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THE EFFECT OF SOIL MOISTURE STRESS ON SOME SUGAR BEET VARIETIES

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Abstract

Two pot experiments were conducted during two successive seasons 1995/1996 and 1996/1997 to investigate the effect of different levels of soil available water (100%, 75% 50% and 25%) on four sugar beet varieties (*Beta vulgaris* L.) The results indicated that:

- Growth and yield of sugar beet shoot were affected by water deficit more than the corresponding roots.
- In spite of increasing sucrose percentage in root juice, purity and sugar yield per plant were decreased under water strees.
- Biosynthesis of chlorophyll A was more degraded by water stress than chlorophyll B or carotenoids.
- Nitrogen and sodium concentrations in both root and leaves were more reduced than phosphorus and potassium with lowering soil moisture availability at 50% and 25% from control.
- Proline concentration increased in sugar beet leaves while acid invertase activity was inhibited in plant's roots under drought condition.
- Varieties of sugar beet significantly differed in their response to water stress; both Ras Poly and Del 939 varieties were less affected by water deficit. M 9340 variety was the most sensitive. Top variety was moderately affected.
- The increase in free proline concentration under water stress was much higher in the leaves of tolerant sugar beet varieties than that in the sensitive ones. This proved that proline plays a role in drought tolerance in sugar beet.
- Varieties of sugar beet could be arranged ascendingly according to their root invertase activity. Ras poly, Del 939, Top and M 9340.

INTRODUCTION

Sugar beet (*Beta vulgaris* L.) is the second important sugar crop all over the world. It can produce high yield of sugar under unfavorable ecological condition, unsuitable for sugar cane. In Egypt, lack of available water due to either high salinity or shortage of water resources represent the main problems which eliminate agricultural development. Hisao (1973) and Boyer (1976) indicated that in arid and semi arid regions soil moisture stress plays an important role in the physiology and metabolism of the plant. Slatyer (1967) stated that under drought stress, there was a conversion of starch to sugar, where the metabolism of carbohydrate was affected due to direct and indirect influence on photosynthesis and intermediate components of biochemical processes. Shaw and Laing (1968) indicated that soil moisture stress did not affect all aspects of plant development equally; some processes were highly susceptible to the increase of moisture stress, while others were far less affected. Simpson (1981) obtained similar results.

Sugar beet production is markedly influenced by the interaction effect between its varieties and environmental factors (Garg and Srivastava; 1988 and Vigoureux and Roelants 1990).

The previous facts justify studying the influence of soil moisture level on physiological state of sugar beet varieties. Hills *et al.* (1986) indicated that sugar beet was able to tolerate moderate soil water stress and produce a profitable crop. Brown *et al* (1987) reported that when sugar beet was exposed to both early and late draught stress, it had a higher sugar content in the root, although there was a reduction in growth of sugar beet and its productivity (root and sugar yields). Similar results were obtained by Schilling *et al* (1991), Dunham and Calrke (1992), Mekki *et al* (1994) and Soudi, Amal (1998). Water regime, as ecological factor, causes some changes in biochemical processes during the different stages of plant growth. Petrovic *et al* (1991) and Gzik (1996) indicated that the drought stress caused a rapid increase in proline concentration in the leaves of sugar beet plant, accompanied by inhabitance of the growth rate. On th other hand, photosynthetic pigments markedly decreased, when sugar beet plants were exposed to water stress (Mekki *et al*, 1994).

The aim of this study was to investigate the effect of drought stress on sugar beet and to evaluate the behavior of sugar beet varieties grown under different levels of soil moisture.

MATERIALS AND METHODS

This investigation was conducted in the Agricultural Research Center, at Giza during two successive seasons, 1995/1996 and 1996/1997 to study the effect of four soil moisture levels of 100%, 75%, 50%, and 25% of the maximum available water of the soil on four beet varieties, namely Top, Del 939, Ras Poly and M 9340.

Sugar beet seeds were sown in tin pots (50 cm in height and 35 cm in diameter). The inner surface of the pots was coated with three layers of bitumen to avoid the direct contact between the soil and metal. In each pot two kilograms of gravels were placed at the bottom to maintain good drainage. The pots were filled with 30 Kg of air dried silty clay soil of Kafr El-Shik Governorate, where sugar beet is a commercial crop. The mechanical and chemical analyses of the soil are represented in Table (1).

The Seedlings of sugar beet were thinned to two plants per pot after fourty days from sowing. Fertilization and other cultutal practices were carried out as usual. Irrigation treatments were commenced six weeks after planting. The soil available water was determined according to the equation of Israelsen and Hansen (1962). The required water for each treatment was added to maintain the desired level of soil moisture through out the course of the growing two seasons.

