Stevia plant: Growth Yield and Its Chemical Constituents for Different Soil Types and Water Table Depths

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ABSTRACT

The present study was conducted in a lysimeter experiment to identify *Stevia rebaudiana Bertoni* growth habit and its chemical constituents under two different soil types and five soil water table (SWT) levels. Only two yield cuts were harvested due to the weather conditions in winter time, with its short time light and low temperature, that affected and minimized stevia growth yield. Identification of stevia sweetener compounds present in leaves was assayed using HPLC.

Loamy soil was significantly surpluses the calcareous soil in number of branches/plant, number of leaves/branch, plant fresh weight, plant dry weight, leaves fresh and dry weights. Meanwhile, 40 cm of (SWT) levels produced heavier fresh and dry leaves by 7 to 30% higher than deeper depths. The same advantage was found for plant dry weight.

The relationships between chemical constituents and the studied factors were detected. Fat percentage was identical in both soils, whereas loamy soil produced higher protein than calcareous. Meanwhile, no effects of SWT levels on any previously mentioned parameters. The amounts of stevia sweeteners, determined and calculated stevioside were decreased gradually in the first cut and deeply in the second cut with increasing the SWT up to 160 cm depth. Meanwhile, rebaudioside A, was not responded to SWT where it varied only between 36.4 to 29.4 g/m^2. Total carbohydrate decreased deeply up to 100 cm SWT depth then the decreasing rate reduced up to 160 cm depth. The results indicated that loamy soil was surpluses the calcareous in all of the determined characterizes. The Average quantity levels of stevia sweeteners varied from 159.19 to 77.40 g/m^2 for calcareous soil where those for loamy were from 210.40 to 83.15 g/m^2.

INTRODUCTION

Optimum crop drainage-requirement is basically decided by the minimum depth of soil water table (SWT) that must be sustained to produce optimum crop yield (Benz et al., 1984). Such like requirement depends upon many factors which include plant root system, soil type as reflected by its hydrodynamic properties and environmental demand (Raats and Gardner, 1974; Van Bakel, 1981; and Mohamed and Aboushal, 1999).

Accordingly, Shallow rooted crops tolerate a higher SWT than deep rooted crops, where supplying considerable water quantities to the crop system occur.

Stevia rebaudiana Bertoni is an herbaceous perennial native to the highlands of Paraguay. It is especially known for the sweetening principles contained in the leaves, which have attracted the attention of both researchers and industrial producers because of their potential dietetic, alimentary and pharmaceutical interest (Jeppesen *et al.*, 2000).

The natural stevia sweeteners which extracted from *Stevia rebaudiana* Bertoni leaves, is a high intensity sweetener that taste about 300 times sweeter than sucrose (0.4% solution). Stevioside and rebaudioside A, as the principle diterpene and the main constituents (Geuns, 2003). Leaf yields of 3000 kg/ha with a stevioside concentration of 105 mg/g gives a stevioside yield of 315 kg/ha. Assuming that stevioside is 210 times sweeter than sucrose, the stevioside yields are equivalent to 66.2 tones per hectare of sugar. (Brandle and Rosa, 1992). In 1999, the joint FAD/WHO Expert Committee on Food Additives (JECFA) clearly stated that there was no indication of carcinogenic potential of stevioside (WHO, 1999).

The reported studies to identify stevia growth habit under different soil and environmental conditions are not many. Warm temperature and subtropical climate and high light intensities are necessary for better growth (Zaidan et al., 1980 and Matejka, 1992). The effect of long and short day on the growth and stevioside contents in the leaves were studied by Metivier and Viana (1979) whose results indicated that the long day conditions increased the intern ode length, leaf area and the plant dry weight.

In Egypt, there is a great interest on the strategically agriculture plan to cultivate stevia plant at commercial scale. An attempt to reach the ultimate goal of such strategy is the present study. The question remains whether the stevia yield will be affected by shallow fluctuated water table conditions. Thereupon, the objective of this research was to evaluate quantitatively the response to stevia plant and its stevioside contents to soil type accounting for different soil water table levels.

MATERIALS AND METHODS

Experimental complex:

A spilt plot experiment was conducted in reinforced double wall concrete lysimeters during 2006–2007 years at the Soil Salinity Lab. in Alexandria, Egypt. The main plots were assigned to two different soil types.

The first was clayey soil representing the up-northern Delta area, while the other was a newly reclaimed calcareous soil of North Tahreer. The Sub-plots were designated to five water table depths, i.e., 40, 70, 100, 130, and 160 cm from soil surface with four replications. Accordingly, each main plot contains twenty lysimeters, each 1 m^2 surface area and 2 meters in depth. Each lysimeter was provided with a 1 cm inside diameter tile drain with a side outlet at the designated levels of the water tables in addition to a feeding tube at the bottom. Prior to planting, all lysimeters were washed free from any residual salts. A representing soil samples were then collected and analyzed for main characterization as shown in Table 1. The two examined soil types I and II are referred to hereafter as clay and calcareous soils, respectively.

