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STUDIES ON SOME CACTI AND SUCCULENTS, AND THEIR USE IN EGYPTIAN BOTANIC GARDENS. 1. EFFECT OF SALINITY LEVELS AND FERTILIZATION ON VEGETATIVE GROWTH AND LEAF ANATOMICAL Structure OF *Agave sisalana* PERRINE PLANTS.

H.A. Mansour; Abou Dahab, T. A.M. and *Ahmed, A.A.I.
Ornamental Horticulture Department, Faculty of Agriculture, Cairo University, Egypt.
**Green Paradise Agricultural Contracting Co. , Egypt.*

ABSTRACT

A pot experiment was conducted in the two successive seasons 2004/2005 and 2005/2006 at the Experimental Nursery of the Ornamental Horticulture Department, Faculty of Agriculture, Cairo University, Giza, Egypt., with the aim of investigating the tolerance of sisal plant (Agave sisalana) to different levels of irrigation water salinity (0, 1000, 2000, 3000, 4000, 5000, 6000 and 7000 ppm) as NaCl & $CaCl_2$ (1:1 by weight). In addition the effect of different fertilization treatments [unfertilized (control), organic fertilization (50 g compost / pot), chemical fertilizer (NPK) (2 g / pot), and compost plus NPK fertilizer], on reducing the unfavorable effects of salinity on vegetative growth and anatomical structure. The recorded results indicated that increasing salinity levels decreased most of the studied parameters (plant height, number of leaves /plant, leaf area, leaf thickness, and dry weights of foliage and fibrous roots /plant). The anatomical study supported and explained the recorded reduction of morphological traits under investigation due to salinity treatments. In general, it was noted that raising the level of salinity of irrigation water caused gradual decreases in means of all the studied characteristics in both seasons, and these decreases were remarkable at a salinity level of 7000 ppm. On the other hand, the fertilization treatments reduced, to some extent, the negative effect of salinity.

Key words: Cacti, Succulents, *Agave sisalana*, sisal, salinity, fertilization, vegetative growth, leaf anatomy.

INTRODUCTION

Cacti and succulent plants are very adaptable, and will grow in a range of extreme climates. These fascinating plants also offer the gardener great diversity of form, texture and size, while some flower constantly, others provide rare but spectacular flower displays, made all the more special by the wait (Brickell, 1999).

Agave sisalana [family: *Agaveceae*; the common name: Sisal or Hemp (Johnson, 1999)] is native of Mexico and Central America (Pandey, 2003). Plants are surculose, long-stemmed rosettes of up to 2 m in height. Leaves are up to 130 cm long, 12 cm wide, spreading, fleshy, narrowly lanceolate or ensiform, bright green, smooth, fibrous, sometimes minutely denticulate, with a terminal spine of up to 2.5 cm in length, subulate, dark brown, non-decurrent (Huxley *et al.*, 1992). *Agave sisalana* is considered a succulent xerophyte (Pandey, 2004); hence it is suitable for landscaping and gardening in arid soils of Egypt. In addition, *A. sisalana* is one of the best plants for soil conservation, and can be used as anti erosion plant, as well as for soil reclamation (Abdel-Hady *et al.*, 1995). In ornamental horticulture *A. sisalana* has become a favorite decorative plant in botanical and private gardens around the world (Nobel, 1994). Also, sisal is often cultivated for its long leaf hard fibers, and many useful medical products (Johnson, 1999).

Everywhere in the world, environmental stresses represent the most limiting factors for agricultural productivity. Salinity is currently one of the most severe abiotic stresses that adversely affect crop productivity and quality (Paranychianakis and Chartzoulakis, 2005). Salinity has long been recognized as a problem in arid and semiarid climate regions of the world as in the Mediterranean region (Morsy, 2003). The soils of Egypt are located in the arid region; about 30-35% of irrigated soils of Egypt are affected by salinity and water logging (EL-Kouny *et al.*, 2004). The tolerance of various ornamental plants to drought and saline stresses is very important for landscaping and gardening of these areas, since the use of saline water in irrigation becomes necessary under water deficiency conditions, which are common in most of the new reclaimed lands (El-Khateeb, 1994).

Several investigators have studied the relative salt tolerance of various ornamental plants. In general, salinity was found to have adverse effects on the growth characteristics of different ornamental plant species [Agarwal and Pandey (2004) on *Cassia angustifolia*, Gars (2004) on *Bombax ceiba*, Parida *et al.* (2004) on *Bruguiera parviflora*, Rowland *et al.* (2004) on *Poplus deltoids*, Renault (2005) on *Cornus stolonifera*, and Assefat (2006) on *Khaya senegalensis*].