After 135 days from sowing, one plant from each pot was taken to determine the following data:

1. Root growth characteristics:
   - Length and diameter of the root/plant,
   - Fresh and dry weights of the root.

2. Shoot growth characteristics:
   - Number of leaves/plant,
   - Fresh and dry weights of the shoot.

3. Root juice quality:
   - Total soluble solids (T.S.S. %) was determined using hand refractometer (A.O.A.C., 1996).
   - Sucrose percentage was determined according to the procedure of Le Docte (1927).
   - Juice purity was determined as described by Carruthers and Oldfield (1961).

4. Biochemical analyses:
   - Acid invertase activity was determined in roots as described by Bergmayer (1979).
   - Photosynthetic pigments chlorophyll A, B and carotenoids were determined according to the method of Westtstein (1957).
   - Free proline concentration in leaves was determined using the method of Bates *et al.* (1973).

5. Chemical analyes:

- In the digested solution of the dried powder of the leaves and root materials, nitrogen was determined using micro-kjedahl methods (A.O.A.C., 1986). Phosphorus was determined colorimeterically according to Chapman and Pratt (1961). Potassium and sodium were estimated by flame photometeric method of Brown and Lilliand (1964).

At harvest time (210 days), data on all previous criteria were recorded, in addition, sugar yield per plant was determined at the Delta Sugar Company. Approximately 3.07% of the sucrose percentage was considered as a loss during industrial processing.

Sugar yield in g/plant = weight of root in g X adjusted sucrose % X juice purity. Statistical analyses for growth characteristics were based on completely randomized in factorial design over two growing seasons. Least significant differences test was used to compare treatment means as described by Steel and Torrie (1980).

Table 1. Physical and chemical analysis of soil.

Particle size distribution (Pipette method, Piper (1950)	
Clay %	38.25
Silt %	41.98
Sand %	19.77
Electrical conductivity	
EC. Mmhos/cm	4.80
T.S,S. g/100g soil	1.31
PH	8.00
Cations and anions in meq/l (Chapman and Prett, 1961)	
Mg	10.26
Na	24.69
K	0.44
Ca	13.26
HCO_3	2.40
Cl	34.00
SO_4	12.20

RESULTS AND DISCUSSION

Root and Shoot Characteristics:

Statistical analyses of data indicated a significant differences in length, diameter, fresh and dry weights of root (Table 2) as well as leaves number, fresh and dry weights of shoot (Table 3) among the four different varieties of sugar beet under investigation. Ras Poly variety recorded the highest values for all the prior mentioned parameters for both samples at 135 and 210 days after sowing. In fist sample (135 days) Ras Poly significantly differed when it compared with other varieties and Del 939 variety was ranked the second. While, insignificant differences were found between root characteristics (except root length) for Top and M 9340 varieties after 135 days from sowing. At harvest time, Top variety recorded significantly higher values than M 9340 in all of root and shoot measurements. These differences among sugar beet varieties might be due to their genetic background. Similar results were obtained by Leilah and Nasr (1992), Dixon and Mc Cullagh (1994) and El Sayed (1997).

As the soil moisture stress increased significant and gradual decrease in all growth measurements of sugar beet (except for root length) were recorded as shown in Table 2 and 3. It could be noticed that moisture stress markedly affected the growth of shoot more than root. Therefor, Fresh shoot weight was declined by 8.7%, 22.6% and 30.6% at the samples of 135 days old and by 12.6%, 23.4% and 31%, at the harvest time for the treatments of 75%, 50% and 25% of the maximum available water, respectively comparing with normal moisture level (100% of available water). The corresponding reduction for fresh root weight were 10.3%, 17.3% and 24.0%, respectively, at the first sample, and 9.2%, 15.9% and 23.8%, respectively at the harvest time. The changes of the weights of dry samples of both root and shoot followed the same pattern as fresh ones.

It is clear that the adverse effect of water stress was magnified by age. Thus, under severe water stress (25% of the available water), diameter, fresh and dry weights of root at 135 days old, decreased by 18.4%, 24.0% and 24.9%, respectively, in comparison with the control. The same criteria decreased at the harvest time (210 days) by 22.2%, 23.8% and 27.3%, respectively. The decrease in leave number, fresh and dry weights of shoot after 135 days from sowing reached 22.4%, 30.6% and 29.9%, respectively while the same criteria were lower by 24.4%, 31.0% and 31.3%, respectively, at the harvest time, when these values compared with plants grown at maximum available water.

Table 2. Effect of water deficit on root growth characters of four sugar beet varieties. (Combined analysis over two growing seasons).