Table 1. Some characteristics of the lysimeters soil.

Soil characteristics	Type I	Type II
EC*, dS/m.	1.33	1.42
$CaCO_3$ %	6.06	30.11
pH	7.44	7.87
Sand, %	69.80	66.00
Silt, %	10.00	6.20
Clay, %	20.00	28.30
Textural group	silty clay loam	calcareous silty clay loam

EC* = Electrical conductivity of the saturated paste extract of the top 30 cm.

The ground water was developed and controlled constant during the growing seasons (static condition of the ground water table) by daily feeding, from a supply tank placed at the level of the soil surface, through the feeding tubes. Irrigation water was metered as needed to all lysimeters at the same time in amounts sufficient to saturate the whole soil profile with respect to the water table level. The effluent drainage water was then evacuated and measured.

Cropping pattern:

In accordance with standard growing practice, eight seedlings of stevia were planted in each lysimeter in two ridges, 50 cm apart, where each seedling was planted in 25 cm-hill at the end of May 2006. At planting the lysimeters were fertilized with 20 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 60 kg/fed. in two applications, one after each cut (harvesting). The same was followed with adding K-fertilizer at a rate of 15 kg K_2O/fed. in two doses, one after each cut. Only two harvesting cuts were collected each year, the first one after four months of planting while the second one was seven months later.

Quantitative analysis of stevia leaves:

The stevia leaves were sun dried for at least 5-6 hours per day till reached the required constant moisture content of 9-11%, then extracted and purified according to Hassan *et al.*, (2002). Stevioside standard preparation was carried out according to the method described by Nishiyama *et al.* (1992). Moisture, crude protein (N×6.25), crude fat, ash, sucrose, reducing sugar were analyzed according to the procedures of A.O.A.C. (2000). Total carbohydrate was calculated by difference. Stevioside content was calculated according to Nishiyama, *et al.* (1991) by the following equation:

Total soluble carbohydrate = 7.56 + 0.96 Stevioside content

Stevia leaves sweetener was separated and identified on HPLC as follows: Stevioside and other sweet component standard as prepared above were filtered through a Millipore membrane (13 mm diameter, 0.5 µm pore size) and injected straight a way for chromatography with stevioside standard as internal standard. Different extracts of stevia leaves were injected for chromatography. Acetonitrile used in this study as mobile phase was HPLC grade (Fisons Co. England). HPLC separation was carried out on Shimadzu (SPD-6 AV) with UV-Vis spectrophotometer, detector of LC-GA and an Alex C-R 4A recorder. The operating conditions for HPLC were as following: Column, Zorbax NH_2, 25 cm x 0.4 mm I.D. (Dupont, Wilmington, DE, U.S.A.), eluting solvent acetonitrile: water (84 : 70 v/v), pH 5 adjusted with H_3PO_4, flow rate 2 ml/min, wave length of UV detector, 210 nm, recorder chart speed 20 nm/min at ambient temperature (25°C). All this conditions are completely as the same conditions used by Makapugay *et al.*, (1984). For each sample identification and quantification the retention time obtained by Makapugay *et al.* (1984) and area under each peak used for calculation the percent of each compound. Significant differences among all the experimental means were statistically identified at 0.05 probability level for a split plot design using SAS-GLM producer (SAS, 1989).

RESULTS AND DISCUSSION

It is worthwhile to mention that only two growth cuts were collected during the whole year. The other cut was not harvested due to the cold weather of winter time, that negatively affected the growth yield and produced very weak growth that can be completely neglected. This founding insures that the weather conditions with its short time light and low temperature have affected and reduce stevia growth yield. Such observation has been confirmed by many investigators (Zaidan et al., 1980; Matejka, 1992; and Ermakov and Kochetov, 1994).

Identification of stevia growth yield:

The effect of the study soil parameters i.e., soil texture and water table levels on growth yield of stevia plant and there interactions were shown in Tables 2 and 3 for first and second cuts, respectively.

Stevia plants which were subjected to different SWT levels were not significantly affected and produced the same number of branches in each plant. Nevertheless, the soil texture factor showed a significant effect on branches number where the loamy soil surpluses the calcareous soil by 96.8% overall the studied SWT depths (Table 2). The same trend was recorded for the number of leaves per branch where all SWT levels produced significantly the same number of leaves, while, the loamy soil had 78.6% more than calcareous one. As regards to the plant fresh weight, SWT depths had insignificant effect over both studied soil types. Yet, the loamy soil significantly produced heavier fresh plants by 37.32% as compared to calcareous soil. The superiority of loamy soil over calcareous soil was revealed too for the plant dry weight data by 30.73 %, as recorded in Table 2, regardless of the existing levels of the SWT. On the other hand, diminishing SWT levels up to 40 cm depth significantly increased the plant dry weight. The percentage of decreases were determined to be 5.7, 19.0, 22.0, and 29.0 as SWT increased from 40 cm, respectively to 70, 100, 130, and 160 cm.

