$...............(6)

The regression coefficient value (r^2 = 0.9443) implies that irrigation contribution (Ic) is well correlated with the water-table depth. Figures 1 depicts the polynomial regression curve as manifested in equation 6. The increase of Ic due to increasing in WTd was also illustrated in Table 3 where Ic means were significantly magnified with increasing the SWT depth, the deeper the SWT the higher is irrigation contribution to the SCU. Ic values were compounded by 146.55, 290.63, 397.46 and 470.40% as SWT depth increased from 40 to 70, 100, 130 and 160 cm, respectively. This pointed that the increase in Ic per each 1 cm increase in SWT were 1.69, 1.68, 1.53 and 1.36 cm head of water as the SWT depth extended from 40 cm to 70, 100, 130 and 160, respectively. Overall the soil profile depth, 1 cm increase in WT depth required an average increase of 1.57 cm as irrigation contribution to the SCU.

Table 3 shows also the dependence of moisture depletion Dc on WTd values, where significant increase in Dc was remarked as WTd values increased from 40 to 160 cm. This means that as soil profile becomes deeper more moisture is depleted by plant as transpiration or by evaporation through soil surface. A straight-line model was established to define such relationship as depicted in Fig 1. The equation that covers the experimental data and gives best fit ($r^2 = 0.9861$) was in the form:

Dc = 0.0888 WTd - 1.966 ....(7)

It is remarkable that the increasing rate of Dc increased as SWT was getting deeper up to 160 cm depth with an average increase in Dc per each 1 cm increase in WT level was 0.104 cm head of water during the whole season. It is interesting to notice also that, in order to minimize the surface watering use by sugarcane a critical depth to the water-table should be maintained at 22.0 cm. At such depth the resultant values according to equations 6 and 7 showed that the contribution due to both irrigation and depletion (Ic and Dc) reached the null value, whereas, the calculated SWT contribution according to equation 4 at 22 cm WTd was given by 137.8 cm head of water, by which it meets all water needs of sugarcane. So it can be concluded that irrigation and depletion water have a great application for deep water-table profiles. Though, water-table contribution has appreciable values with shallow soil profiles.

In regard to the seasonal sugarcane consumptive use SCU its mean values were significantly affected by SWT depth (Table 3 and Fig 1). The general tendency is the deeper the SWT, the larger are SCU means. However, 40cm depth was significantly higher than that of 70 cm. This may be owing to the parallel balance between the SCU constitutes where WTc value at 40 cm was extremely higher than that at 70 cm by which the total SCU was positively affected. In the meantime, the remarkable decrease in WTc values for depths deeper than 70 cm, caused, in sequence remarkable increase in Ic values. Consequently, SCU values significantly enlarged by 15.84, 34.20 and 49.07 % when SWT diminished from 70 to 100, 130 and 160 cm, respectively. This behavior may be clarified from Fig 1, where the CU curve has a negative small slope (-0.0698) for SWT ranged between 40 and 70 cm. The slope, on the contrary, goes then to its maximum, as water-table was maintained between 70 to 160 cm depth, with a positive value of +0.862 referring to compounded SCU values needed for deeper soil profile.