Varieties (V)	Soil Moisture level (SML)	135 days after sowing				210 days after sowing			
		Root length (cm)	Root diameter (cm)	Root fresh weight (g)	Root dry weight (g)	Root length (cm)	Root diameter (cm)	Root fresh weight (g)	Root dry weight (g)
Top	100% **	13.0	6.2	398	92.1	16.3	9.2	930	236.3
	75%	13.7	5.8	345	78.8	18.7	8.2	837	211.3
	50%	14.7	5.5	324	73.2	20.7	7.6	776	194.3
	25%	15.0	5.0	296	67.1	22.3	7.1	672	168.3
	Mean	14.1	5.6	341	77.8	19.5	7.9	804	202.6
M 9340	100%	10.7	6.5	407	94.4	14.3	9.8	932	234.3
	75%	12.3	5.8	348	78.7	15.7	8.7	819	204.7
	50%	12.7	5.0	326	74.3	17.3	7.9	729	182.7
	25%	14.3	4.9	294	67.0	20.7	7.2	627	157.7
	Mean	12.5	5.6	344	78.6	17.0	8.4	777	194.9
Ras Poly	100%	15.0	7.1	449	103.5	19.3	11.2	1132	284.0
	75%	17.0	6.8	412	94.8	22.0	10.7	1031	259.0
	50%	18.0	6.4	369	84.5	21.7	9.3	961	241.0
	25%	19.0	6.1	348	79.5	25.7	9.0	940	231.3
	Mean	17.3	6.6	395	90.6	22.7	10.1	1016	253.8
Del 939	100%	12.7	6.0	411	95.3	19.0	9.5	977	244.3
	75%	14.3	5.9	389	88.8	19.2	9.0	920	226.3
	50%	15.0	5.6	359	81.4	20.8	8.0	875	219.3
	25%	15.7	5.1	330	75.5	22.8	7.7	798	189.0
	Mean	14.4	5.7	372	85.3	20.9	8.6	890	219.7
Mean of (SML)	100%	12.9	6.5	417	96.3	17.3	9.9	993	249.8
	75%	14.3	6.1	374	85.3	19.2	9.2	902	226.3
	50%	15.1	5.5	345	78.4	20.8	8.2	835	209.3
	25%	16.	5.3	317	72.3	22.8	7.7	757	181.6
LSD 0.05 for V		0.89	0.48	11.7	2.87	0.78	0.36	14.3	4.64
LSD 0.05 for (SML)		0.89	0.48	11.7	2.87	0.78	0.36	14.3	4.64
LSD 0.05 for Vx(SML)		NS	NS	NS	NS	NS	NS	28.7	NS

** 100% (control) = maximum available soil moisture

75% = 75% from maximum available soil moisture

50% = 50% from maximum available soil moisture

25% = 25% from maximum available soil moisture

Table 3. Effect of water deficit on shoot growth characters of four sugar beet varieties. (Combined analysis over two growing seasons).

Varieties (V)	Soil Moisture level (SML)	135 days after sowing			210 days after sowing		
		Leaves number	Fresh weight (g)	Dry weight (g)	Leaves number	Fresh weight (g)	Dry weight (g)
Top	100% **	16.0	397	63.6	21.3	600	122.3
	75%	14.7	368	58.7	19.0	523	106.2
	50%	12.0	316	51.0	17.3	470	94.8
	25%	12.0	267	41.5	15.7	385	78.0
	Mean	13.7	337	53.7	18.3	495	100.3
M 9340	100%	14.0	348	53.9	19.0	530	108.9
	75%	12.6	299	46.4	16.7	442	90.8
	50%	11.3	233	35.2	15.0	345	70.5
	25%	10.7	215	32.8	13.3	307	62.3
	Mean	12.2	274	42.1	16.0	406	83.1
Ras Poly	100%	17.3	434	64.8	26.3	662	135.9
	75%	16.0	395	63.5	24.0	593	122.3
	50%	14.3	340	54.8	22.0	536	109.6
	25%	13.7	313	50.6	20.3	525	107.1
	Mean	15.3	371	58.5	23.2	579	118.6
Del 939	100%	15.0	379	61.2	21.7	582	118.6
	75%	14.0	359	57.3	20.3	518	104.9
	50%	13.0	317	50.9	18.7	470	95.1
	25%	12.7	285	42.7	17.3	423	96.0
	Mean	13.7	335	53.8	19.5	498	101.2
Mean of (SML)	100%	15.6	389	60.9	22.1	594	121.4
	75%	14.3	355	56.5	20.0	519	106.1
	50%	12.7	301	48.0	18.3	455	92.5
	25%	12.1	270	42.7	16.7	410	83.4
LSD 0.05 for V		1.13	14.8	2.24	0.51	20.5	4.15
LSD 0.05 for SML		1.13	14.8	2.24	0.51	20.5	4.15
LSD 0.05 for VxSML		NS	NS	NS	NS	41.1	NS

** 100% (control) = maximum available soil moisture
75% = 75% from maximum available soil moisture
50% = 50% from maximum available soil moisture
25% = 25% from maximum available soil moisture

Root length was signifianctly enhanced deeply, when sugar beet plants were exposed to water stress (Tabel 2). Such stresses at 135 days was 10.9%, 17.1%, and 24.0 while, at harest time it was 11.0%, 20.2% and 31.8%, for 75%, 50% and 25% of the available water, respectively.