It is therefore clear that there is an urgent need to identify plant species that can grow with saline water (Soyza *et al.*, 2002). This study will provide information about the growth behavior of *Agave sisalana* under salinity stress, and hence the feasibility of using this plant species for landscape purposes in newly reclaimed desert areas.

MATERIALS AND METHODS

This investigation was carried out at the Experimental Nursery of the Ornamental Horticulture Department, Faculty of Agriculture, Cairo University, Giza, Egypt, during the two successive seasons of 2004/2005 and 2005/2006. The objective of this work was to study the effect of different salinity levels and fertilization treatments on vegetative growth and anatomical characteristics of *Agave sisalana* plants. On 1st February 2004 and 2005 in the first and second seasons, respectively, seedlings of *Agave sisalana* (one year old, 5-8 cm high, with 5-7 leaves, and a fresh weight of 17-21 g.) were planted in 12 cm plastic pots filled with sand. The physical and chemical properties of the sand used for potting are shown in Table 1.

Table 1: Physical and chemical properties of the sandy soil used for growing *Agave sisalana* plants during the 2004/2005 and 2005/2006 seasons.

Physical properties							
Soil particle size distribution (%)				Textural class	Organic Matter (%)	Saturation percentage	Electrical Conductivity (dS/m)
Coarse sand	Fine sand	Silt	Clay				
14.7	79.5	2.5	3.3	Sandy	0.3	23	1.3

Chemical properties										
Soluble anions (meq./L)			Soluble cations (meq./L)				Available elements (ppm)			pH
HCO_3^-	Cl^-	SO_4^{--}	Ca^{++}	Mg^{++}	Na^+	K^+	N	P_2O_5	K_2O	
1.09	1.77	1.45	1.55	0.79	1.7	0.49	47.7	5.3	21.3	7.1

In the first season, six levels of salinity (0, 1000, 2000, 3000, 4000 and 5000 ppm) were added in the irrigation water, whereas in the second season, two higher salt concentrations (6000 and 7000 ppm) were also included in the experiment in addition to the previous salt concentrations. Saline solutions were prepared using a mixture of sodium chloride (NaCl) and calcium chloride ($CaCl_2$) at a 1:1 ratio (by weight). Plants receiving each of the salinity treatments were supplied with the following four fertilization treatments: (1) Unfertilized as control, (2) Organic fertilization, (3) Chemical fertilization (NPK), and (4) a mixture of organic and chemical fertilization. Organic fertilization was applied by mixing compost into the soil before transplanting, at the ratio of 1:5 by weight (approximately 50 g compost / pot). The physical and chemical composition of the compost used in this experiment (Al-Neel compost, manufactured by the Egyptian Company for Solid Waste Recycling, El-Obour City) is shown in Table 2. Plants receiving chemical fertilization (NPK) were supplied with a mixture of calcium super phosphate, ammonium nitrate, and potassium sulphate (with a fertilizer formula of approximately 2:1:1) at the rate of 2.0 g /pot /month, for one year each season. Preparation of salt solution was done immediately before each irrigation. The plants were irrigated until saturation (using 50-100 ml /pot of the prepared saline solutions) once /week in winter and twice /week in summer during the growing season. The layout of the experiment was a split plot design, with the main plots assigned to the salinity treatments (six treatments in the first season, and 8 treatments in the second season), while the sub-plots were assigned to the fertilization treatments (4 treatments, in both seasons). The main plots were arranged in a randomized complete blocks design, with each block (replicate) consisting of 3 pots /treatment. Data recorded on morphological plant characteristics were statistically analyzed using the Mstat-C (1986) computer software. The "Least Significant Differences (L.S.D)" test at the 5% probability level was used for comparison of means, as recommended by Snedecor and Cochran (1982).

At the end of each season (on 1st Feb. 2005 and 2006, in the first and second seasons, respectively), data were recorded on vegetative growth characteristics, including plant height (cm), number of leaves /plant, leaf area (cm^2) of the fourth leaf (measured using a Licor Portable area meter, Model L1-3050), leaf thickness (mm) at the middle of the fourth leaf (measured using a Vernier caliper), and dry weights of foliage and fibrous roots /plant (g).