The behavior of the total sugarcane SCU during the entire growth period for all SWT treatments is demonstrated in Table 4, while Fig.2 represented the functional relationships between water-table depth and the accumulative sugarcane consumptive use. S-shape relationships were obtained in which, four distinguished growth stages may be marked. The first stage is limited by planting date and 90 days of plant age (Emergence and establishment stages) where the SCU rate of change is relatively small. The values of CU in this stage for the different SWT depths were rather interfered. Overall SWT depths, plant water consumption averaged of 36.87 cm which represents 19.7 % of its average seasonal SCU with an average daily consumption of 0.41 cm/day. The second stage is between the 4th and 8th months of the growth period that may be defined as (Vegetative and flowering stages) and characterized by sharp slopes, i.e., high and consistent rate of SCU change during this interval. The SWT treatments were ruptured and the high SCU values were setting for deeper SWT and vice versa. In respect of water consumption in this stage, plant consumed the major portion of its SCU. Average water consumption of 96.28 cm was marked in this stage which gives 51.45% of the total SCU with an average daily of 0.64 cm/day. The third stage, including the last 3 months before depletion factor interfered, where the slope again descended as a result of decreasing CU rate of change. The amount of water consumed in this stage averaged 47.93 cm representing 25.61% with an average daily consumption of 0.533 cm/day. The fourth stage is one month long and covers the water consumption due to moisture depletion at the end of the season. The value of CU, accordingly goes to its minimum and amounted to 6.513 cm which is 3.48 % of the total CU and 0.217 cm /day. In this concern, it's to be noticed that the water requirement during flowering and ripening stages was higher than that at emergence and establishment ones. It may be added that there was a sort of overlapping between 40 and 70 cm WTd-curves. This may be expected since their CU means revealed inverse significant differences as marked in Table 3.

Table (4): Accumulative consumptive use (CU) as influenced by soil water-table depth.

Plant age (days)	Soil water-table depth (cm)				
	40	70	100	130	160
	Accumulative consumptive use (cm)				
30	6.57	6.55	8.04	8.71	9.68
60	17.10	16.94	20.19	22.64	25.16
90	31.61	30.83	35.79	40.82	44.98
120	47.43	45.78	53.10	60.64	66.27
150	63.36	61.40	71.01	81.19	88.91
180	80.07	77.63	89.54	102.53	112.61
210	97.10	94.20	108.66	124.67	136.91
240	114.77	111.43	128.56	147.91	161.81
270	129.95	126.08	144.94	166.88	182.74
300	143.00	139.47	160.57	183.90	202.11
330	155.75	152.16	174.13	199.57	219.52
360	157.96	155.87	180.60	209.16	232.10

The actual sugarcane CU as a function of water table treatments through the entire growing season was given (Table 5 and Fig 3). The foregoing mentioned four stages were also clearly distinguished. The monthly rate of change in CU during the first stage was ranged between 3.97 and 5.08 cm when SWT depth increased from 40 to 160cm, in sequence. These rates were reduced to 0.632 and 1.014 cm per month during the second stage as water-table level changed from 40 to 160 cm, respectively. As the third stage, the monthly change in CU was retarded and became negative as given by -1.64 and -2.49 cm for WT depths changed from 40 to 160 cm, respectively. Finally, at depletion stage the rate became negatively higher, i.e. -10.55 and -4.84 as WT increased from 40 to 160 cm, respectively.

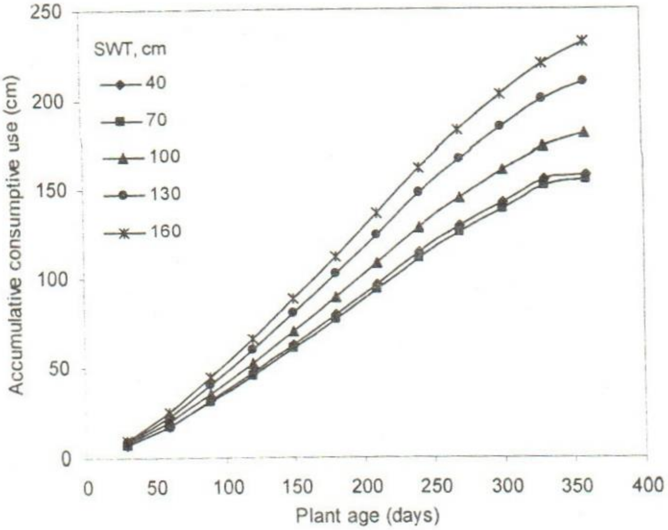

Fig. (2): Accumulative consumptive use during the entire growth period for the different soil water table (SWT) depths.