These results are in agreement with data of Slatyer (1967), Shaw and Laing (1968), Mekki *et al* (1994) and Soudi, Amal (1998). Simpson (1981) explained that lengthening the roots in the soil was to exploit the deeply stored soil moisture to avoid drought stress damage. On contrast, the decrease in the root weight might be due to the reduction in both metabolic products and transport of photosynthetic assimilates under the water stress condition.

Data in Tables 2 and 3 show that all growth criteria, i.e. length, diameter, dry weight of both root and shoot and leave number at 135 days old and at harvest time were insignificantly affected by interaction effect between soil water stress levels and varieties of sugar beet. This indicated that all varieties of sugar beet under investigation had the same response to water stress for the previous characteristics. While, fresh weights of root and shoot at harvest time were significantly affected by interaction effect between stress level and variety of sugar beet. Thus under 25% of maximum available water the reduction in the root fresh weight of Top, M 9340, Ras Poly and Del 939 varieties were 27.7%, 32.7%, 17.00% and 19.3% respectively and in shoot fresh weight were 35.8%, 42.1%, 20.7% and 27.3% respectively as compared to control. It could be noticed that the highest fresh weights of both root and shoot were while the lowest figures for their criteria were obtained by M 9360 variety under severe water stress water stress (25%). Dunham and Calrke (1992) pointed out that loss in yield of some sugar beet varieties were correlated directly with the level of water stress.

Root juice quality and sugar yield

Data in Table (4) indicate that the varieties of sugar beet differed in their root quality. At 135 days old, Del 939 variety recorded the highest values of sucrose, total soluble solids and purity percentages. Top ranked the second followed by Ras Poly variety. M 9340 had the lowest values for the previous criteria. At harvest time Ras Poly was the first. The same order was observed for sugar yield per plant, i.e. the varieties ranked in following descending order (Ras Poly, Del 939, Top and M 9340). Dixon and Mc Cullagh (1994), Glattkowski and Marlander (1995) and Fronek *et al* (1996) reported this differentiation between sugar beet varieties in relation to root quality and sugar yield.

Table 4. Effect of water deficit on root juice quality and sugar yield per plant of four sugar beet varieties. (Means of two growing seasons).

Varieties (V)	Soil Moisture level (SML)	135 days after sowing			210 days after sowing			
		Sucrose %	Total soluble solids %	Purity %	Sucrose %	Total soluble solids %	Purity %	Sugar / root (g)
Top	100% **	12.24	18.0	68.0	17.4	20.8	83.7	111.5
	75%	12.40	18.8	66.0	17.9	22.0	81.4	101.0
	50%	13.00	19.4	67.0	17.8	23.0	77.4	88.5
	25%	13.62	20.5	66.4	17.8	23.0	77.4	76.6
	Mean	12.80	19.2	66.9	17.7	22.2	79.7	94.4
M 9340	100%	11.00	17.0	64.7	16.8	21.0	80.0	102.4
	75%	11.38	18.0	63.2	17.0	21.4	79.4	90.6
	50%	11.80	19.2	61.5	17.6	22.6	77.9	82.5
	25%	11.84	19.5	60.7	17.4	22.8	76.3	68.6
	Mean	11.60	18.4	63.0	17.2	21.95	78.4	86.0
Ras Poly	100%	11.88	18.0	66.0	18.5	21.8	84.9	148.3
	75%	11.62	18.0	64.6	18.5	22.0	84.1	133.8
	50%	12.47	19.4	64.3	19.0	23.0	82.6	126.5
	25%	13.44	21.0	64.0	19.2	23.8	80.7	122.4
	Mean	12.40	19.1	64.7	18.8	22.7	83.1	132.4
Del 939	100%	12.78	18.6	68.7	18.0	21.6	83.3	121.5
	75%	13.12	19.2	68.3	18.5	22.6	81.9	116.3
	50%	13.64	20.3	67.2	18.8	23.2	81.0	111.4
	25%	13.60	20.1	67.7	19.0	23.5	80.8	101.6
	Mean	13.30	19.6	68.0	18.6	22.7	81.9	110.9
Mean of (SML)	100%	11.96	17.9	66.9	17.8	21.3	82.9	120.9
	75%	12.13	18.5	65.5	18.0	22.0	81.7	110.4
	50%	12.73	19.6	65.0	18.3	22.9	79.7	102.3
	25%	13.13	20.3	64.7	18.3	23.3	78.8	92.3

** 100% (control) = maximum available soil moisture
75% = 75% from maximum available soil moisture
50% = 50% from maximum available soil moisture
25% = 25% from maximum available soil moisture

Table 5. Effect of water deficit on Photosynthetic pigments (mg/g dry weight) and proline concentration (μ mole/g fresh weight) in leaves of the four sugar beet varieties. (Means of two growing seasons).