Both leaves fresh and dry weights were significantly influenced by soil and SWT factors. Loamy soil produced weightier fresh and dry leaves by 22.6% and 16.0%, respectively than calcareous soil. As for SWT, the rule covered that the shorter the SWT the heavier the fresh and dry leaves. The decreasing percentages were 7.0, 19.0, 25.5, and 30.0% for fresh leaves weight and 9.3, 21.9, 26.3, and 28.4 for dry leaves weight when SWT increased from 40 cm depth, respectively to 70, 100, 130, and 160 cm. Stem dry weights were significantly the same due to SWT factor, yet it significantly increased by 67% in loamy soil as compared to calcareous soil. Nevertheless, the data showed that the ratio between the produced leaves and stem was not affected due to either SWT and/or soil type factors.

The tabulated data of the chlorophyll analysis may be helpful to interpreting the above mentioned results, where both SWT and soil type had significant effects on the chlorophyll. The 40 cm SWT depth and loamy soil reflected the highest chlorophyll levels in the stevia. It was found that the decreasing rates were 8.2, 12.1, 9.9, and 12.6% as the SWT diminished from 40, respectively to 70, 100, 130, and 160 cm depth. Meanwhile, loamy soil had the superiority by 7.7 % over the calcareous one. As given in Table 2, none of the studied growth parameters revealed significant differences due to the interaction of SWT by soil type.

As for the second cut yields, Table 3 shows the results of the stevia growth properties as affected by SWT and soil type. Significantly, all the tested SWT depths produced the same number of branches/plant, but loamy soil was superior in producing number of branches/plant. This finding was also observed in number of leaves/branch although, it was decreased as the SWT depths increased (Table 3). In general, such observation was existed also in case of plant fresh weight, plant dry weight, leaves fresh and dry weights. Stem dry weight was the same as SWT depth increased from 40 to 160 cm. Meanwhile, the loamy soil produced heavier stem weight than the calcareous soil. Leaves to stem ratio revealed insignificant effects due to the SWT levels and the soil type factors. Chlorophyll contents were decreased as the SWT increased up to 70 cm depth, afterwards it became significantly constant up to 160 cm depth, with the superiority of loamy over calcareous soil. As the interaction effects between the SWT and soil type, it was found that not significant effects for most of the growth properties except leaves fresh and dry weights in addition to the plant fresh weight (Table 3). Plants that were subjected to loamy soil with SWT at 40 or 70 cm depth showed the highest means, followed by loamy with 100 cm depth or calcareous with 40 cm depth.

Table 2. Parameters of the stevia first cut yield (2006) as influenced by soil water-table depth and soil type.

Soil	Soil water-table (SWT) depth, cm.						LSD
(S)	40	70	100	130	160	G.average	SWT x S
			No. of branches / plant				
Calcareous	9.5	6.5	6.5	6.3	6.0	7.0b	
Loamy	17.3	13.5	13.5	11.3	12.8	13.7a	
Means	13.4a	10.0a	10.0a	8.8a	9.4a	10.3	N.S.
			No. of leaves / branch				
Calcareous	162.5	140.0	138.3	128.5	109.3	135.7b	
Loamy	284.5	277.0	232.5	213.5	204.3	242.4a	
Means	223.5a	208.5a	185.4a	171.0a	156.8a	189.0	N.S.
			Plant fresh wt., kg / m^2				
Calcareous	3.5	2.9	2.1	2.7	2.7	2.8b	
Loamy	4.6	3.9	3.8	3.8	2.8	3.8a	
Means	4.0a	3.4a	3.0a	3.3a	2.7a	3.3	N.S.
			Plant dry wt., g / m^2				
Calcareous	1004.8	977.5	905.3	833.8	740.0	892.3b	
Loamy	1421.3	1311.3	1059.8	1060.0	980.0	1166.5a	
Means	1213.0a	1144.4ab	982.5abc	946.9bc	860.0c	1029.4	N.S.
			Leaves fresh wt., g/m^2				
Calcareous	706.3	719.3	674.0	598.3	574.3	654.4b	
Loamy	1032.3	898.0	735.0	697.0	648.8	802.2a	
Means	869.3a	808.6ab	704.5ab	647.6b	611.5b	728.3	N.S.
			Leaves dry wt., g/m^2				
Calcareous	542.5	511.3	482.5	458.8	463.8	491.8b	
Loamy	735.0	666.3	516.3	482.5	451.3	570.3a	
Means	638.8a	588.8ab	499.4ab	470.6b	457.5b	531.0	N.S.
			Stem dry wt., g				
Calcareous	462.3	468.8	422.8	375.0	276.3	401.0b	
Loamy	686.3	645.0	543.5	577.5	528.8	596.2a	
Means	574.3a	556.9a	483.1a	476.3a	402.5a	498.6	N.S.
			Leaves / Stem ratio				
Calcareous	1.2	1.1	1.2	1.5	3.8	1.8a	
Loamy	1.1	1.0	1.0	0.9	0.9	1.0a	
Means	1.2a	1.1a	1.1a	1.2a	2.3a	1.4	N.S.
			Chlorophyll,%				
Calcareous	41.5	39.5	37.2	38.1	37.0	38.6b	
Loamy	46.3	41.1	40.0	41.1	39.8	41.6a	
Means	43.9a	40.3b	38.6b	39.6b	38.4b	40.1	N.S.