So far, it's suggested that at the 70 cm depth, maximum sugarcane yield may be obtained with less water consumption and efficiency of water utilization might be expected. Thereupon, it may be concluded that although shallow water-table may reduce the need for supplementary irrigation, due to its higher contribution to plant CU, it caused a drastic drop in sugarcane yields. The above conclusion may lead to explore the efficiency of water use by corn plants grown at different SWT treatments.

Table (5): Actual sugarcane consumptive use as influenced by soil water-table depth.

Plant age (days)	Soil water-table depth (cm)				
	40	70	100	130	160
	Actual consumptive use (cm)				
30	6.57	6.55	8.04	8.71	9.68
60	10.54	10.39	12.15	13.93	15.48
90	14.51	13.89	15.60	18.19	19.83
120	15.82	14.96	17.32	19.82	21.29
150	15.93	15.62	17.91	20.55	22.64
180	16.71	16.24	18.53	21.35	23.70
210	17.04	16.57	19.13	22.14	24.31
240	17.67	17.23	19.90	23.25	24.90
270	15.18	14.66	16.39	18.97	20.93
300	13.05	13.39	15.63	17.02	19.37
330	12.76	12.69	13.56	15.68	17.42
360	2.21	3.71	6.47	9.59	12.58

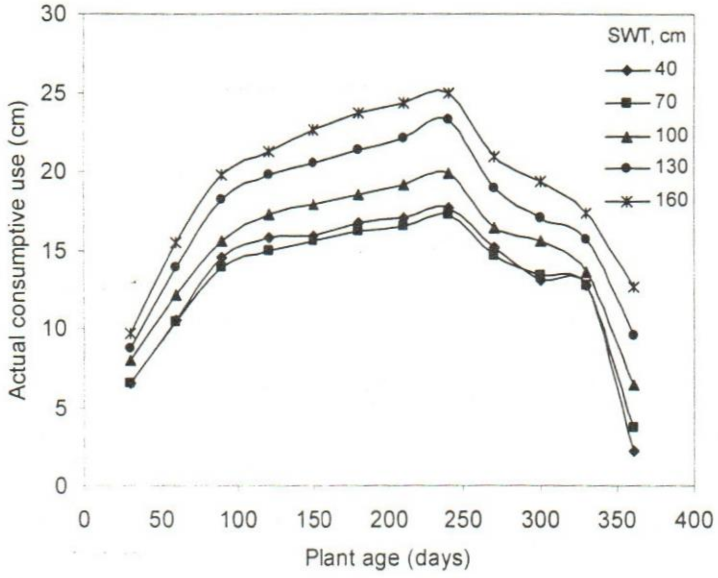

Fig.(3): Actual consumptive use as a function of plant age for the different soil water table (SWT) depths.

Water-use efficiency (WUE):

The efficiency of water utilization by sugarcane was developed on the basis of water to yield ratio, where plant cane and sugar crops were taken into consideration. Table 6 and Fig 4 described the influence of SWT depth on the efficiency of sugarcane yields to water use under the experiment conditions. Significant diminution in WUE values was observed, as SWT increased from 40 to 70 cm, which significantly higher efficiency of water utilizations for plant cane crop and sugar productions. This behavior may also be clarified as the amount of water needed to produce 1 kg of plant cane and sugar yields were, respectively reduced by 15.69 and 20.29%. Deeper than 70 cm, the obtained results revealed significantly higher WUE means which denoted lower efficiency of water use (Table 6 and Fig 4). For example, the amount of water needed to produce 1 kg of plant cane crop was augmented by 10.95, 32.07 and 52.64 % and of sugar 22.31, 71.15 and 95.84 % as water-table depth increased, respectively to 100, 130 and 160 cm. This trend is in accordance with this given by Shih (1986) and Fogliata (1974) they found that, the sugarcane required, under arid conditions, between 1.26 and 1.49 cm of water to produce one ton of cane and 10.49 to 14.42 cm to produce one ton of sugar. This is equivalent of 1000 to 1500 liters of water for each kg of sugar.