Varieties (V)	Soil Moisture level (SML)	135 days after sowing				135 days after sowing			
		Ch.A	Ch.B	Carot.	Free proline u mol/g F.wt	Ch.A	Ch.B	Carot.	Free proline μ mol/g F.wt
		Mg / g d.wt.				Mg / g d.wt.			
Top	100% **	6.54	4.69	0.75	1.59	5.69	3.97	0.93	1.64
	75%	5.68	4.24	0.76	1.77	4.93	3.80	0.96	1.72
	50%	4.86	4.08	0.72	1.87	4.62	3.73	0.97	1.90
	25%	4.44	3.94	0.73	2.09	4.23	3.06	0.92	2.01
	Mean	5.38	4.24	0.74	1.83	4.87	3.64	0.95	1.82
M 9340	100%	6.63	4.83	0.86	1.56	5.90	4.13	0.99	1.65
	75%	5.10	4.74	0.86	1.58	4.99	3.89	0.88	1.70
	50%	4.62	4.38	0.76	1.70	4.67	3.80	0.81	1.55
	25%	4.91	4.20	0.75	1.80	4.53	3.18	0.75	1.78
	Mean	5.32	4.53	0.81	1.66	5.02	3.75	0.86	1.67
Ras Poly	100%	6.73	5.10	0.92	1.61	6.19	4.21	1.02	1.80
	75%	5.49	4.97	0.92	1.95	5.10	3.80	0.93	1.95
	50%	5.09	4.76	0.85	2.52	4.97	3.68	0.97	2.11
	25%	4.95	4.61	0.85	2.65	4.95	3.40	0.92	2.47
	Mean	5.57	4.86	0.89	2.19	5.30	3.77	0.96	2.08
Del 939	100%	6.60	5.01	0.86	1.33	5.77	3.88	1.00	1.32
	75%	5.63	4.83	0.85	1.54	4.95	3.62	1.00	1.33
	50%	5.07	4.43	0.84	1.65	4.87	3.48	0.97	1.52
	25%	4.92	4.50	0.82	1.90	4.60	3.12	0.90	1.68
	Mean	5.56	4.69	0.84	1.61	5.05	3.53	0.97	1.46
Mean of (SML)	100%	6.63	4.91	0.85	1.52	5.89	4.05	0.99	1.60
	75%	5.48	4.70	0.85	1.72	4.99	3.78	0.94	1.68
	50%	4.91	4.41	0.79	1.94	4.78	3.67	0.93	1.77
	25%	4.81	4.31	0.79	2.11	4.58	3.19	0.87	1.99

** 100% (control) = maximum available soil moisture
75% = 75% from maximum available soil moisture
50% = 50% from maximum available soil moisture
25% = 25% from maximum available soil moisture

The same Table shows a gradual increase in total soluble solids and sucrose percentage by increasing water stress levels. On the contrary, either purity percentage or sugar yield was lowered by drought. At harvest time the decline in sugar yield was lowered by drought. At harvest time the decline in sugar yield reached 8.7%, 15.3%, and 23.7% under the condtion of 75%, 50% and 25% of available water, respectively, compared to that grown under water normal condition (100% available water). These results were in full agreement with that obtained by Dunham and Calrke (1992), Schilling *et al* (1991), Mekki *et al* (1994) and Soudi (1998). In this respect, Simpson (1981) and Brown *et al* (1987) observed an increase in respiration rate during the early phases of stress followed by a reduction in the rate by continuing seaver stress as a results of hydrolysis of starch to sugar.

At harvest time, juice purity of such varieties Top, M 9340, Ras Poly and Del 939 was decreased as a result of severe water stress (25% of the available water) by 7.5%, 4.6%, 4.9% adn 3.1%, respectively. While sugar yield per plant under the same level of water stress was lowered by 31.3%, 33.0%, 17.5% and 16.4%, respectively. Superiority of Ras Poly and Del 939 varieties in terms of sugar yield might be due to the production of heavy roots (Table 2) also they had the highest values of root quality (Table 4). On the other hand, M 9340 variety was the most sensitive one to drought stress, but survived healthy till harvest time.

Photosynthetic Pigments and Proline Concentrations

Table (5) shows that the varieties of sugar beet under this investigation slightly differed in their concentration of photosynthetic pigments (chlorophyll A, B and carotenoids) through their life period. In general, the concentration of photosynthetic pigments decreased during maturation and storage stages. It was obvious from the same data that the concentration of all photoynthetic pigments were decreased by increasing water stress levels, but biosynthesis of chlorophyll A was more degraded than chlorophyll B or carotenoids. At 135 days age, chlorophyll A was minimized by 17.3%, 25.9% and 27.5%, chlorophyll B by 4.3%, 10.2% and 12.2%, Carotenoids by 0.0%, 7.1% and 7.1%, respectively. That was occurred when plants were subjected to 75%, 50% and 25% of the maximum available water. Similar trend was observed at the harvest time.