N.S.= Not Significant.

Table 3. Parameters of the stevia second cut yield (2006) as influenced by soil water-table depth and soil type.

Soil (S)	Soil water-table (SWT) depth, cm. 40	70	100	130	160	G.average	LSD SWT x S
			No. of branches / plant				
Calcareous	13.3	11.3	11.3	9.8	10.0	11.1b	
Loamy	22.8	21.0	21.3	21.5	20.0	21.3a	
Means	18.0a	16.1a	16.3a	15.6a	15.0a	16.2	N.S.
			No. of leaves / branch				
Calcareous	45.3	39.8	38.5	33.5	32.3	37.9b	
Loamy	68.5	63.8	61.8	55.8	46.3	59.2a	
Means	56.9a	51.8ab	50.1ab	44.6bc	39.3c	48.5	N.S.
			Plant fresh wt., kg / m^2				
Calcareous	1.7	1.5	1.2	1.0	0.8	1.2b	
Loamy	2.7	2.4	1.9	1.3	1.0	1.8a	
Means	2.2a	1.9a	1.5b	1.1c	0.9c	1.5	0.42
			Plant dry wt., g / m^2				
Calcareous	582.5	546.1	479.1	292.9	255.8	431.2b	
Loamy	991.0	802.3	746.2	452.8	352.5	668.9a	
Means	786.7a	674.2a	612.6a	372.8b	304.1b	550.1	N.S.
			Leaves fresh wt., g/m^2				
Calcareous	1165.5	1049.5	891.3	704.3	572.3	876.6b	
Loamy	1790.5	1624.3	1178.0	826.3	653.7	1214.5a	
Means	1478.0a	1336.9b	1034.6c	765.3d	613.0e	1045.5	180.7
			Leaves dry wt., g/m^2				
Calcareous	370.3	314.3	278.0	211.5	158.0	266.4a	
Loamy	594.5	494.0	356.5	248.3	195.8	377.8b	
Means	482.4a	404.1b	317.3c	229.9d	176.9d	322.1	87.5
			Stem dry wt., g				
Calcareous	212.2	231.8	201.1	81.4	97.8	164.8b	
Loamy	396.5	308.3	389.7	204.5	156.8	291.1a	
Means	304.3a	270.0a	295.4a	142.9a	127.3a	228.0	N.S.
			Leaves / Stem ratio				
Calcareous	2.0	1.4	3.3	3.3	2.0	2.4a	
Loamy	1.6	2.7	1.2	1.2	1.3	1.6a	
Means	1.8a	2.1a	2.3a	2.3a	1.6a	2.0	N.S.
			Chlorophyll,%				
Calcareous	42.3	39.6	35.4	32.6	32.4	36.4b	
Loamy	47.3	42.1	39.8	39.0	37.9	41.2a	
Means	44.8a	40.8b	37.6c	35.8c	35.2c	38.8	N.S.

N.S.= Not Significant.

Leaves components performance:

For each studied soil only five representatives leaves samples were chosen, one sample from each SWT level, for leaves components analysis. The obtained results are shown in Table 4 and presented in Figures 1 and 2 for the first cut and Table 5 and Figure 3 for the second cut.

As given in Table 4 and Figure 1, it is obvious that fat content was negligibly increased as the SWT depths increased by a rate of 3% and 1.6% of SWT depth with acceptable correlation factors, Equations 1 and 2, for calcareous and loamy soil, respectively. The ash contents in calcareous were almost the same up to 130 cm depth, whereas it was decreased in loamy by 12.4% also up to 100 cm depth, after which it was increased as the SWT increased up to 160 cm depth (Equations 3 and 4). As for protein content, the decreasing rate with increasing the SWT in calcareous was less than that of loamy soil, in addition, loamy soil revealed higher protein values than calcareous (Equations 5 and 6 for calcareous and loamy soils, respectively).