Again, the importance of 70 cm SWT level is proven, since it showed the highest efficiency of water-use for the tested sugarcane yield parameters and the highest significant means for sucrose and other growth parameters over all varieties, as shown from the foregoing results. Such level is of great importance since that depth is somewhat higher than for most commercial sugarcane grown in Egypt. Thus, there may be an opportunity to maintain higher water table levels in commercial fields without scarifying sugar yield with higher water-use efficiency. Hence, the results may suggest that controlling the water-table level at 70 cm from the soil surface is of interest in order to optimize the sugarcane production with less water use.

Table (6): Water use efficiency as affected by soil water-table depth for plant cane and sugar yields.

Yield	Soil water table depth (cm)				
	40	70	100	130	160
	Water use efficiency (Kg water / kg yield)				
Plant cane	81.47 c	68.69 e	76.21 d	90.72 b	104.85 a
Sugar	550.59 c	438.88 d	536.81 c	751.14 b	859.49 a

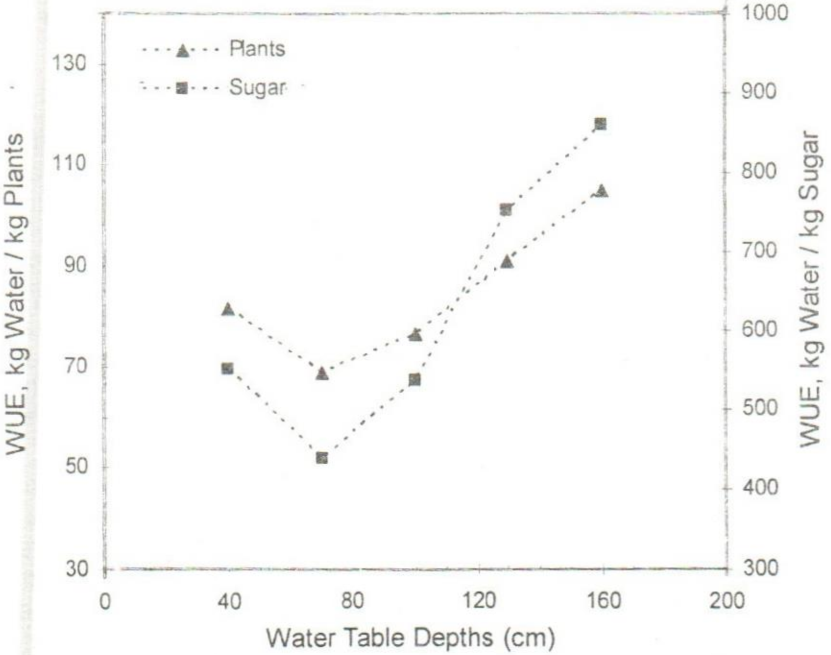

Fig.(4): Water use efficiency (WUE) as influence by water table depth depicted for plant cane and sugar production.

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J. Agric. Sci. Mansoura Univ., 29 (8), August, 2004

التقييم الكمى لكل من الاحتياجات الصرفية ومساهمات الاستهلاك المائى وكفاءة استخدام المياه لمحصول قصب السكر.

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من عوامل ارتفاع منسوب الماء الأرضى فى المناطق الزراعية بمصر وخاصة مناطق الدلتا والتى تؤثر سلبا على إنتاجية المحاصيل الاقتصادية هو الاستخدام الزائد لمياه الرى علاوة على الرشح المستمر من القنوات الغير مبطنة مع عدم وجود نظام صرف كافى وذو كفاءة عالية. والسؤال الآن هو هل محصول قصب السكر يتأثر أيضا بظروف الماء الأرضى المرتفع والمتذبذب فى مثل هذه المناطق.