It could be noticed that sugar beet varieties acted differently against drought in terms of concentration of photosynthetic pigments. Top variety was more sensitive than other varieties; as both chlorophyll A and B decreased at 135 days old by 32.1%

and 16.0% but at harvest time by 25.7 and 22.9% respectively, when plants were subjected to severe drought (25% of the available water). Mekki *et al* (1994) reported that the content of photosynthetic pigments in sugar beet leaves reduced under drought stress at early growth stage (120 day old). Soudi (1998) pointed out that there was no trend, regarding the effect of soil moisture levels and the concentration of soil moisture levels and the concentration of photosynthetic pigments in sugar beet leaves. Kech and Boyer (1974) found that the inhibition in photosynthetic pigments, which was caused by low water potential might be due to the inhibition of chloroplast activity, which consists of reduction of electron transport, followed by photophosphorylation. It is known that chlorophyll existed in vivo in several forms differing in their chemical and physical properties. Opsipova and Ashour (1964) suggested that a correlation might exist between the rate of photosynthesis and the amount of photosynthetic active forms of chlorophyll but not to the total chlorophyll. Data of Table (5) indicate that sugar beet varieties had a marked variation in their free proline concentration. Ras Poly exhibited the highest proline values, while Del 939 had the lowest one. Top and M 9340 got moderate free proline concentration. This variation among sugar beet varieties was observed by (1999). Water stress caused the accumulation of proline in the plant leaves in comparison to that grown on better moisture condition. Table (5) shows a gradual increase in proline concentration which was associated with lowering the water availability in the soil. The relative proline concentration (% of control) under 75%, 50%, and 25% of available water, were 113.2, 127.6 and 138.8, respectively, at 135 days old. The corresponding values at the harvest time were 105, 110.6 and 124.1, respectively. These data coincided with results of Petrovic *et al* (1991) and Gzik (1996).

The four sugar beet varieties under this investigation varied in their free proline accumulation as response to water stress. Under the conditions of water availability of 75%, 50% an d 25%, at 135 days old, proline concentration in Top variety increased by 11.3%, 17.6%. and 31.4%. But in M 9340 variet the increase to 1.3%, 8.9%, and 15.4%, in Ras Poly variety the increase was 23%, 56.5% and 64.6% and in Del 939 variety increased by 15.8%, 24.11%, and 42.9%, respectively. At the harvest time, sugar beet varieties followed the same trend. It could be stated that M 9340 variety, which markedly affected by water stress, recorded the lowest amount of proline. The reverse was observed for Ras Poly and Del 939 varieties, which were less affected by water stress. Higazi *et al* (1994) and Shehata, Mona *et al* (1999) reported that proline accumulation might favor the increase of tolerance of sugar beet against salinity stress. They found highly positive correlation between salinity level and proline concentration in moderate and very tolerant sugar beet varieties, while in sensitive varieties there was no correlation between the two factors.

Table 6. Effect of water deficit on nitrogen, phosphorus, potassium and sodium percent(%) in root of four varieties of sugar beet (Means of two growing seasons).

Varieties (V)	Soil Moisture level (SML)	135 days after sowing				210 days after sowing			
		N %	P %	K %	Na %	N %	P %	K %	Na %
Top	100% **	1.80	0.70	0.65	0.56	1.20	0.59	0.60	0.38
	75%	1.60	0.66	0.61	0.52	1.05	0.56	0.54	0.28
	50%	1.10	0.60	0.60	0.48	1.20	0.53	0.44	0.24
	25%	0.90	0.6	0.58	0.36	0.75	0.47	0.41	0.24
	Mean	1.35	0.63	0.61	0.48	1.05	0.55	0.50	0.29
M 9340	100%	1.50	0.73	0.69	0.60	1.20	0.56	0.60	0.36
	75%	1.40	0.63	0.63	0.56	0.90	0.53	0.57	0.28
	50%	1.20	0.57	0.57	0.40	0.90	0.48	0.48	0.32
	25%	0.70	0.52	057	0.32	0.75	0.43	0.39	0.26
	Mean	1.20	0.61	0.62	0.47	0.94	0.50	0.51	0.31
Ras Poly	100%	2.00	0.70	0.63	0.60	1.20	0.64	0.63	0.39
	75%	1.80	0.69	0.63	0.57	0.90	0.57	0.57	0.32
	50%	1.20	0.62	0.60	0.40	0.75	0.53	0.51	0.28
	25%	0.90	0.62	0.57	0.40	0.90	0.48	0.49	0.26
	Mean	1.48	0.66	0.60	0.49	0.94	0.56	0.55	0.31
Del 939	100%	1.80	0.69	0.68	0.56	1.25	0.65	0.57	0.38
	75%	1.80	0.63	0.66	0.56	0.90	0.50	0.57	0.38
	50%	0.90	0.56	0.60	0.44	0.75	0.50	0.48	0.30
	25%	0.80	0.55	0.54	0.36	0.75	0.46	0.46	0.26
	Mean	1.30	0.61	0.62	0.48	0.91	0.53	0.52	0.33
Mean of (SML)	100%	1.70	0.71	0.66	0.60	1.21	0.61	0.60	0.38
	75%	1.65	0.65	0.63	0.55	0.99	0.54	0.56	0.32
	50%	1.10	0.59	0.59	0.44	0.90	0.51	0.48	0.29
	25%	0.83	0.56	0.57	0.36	0.77	0.46	0.44	0.26

** 100% (control) = maximum available soil moisture
75% = 75% from maximum available soil moisture
50% = 50% from maximum available soil moisture
25% = 25% from maximum available soil moisture

Table 7. Effect of water deficit on nitrogen, phosphorus, potassium and sodium percent(%) in leaves of four varieties of sugar beet (Means of two growing seasons).