Table 4. Leaves components of the first cut.

Character g/m^2	Calcareous soil Water Table Depth, cm					Loamy soil Water Table Depth, cm				
	40	70	100	130	160	40	70	100	130	160
Fat	3.2	4.4	4.5	5.3	7.2	3.5	3.7	3.3	5.2	5.2
Ash	50.0	50.8	50.1	50.1	58.0	78.7	71.4	61.8	62.2	64.8
Protein	51.5	49.0	47.0	46.1	48.6	78.1	71.8	56.3	54.3	52.0
Stevia Sweeteners	188.7	161.0	149.6	134.8	111.7	226.9	202.3	145.4	131.0	117.8
Stevioside	123.5	106.4	90.7	88.6	50.7	151.1	125.9	92.5	85.3	67.7
Rebaudioside A	36.4	25.8	29.9	28.9	29.4	43.3	39.9	31.5	33.4	33.9
T.S. carbohydrate	310.0	306.3	293.7	280.3	280.8	419.5	392.6	306.9	290.3	278.9
Calculated Stevioside	280.3	278.8	267.9	255.0	258.8	379.0	356.4	279.0	264.4	255.0

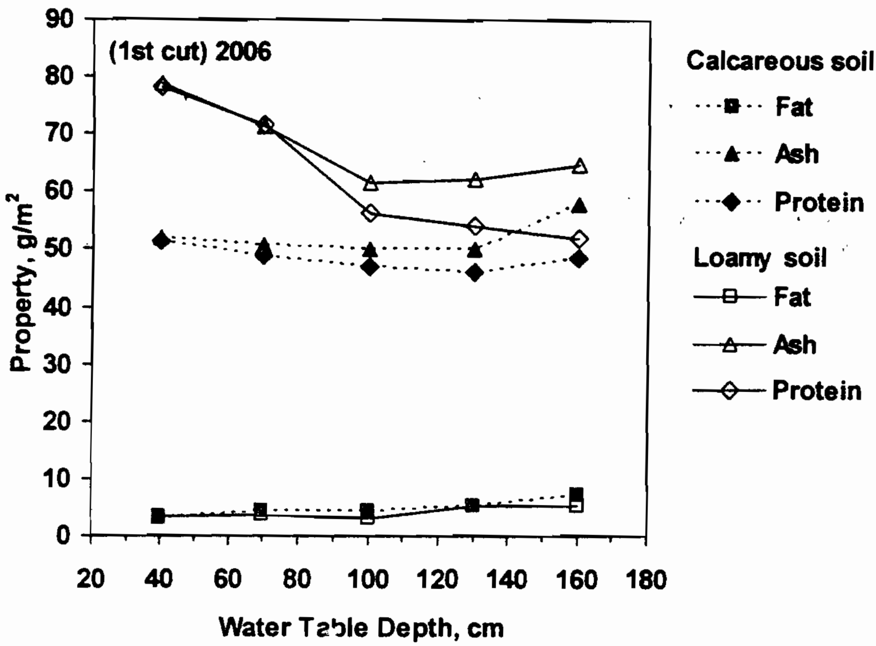

Fig.1. Fat, ash, and protein of leaves (first cut) as influenced by SWT levels and soil type.

Calcareous soil (1st cut)

Fat, g/m^2	$= 1.952 + 0.030$ W.T.	$R^2 = 0.908$	(1)
Ash, g/m^2	$= 47.628 + 0.038$ W.T.	$R^2 = 0.473$	(3)
Protein, g/m^2	$= 51.359 - 0.029$ W.T.	$R^2 = 0.438$	(5)

Loamy soil (1st cut)

Fat, g/m^2	$= 2.524 + 0.016$ W.T.	$R^2 = 0.673$	(2)
Ash, g/m^2	$= 80.169 - 0.124$ W.T.	$R^2 = 0.660$	(4)
Protein, g/m^2	$= 85.676 - 0.232$ W.T.	$R^2 = 0.890$	(6)

Identification of the important sweetener parameters:

The most important of stevia leaves technological parameters, such as stevia sweeteners, stevioside (HPLC), rebaudioside A, as the major stevia sweeteners in stevia leaves, and total carbohydrate, were presented in Tables 4 and 5, and showed in Figures 2 and 3 for first and second cut, respectively.