لذلك كله فان الاحتياجات الصرفية (التى تتحدد أساسا بمنسوب الماء الأرضى الجوفى) وكذلك الاستهلاك المائى وكفاءة استخدام هذه المياه قد درست فى وجود مستويات مختلفة من الماء الأرضى هى ٤٠-٧٠-١٠٠-١٣٠- ثم ١٦٠ سم من سطح الأرض. وللتحكم فى هذه المستويات استخدمت ليزيمترات أسمنتية مساحة كل منها ٤ متر مربع وبعمق ٢ متر وتحتوى على أرض طينية طميية. واختبر فى هذه الدراسة صنفين لنبات قصب السكر هما F153 & C9 وتم توزيع المعاملات عشوائيا فى أربع مكررات. وزرعت الليزيمترات على مدى موسمى ٢٠٠١-٢٠٠٢ & ٢٠٠٢-٢٠٠٣ وذلك لمحصول الغرس ومحصول الخلفه الأولى.

ومن أهم النتائج المتحصل عليها ما يلى:

١- تم تقدير مدى مساهمة الماء الأرضى فى الاحتياجات المائية الكلية للقصب وقد وجد أن العلاقة بين ارتفاع الماء الأرضى وكمية الماء الممتصة على مدار الموسم تخضع لعلاقة أسية سالبة. عندما زاد عمق الماء الأرضى من ٤٠ إلى ٧٠و ١٠٠و ١٣٠ ثم إلى ١٦٠ انخفضت كمية المياه الممتصة من الماء الأرضى على التوالى إلى ٤٤,٨٣ و ٧٦,٧٨ و٧٧,٢٧ وأخيرا ٨١,٤٨ % من الكمية المقاسه عند عمق ٤٠ سم.

٢- بالنسبة إلى مدى مساهمة مياه الرى المضافة فى الاحتياجات المائية الكلية للقصب فهى تخضع لعلاقة متعددة موجبة (بولي نوميال) بحيث زادت كمية مساهمة مياه الرى بنسب مضاعفة تصل إلى ما يقرب من ٥ أضعاف (٤٧٠,٤٠%) عند تعميق مستوى الماء الأرضى من ٤٠ إلى ١٦٠ سم. كما زادت قيمة مساهمة الاستنفاذ الرطوبى الأرضى مع نهاية التجربة مع زيادة منسوب الماء الأرضى.

٣- بالرغم من زيادة الاستهلاك المائى الموسمى مع زيادة عمق الماء الأرضى فان قيمته عند عمق ٧٠ سم كان أقل منه عند ٤٠ سم. والسلوك المائى الشهرى والموسمى للاستهلاك المائى تم استنتاجه على مدى موسم النمو وقد تم تمييز أربعة مراحل لنمو نبات القصب على أساس هذا الاستهلاك المائى.

٤- وجد أن أعلى كفاءة استخدام للمياه كانت قد قدرت عند عمق ٧٠ سم للماء الأرضى مقارنة ببقية الأعماق. فقد وجد أن كمية الماء اللازمه لإنتاج كيلوجرام من السكر قد زادت بنسبة ٢٢,٣١ و ٧١,١٥ و ٩٥,٨٤ % كنتيجة لزيادة عمق الماء الأرضى على التوالى من ٧٠ سم إلى ١٠٠ و ١٣٠ و ١٦٠ سم.

٥- أوضحت النتائج أن الأداء العام لكلا الصنفين المختبرين C9 & F.153 كانا على أعلى مستوى معنوى عند عمق ٧٠ سم لمنسوب الماء الأرضى وذلك بالنسبة إلى محصول النباتات والعيدان والمصاصة و العصير و السكر.

٦- أظهرت النتائج أيضا أن كلا الصنفين كانا على مستوى معنوى واحد مع الأخذ فى الاعتبار إنتاج كل من النباتات والسكر لمحصول الغرس والخلفه الأولى وتفوق صنف C9 على صنف F.135 فى بعض الخواص المحصوليه الأخرى.

مما سبق نستنتج أهمية الحفاظ على منسوب ٧٠ سم للماء الأرضى الجوفى وذلك لتقليل كمية مياه الرى المضافة وتعظيم كفاءة استخدامها مما يؤدى لتعظيم إنتاجية محصول قصب السكر.