Varieties (V)	Soil Moisture level (SML)	135 days after sowing				210 days after sowing			
		N %	P %	K %	Na %	N %	P %	K %	Na %
Top	100% **	5.59	0.98	1.95	2.60	3.92	0.88	1.47	1.84
	75%	5.69	0.94	1.83	2.52	3.39	0.87	1.40	1.64
	50%	4.79	0.85	1.74	2.36	3.59	0.83	1.32	1.60
	25%	4.29	0.83	1.38	2.16	2.39	0.76	1.23	1.44
	Mean	5.08	0.90	1.73	2.41	3.32	0.84	1.36	1.63
M 9340	100%	5.09	0.95	2.07	2.80	3.89	0.84	1.47	1.90
	75%	4.79	0.86	1.91	2.48	3.39	0.81	1.38	1.64
	50%	4.49	0.84	1.69	2.28	3.29	0.78	1.20	1.52
	25%	4.49	0.78	1.41	2.20	2.09	0.74	1.14	1.42
	Mean	4.72	0.86	1.77	2.44	3.17	0.79	1.30	1.64
Ras Poly	100%	5.69	0.95	2.04	2.72	4.19	0.92	1.32	1.96
	75%	5.09	0.91	1.88	2.56	3.77	0.88	1.23	1.76
	50%	4.79	0.85	1.74	2.36	3.49	0.84	1.11	1.56
	25%	4.49	0.80	1.47	2.24	2.79	0.77	1.02	1.44
	Mean	5.02	0.88	1.78	2.47	3.56	0.85	1.17	1.68
Del 939	100%	5.39	0.94	1.92	2.44	3.89	0.90	1.50	1.84
	75%	5.39	0.88	1.63	2.28	3.49	0.85	1.41	1.62
	50%	4.79	0.85	1.59	2.24	3.29	0.80	1.05	1.52
	25%	4.19	0.78	1.40	2.12	2.83	0.71	0.84	1.32
	Mean	4.94	0.86	1.64	2.27	3.38	0.82	1.20	1.58
Mean of (SML)	100%	5.44	0.96	1.81	2.64	3.97	0.89	1.44	1.90
	75%	5.24	0.90	1.81	2.46	3.51	0.85	1.36	1.67
	50%	4.72	0.85	1.69	2.31	3.42	0.81	1.17	1.55
	25%	4.37	0.80	1.42	2.18	2.53	0.75	1.06	1.41

** 100% (control) = maximum available soil moisture
75% = 75% from maximum available soil moisture
50% = 50% from maximum available soil moisture
25% = 25% from maximum available soil moisture

Nitrogen, phosphorus, potassium, and sodium concentrations:

The effect of soil moisture levels on N, P, K and Na concentrations in root and leaves of the four sugar beet varieties are recorded in Table 6 and 7, respectively. It was clear that leaves had higher concentration of these elements than the roots. Also, the concentration of the elements of the four varieties were at maximum rate at the early growing stage; then gradually decreased till the harvest time. There was no marked difference in the concentration of each element among sugar beet varieties under the investigation.

Data indicated that not all the elements were affected equally by the level of soil moisture stress. Nitrogen content was only degraded at 75% of soil available water. But, at 50% and 25% water stress, sodium and nitrogen were more reduced than potassium and phosphoru. The change tendency of all elements showed the same pattern among the four sugar beet varieties. Amal (1998) obtained similar results.

Decreasing of nitrogen, phosphorus, potassium and sodium absorption by sugar beet plants with decreasing soil moisture; migth be due to reduction in solubility of the elements. Also, the thin layer film of water around the soil aggregates inhibited the movement of the concentrated cations and anions. Hisao (1973) stated that water stress caused slowing of transpiration stream, which inhibited the mechanisms of nutrients uptake by roots, movement to the shoot and unloading in the xylem move directly.

Acid invertase activity

Invertase is one of the most important enzymes in sugar beet plant tissue, its activity widely depends on the pH of the media. Data in Table (8) indicate a considerable difference in acid inertase activity in sugar beet root, it had been detected among varieties under investigation. They could be arranged ascendingly according to their invertase activity as follow: Ras Poly, Del 939, Top and M 9340.