In general, stevia sweeteners in both tested soil diminished as SWT level increased up to 160 cm. Yet, loamy soil revealed higher values than calcareous within the SWT range between 40 to 100 cm depth, after which both soils produced stevia leaves of almost identical values of their sweeteners (Table 4 and Figure 2) and (Equations 7 and 8). Both determined and calculated stevioside (HPLC), followed the same trend of stevia sweeteners where higher values were found for plants subjected to 40 cm. SWT in loamy soils (Table 4 and Figure 2) and presented by equations 9 and 10 for determined stevioside , and equations 11 and 12 for calculated one. The behavior of the rebaudioside A was different where almost identical values were found for both tested soils with a negligible differences where the average decreasing rate was calculated according to equations 13 and 14 and found to be 0.75% with increasing the SWT up to 160 cm depth. It was also clear (Table 4 and Figure 2) that the total carbohydrate decreased as the SWT increased from 40 to 160 cm depth but the deflexed point was at the 100 cm depth where the decreasing rate diminished to be less and may be neglected. Furthermore, loamy soil was superior in producing the carbohydrate over calcareous soil as shown in equations 16 and 15, respectively.

Calcareous soil (1st cut)

Stevia sweeteners, g/m^2	= 209.230 - 0.600 W.T.	$R^2 = 0.980$	(7)
Stevioside (HPLC), g/m^2	= 146.440 - 0.545 W.T.	$R^2 = 0.915$	(9)
Calculated stevioside, g/m^2	= 290.420 - 0.223 W.T.	$R^2 = 0.855$	(11)
Rebaudioside A, g/m^2	= 39.088 - 0.070 W.T.	$R^2 = 0.804$	(13)
T.S. carbohydrate, g/m^2	= 322.420 - 0.282 W.T.	$R^2 = 0.926$	(15)

Loamy soil (1st cut)

Stevia sweeteners, g/m^2	= 261.210 - 0.965 W.T	$R^2 = 0.932$	(8)
Stevioside (HPLC), g/m^2	= 173.620 - 0.691 W.T.	$R^2 = 0.956$	(10)
Calculated stevioside, g/m^2	= 420.140 - 1.134 W.T.	$R^2 = 0.894$	(12)
Rebaudioside A, g/m^2	= 44.839 - 0.084 W.T.	$R^2 = 0.649$	(14)
T.S. carbohydrate, g/m^2	= 465.420 - 1.278 W.T.	$R^2 = 0.899$	(16)

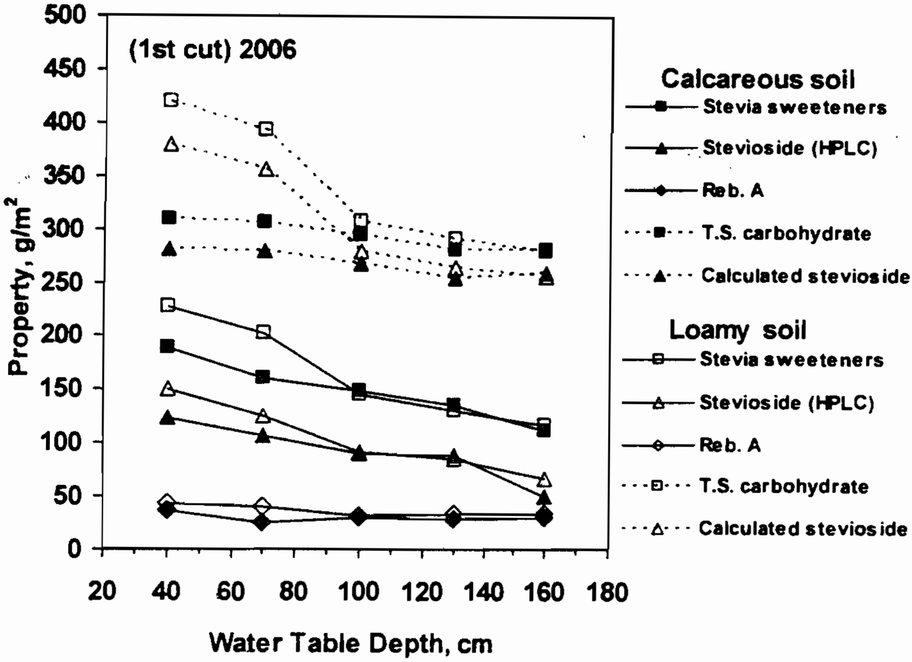

Fig.2. Effect of SWT level and soil type on some of important stevia leaves components of the first cut.

As for the results of the second cut, it is obvious that total stevia sweeteners in both soils decreased with higher rate until the SWT level reached the 130 cm depth then the decreasing rate became less up to 160 cm depth (Table 5 and Figure 3). The superiority of loamy soil over calcareous was also identified from the second cut results (Equations 17 and 18) as previously mention in the case of the first cut. The determined stevioside (HPLC) was affected by the SWT depth (Equations 19 and 20) in higher decreasing rate up to 100 cm depth. The decreasing rate became less from 100 to 160 cm depth. Meanwhile, stevia leaves which produced from loamy soil content higher values of stevioside (HPLC) than calcareous. Even for the calculated stevioside, the 100 cm SWT depth was the limit between higher and lower decreasing rates in addition to the higher values calculated from loamy soils in comparing to those of calcareous soil (Equations 21 and 22). The results of the rebaudioside A parameter showed the same trend as that of stevioside sweetener, with one difference which relayed on the decreasing rate which is less (about

0.7 % for rebaudioside A) than 7.23% for stevioside sweetener), as given also by equations 23 and 24. The given results clearly showed that the total carbohydrate values of the planted subjected to loamy soil was quit higher than those of calcareous soil among all the studied range of the SWT depths (Equations 25 and 26). The limited point between high and low decreasing rate was fixed between 100 and 130 SWT depth depending on the soil type. It is worthwhile to mention here that the decreasing rate with the SWT depth for most of the discussed parameters was higher in loamy soil but the absolute given values was mostly higher in loamy soil than in calcareous, which dives the superiority to the loamy soil.

Table 5. Leaves components of the second cut.

Character g/m^2	Calcareous soil Water Table Depth, cm					Loamy soil Water Table Depth, cm				
	40	70	100	130	160	40	70	100	130	160
Stevia sweeteners	129.6	109.0	86.4	64.5	43.1	193.9	144.4	100.4	66.5	48.5
Stevioside (HPLC)	97.4	70.0	58.3	40.5	27.6	118.7	94.8	55.7	39.7	26.4
Rebaudioside A	21.0	15.2	13.4	9.6	6.5	39.5	29.0	19.7	12.7	9.8
T.S. carbohydrate	236.4	199.3	174.3	132.0	93.2	362.6	305.3	216.9	150.2	117.7
Calculated	217.2	182.9	158.8	119.0	84.6	330.9	271.8	196.1	136.9	109.3

Calcareous soil (2nd cut)

Stevia sweeteners, g/m^2 = 159.040 - 0.725 W.T. $R^2 = 0.999$ (17)

Stevioside (HPLC), g/m^2 = 115.140 - 0.564 W.T. $R^2 = 0.978$ (19)

Calculated stevioside, g/m^2 = 262.140 - 1.097 W.T. $R^2 = 0.995$ (21)

Rebaudioside A, g/m^2 = 24.647 - 0.115 W.T. $R^2 = 0.977$ (23)

T.S. carbohydrate, g/m^2 = 284.990 - 1.179 W.T. $R^2 = 0.994$ (25)

Loamy soil (2nd cut)

Stevia sweeteners, g/m^2 = 233.640 - 1.229 W.T. $R^2 = 0.972$ (18)

Stevioside (HPLC), g/m^2 = 146.940 - 0.799 W.T. $R^2 = 0.963$ (20)

Calculated stevioside, g/m^2 = 401.700 - 1.927 W.T. $R^2 = 0.980$ (22)

Rebaudioside A, g/m^2 = 47.411 - 0.253 W.T. $R^2 = 0.962$ (24)

T.S. carbohydrate, g/m^2 = 445.510 - 2.150 W.T. $R^2 = 0.981$ (26)

Thus, the above results may suggest that, for stevia growth production, the 40 cm SWT depth could be regarded as the optimum depth, regardless of the soil type. Nevertheless, loamy soil has the superiority in all the tested growth and technological parameters over the calcareous ones. Meanwhile, such findings may reflect the nature of root system of stevia plant where short and shallow root system was existed. Such conditions under deeper SWT levels could create problems in absorbing water and nutrients by the crops (Malik *et al.*, 1989; Prathapar *et al.*, 1992; and Thorbum *et al.*, 1992).