The same data also indicated that soil moisture stress markedly decreased acid invertase activity in sugar beet plants. Thus, at 135 day old, invertase activity decreased by 0.06%, 0.7% and 0.10% under 75%, 50% and 25% of the maximum available water, respectively comparing with control (100%). At harvest time (210 days) the corresponding values were 0, 05%, 0.09% and 0.20%, respectively. It could be noticed also that maximum acid invertase activity was obtained in roots of M 9340 variety, under all soil moisture levels. On the contrary, minimum values were obtained from

Ras poly and Del 939 varieties. Generally, high activity of acid investase after beet harvest is not desirable because of its ability to invert sucrose to glucose and fructose. Mostafa, Shafica (1996) obtained similar results under salinity stress. Schilling *et al.* (1991) indicated that acid invertase activity was increased in young leaves and in top roots of sugar beet Cv. Ponemo seedlings and it was respective increase in biomass.

The obtained data of this study obviously cleared that Ras Poly and Del 939 could be considered the most suitable varieties of sugar beet for growing under drought stress condition; as their growth, yield and juice quality were less affected. In addition the increase in proline concentration in their leaves and the decrease in acid invertase activity in their roots under such condition. While, M 9340 variety exhibited antithetical results, but Top variety moderately behaved. Also, it could be concluded that the reduction magnitude in all studied criteria of sugar beet under water stress conditions varied with the different varieties and depended on the degree and duration of water stress as well as development stage of the plant.

Table 8. Effect of water deficit on activity of acid inverstase (mg glucose/30 min./gfw) in root of four sugar beet varieties.

Varieties	135 days after sowing					210 days after sowing				
	Soil moisture level (SML)									
	100%	75%	50%	25%	Mean	100%	75%	50%	25%	Mean
Top	5.35	5.20	4.98	4.76	5.07	2.33	2.30	2.15	1.80	2.15
M 9340	5.78	5.07	5.39	5.21	5.36	2.78	2.45	2.41	2.30	2.49
Ras Poly	5.01	4.75	4.59	4.47	4.71	1.95	1.90	1.78	1.37	1.75
Del 939	4.96	4.78	4.65	458	4.74	1.87	1.80	1.79	1.52	1.75
Mean of (SML)	5.27	4.95	4.90	4.76		2.23	2.11	2.03	1.75	

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تأثير الاجهاد الرطوبي للتربة علي بعض أصناف بنجر السكر

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أقيمت تجربتا أصص بمركز البحوث الزراعية خلال موسمي ٩٥ / ١٩٩٦ و ٩٦ / ١٩٩٧ لدراسة تأثير المحتوي الرطوبي بالتربة علي النمو والمحصول والجودة وايضا التركيب الكيماوي لنبات بنجر السكر.

تضمنت التجربة ١٦ معاملة في ثلاث مكررات عبارة عن التوافق بين ٤ أصناف من بنجر السكر هي Top, Ras Poly, M 9340 , Del 939 مع أربعة معاملات لكمية ماء الري تتمثل في ١٠٠٪ و ٧٥ ٪ و ٥٠ ٪ و ٢٥٪ من الماء الميسر الكلي للتربة. وقد أوضحت النتائج ما يلي:

- أدي نقص المحتوي المائي للتربة إلي زيادة معنوية في طول جذور نبات بنجر السكر مع نقص معنوي في كل من سمك الجذر. مع زيادة معدل النقص للعرض مقارنة بالجذر.
- بالرغم من زيادة النسبة المئوية للسكروز بتعرض بنجر السكر للاجهاد المائي إلا أن ذلك أدي إلي النقص في نقاوة الجذور (السكروز / النسبة المئوية للمواد الصلبة x ١٠٠) وكذلك في محصول السكر للنبات.
- انخفض تركيز الصبغات النباتية لاوراق نبات بنجر السكر تحت ظروف الاجهاد المائي وكان هذا التأثير أكثر وضوحا بالنسبة لكوروفيل (أ) عن كلوروفيل (ب) أو الكاروتينويدات.
- حدث نقص في تركيز كل من النتروجين والصوديوم بأوراق و جذور بنجر السكر بنسبة أكبر من النقص الحادث في تركيز الفوسفور والبوتاسيوم عند ري النباتات بمعدل ٥٠٪ من الماء الميسر الكلي للتربة.
- ارتفع تركيز الحمض الأميني البرولين الحر في أوراق نبات بنجر السكر وعلي العكس من ذلك انخفض نشاط أنزيم الانفرتيز في أوراق وجذور بنجر السكر تحت ظروف الإجهاد المائي بالمقارنة للنباتات المزروعة تحت الظروف الطبيعية.

يتضح من النتائج أن نمو ومحصول وجودة العصير للصنفين Ras Poly و Del 939 أقل تاثرا عند التعرض للاجهاد المائي مع زيادة في تركيز الحمض الأميني البرولين الحر بالأوراق ونقص في نشاط انزيم الانفرتيز الحامضي بالجذور. أما الصنف M 9340 فهو أكثر الأصناف حساسية للاجهاد المائي بينما الصنف Top أظهر اتجاها متوسطا بينهما.