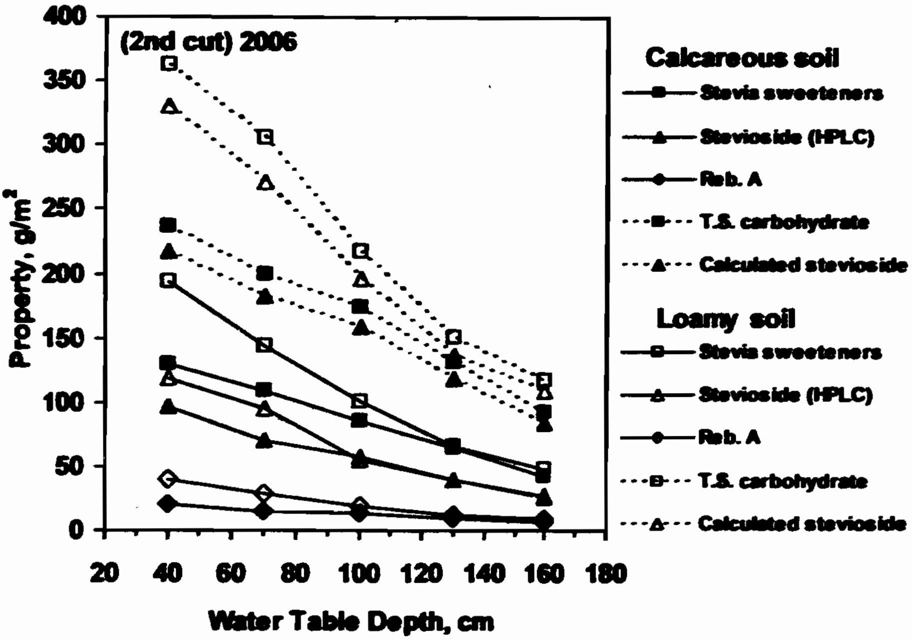

Fig.3. Effect of SWT level and soil type on some of important stevia leaves components of the second cut.

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الملخص العربى

صفات النمو والمحتويات الكيماوية لنبات الاستيفيا باختلاف نوع التربة ومستوى الماء الأرضى

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تتحدد احتياجات الصرف لأى محصول بعمق مستوى الماء الأرضى التى تتعاظم معه إنتاجية هذا المحصول. أقيمت هذه الدراسة لمعرفة مدى تأثر المحصول الأقتصادى لنبات الاستيفيا بارتفاع مستوى الماء الأرضى فى الأراضى المختلفة القوام و تمت الدراسة فى أحواض ليزيمترية ذات خمسة مستويات من عمق الماء الأرضى وهى ٤٠، ٧٠، ١٠٠، ١٣٠، و ١٦٠ سم من سطح الأرض لنوعين من التربة الأولى طميية والأخرى جيرية.

تم تقدير صفات النمو الخضرى بجميع عناصر محصول الاستيفيا وتم تقييم هذا المحصول من خلال تقدير التركيب الكيميائي للنبات وأيضا استخلاص وعزل المركبات المحلية والتقدير الكمي للمواد المحلية (محليات الاستيفيا) باستخدام طريقة كروماتوجرافيا السائل عالية الكفاءة ومن أهم النتائج المتحصل عليها ما يلى :

١- تم الحصول على حشتين فقط خلال السنة المحصولية وهما خلال فترة الصيف حيث ارتفاع درجة الحرارة وطول الفترة النهارية مما أثر على النمو بصورة إيجابية . وهذا بعكس الفترة الشتوية وما بها من انخفاض درجة الحرارة وقصر الفترة النهارية مما أثر سلبا على نمو نبات الاستيفيا.

٢- أظهرت الأرض الطميية استجابة معنوية على الأرض الجيرية فى الكثير من الصفات المحصولية مثل الوزن الرطب والجاف للأوراق وللنبات الكامل وكذلك عدد الأفرع لكل نبات وعدد الأوراق لكل فرع.

٣- كان عمق مستوى الماء الأرضى ٤٠ سم الأفضل بالنسبة لوزن الأوراق الجافة والرطبة وكانت معدل الزيادة تتراوح بين ٧ – ٣٠ % مقارنة بالأعماق الأخرى.

٤- تم استنباط العلاقات بين التركيب الكيماوى للأوراق وكل من عمق الماء الأرضى ونوع التربة. وقد وجد أن نسبة البروتين بأوراق الاستيفيا النامية فى الأرض الطميية كانت أعلى عن تلك النامية بالأرض الجيرية فى حين لم يتأثر محتوى الأوراق من الدهن بنوع الأرض.

٥- وجد أن محليات الاستيفيا المستخلصة من الأوراق تتأثر بزيادة عمق مستوى الماء الأرضى وبالأخص استيفيوسيد و ريبوديوسيد أ وهما يمثلان أكبر نسبة من محليات الاستيفيا حيث انخفضت نسبة محلى الأستيفيوسيد المقدر والمحسوب بمعدل بطىء فى الحشة الأولى وبمعدل متزايد فى الحشة الثانية وذلك مع زيادة عمق مستوى الماء الأرضى إلى ١٦٠ سم ، فى حين لم تتأثر كمية ريبوديوسيد أ بزيادة عمق الماء الأرضى .ومن جهة أخرى فان الكربوهيدرات الكلية تناقصت بمعدل سريع مع زيادة عمق الماء الأرضى حتى عمق ١٠٠ سم ثم انخفض معدل النقص حتى عمق ١٦٠ سم.

٦- تبين من نتائج التحليل الكيماوي لأوراق نبات الاستيفيا أن متوسط محليات الاستيفيا فى الأرض الجيرية تراوحت بين ١٥٩,١٩ – ٧٧,٤ جرام / متر^{٢} فى حين أنها كانت ما بين ٢١٠,٤ – ٨٣,١٥ جرام / متر^{٢} فى الأرض الطميية.وذلك يؤكد تفوق الأرض الطميية على الأرض الجيرية تحت الظروف المناخية لمنطقة التجربة.