The anatomical study was conducted on specimens resembling two plants per treatment taken from the fourth leaf from the top of the plant with the aim of investigating the effect of salinity on the anatomical structure of the leaves. The micro-technique procedures were carried out (according to Sass, 1961). Plants used for the anatomical study were taken in the second season (2005/2006), after 10 month from the planting date. Specimens were killed and fixed for at least 48 hours in F.A.A. (10 ml formalin, 5 ml glacial acetic acid, 50 ml ethyl alcohol 95%, 35 ml distilled water). The fixed plant material was washed in 50% ethyl alcohol and dehydrated in normal butyl alcohol series, before being embedded in paraffin wax (melting point 52-54° C). Transverse sections, 20 µ (micron) thick, were cut using a rotary microtome, stained with Safranin light, and mounted in Fast green. Thereafter, sections were examined by micrometric lens to detect anatomical manifestation of noticeable responses resulting from salinity treatments. Anatomical plates and micrographs were performed using Microscope Olympus AX70 made in Japan with magnified power 40X.

Table 2. Physical and chemical analysis of compost Al Neel as derived from the Company

Dry weight (kg/m^3)	pH	Saturation percentage	E.C (dS/m)	Percentage				
				Humidity	Organic Matter	Total Nitrogen	Organic (C)	Ash
600-650	7.5	250-300	4-6	25-30	45-55	2	33.26	45-55

C/N ratio	Percentage		ppm				Nematode	Parasites
	Total P	Total K	Fe	Mn	Cu	Zn		
16:1	1.47	1.23	1021	111	180	28	----	----

RESULTS AND DISSCUSION

I- Vegetative growth

Plant height (cm)

From Table 3, it is obvious that control plants had an average height of 18.08 cm in the first season, and 18.38 cm in the second season, which was significantly higher than the mean heights of plants receiving the different salinity treatments. It is also evident that increasing salt concentration in the irrigation water caused steady gradual decreases in plant height. In the first season, the two highest salinity levels (4000 and 5000 ppm) caused decreases of 17.20 and 19.47%, respectively, in the height of *Agave sisalana* plants, whereas in the second season, the two highest salinity levels (6000 and 7000 ppm) caused decreases 22.36 and 53.54% in height, respectively, compared to the height of control plants. Similar findings were reported

Table 3 : Effect of irrigation water salinity levels, and fertilization treatments on plant height (cm) of *Agave sisalana* during the 2004/2005 and 2005/2006 seasons.

Fertilization treatments (F)	(2004-2005) Salinity (ppm) (S)						Mean (F)
	0	1000	2000	3000	4000	5000	
0	16.07	15.48	14.50	13.53	12.03	11.50	13.85
Compost	17.47	16.28	16.37	15.43	14.37	13.88	15.63
NPK	18.73	18.57	17.78	17.72	16.68	16.15	17.60
Compost+ NPK	20.05	19.60	18.57	18.70	16.80	16.73	18.41
Mean (S)	**18.08**	**17.48**	**16.81**	**16.34**	**14.97**	**14.56**	
L.S.D. at 0.05	F : N.S.	S : 0.60	F X S : N.S.				

Fertilization treatments (F)	(2005-2006) Salinity (ppm) (S)								Mean (F)
	0	1000	2000	3000	4000	5000	6000	7000	
0	15.58	15.10	14.83	14.45	12.43	11.38	10.45	6.43	**12.58**
Compost	18.08	16.53	16.25	15.43	14.75	13.87	12.13	7.63	**14.33**
NPK	18.38	17.75	17.12	17.15	16.38	16.50	16.00	8.62	**15.99**
Compost+ NPK	21.50	21.25	20.50	20.62	19.37	19.13	18.50	11.50	**19.04**
Mean (S)	**18.38**	**17.66**	**17.18**	**16.91**	**15.73**	**15.22**	**14.27**	**8.54**	
L.S.D. at 0.05	F : 0.34	S : 0.45	F X S : 0.87						

by Reda *et al.* (2000) on *Leucaena leucocephala*, Awan *et al.* (2002b) on *Eucalyptus camaldulensis*, and Parida *et al.* (2004) on *Bruguiera parviflora*.

The data in Table 3, also showed that, in both seasons, all the fertilization treatments increased plant height compared to the control. However, these increases were statistically insignificant in the first season, but were significant in the second season. In both seasons, adding compost + NPK was the most effective treatment for increasing the height of *Agave sisalana* plants under different salinity levels, followed by application of chemical fertilization (NPK) alone, whereas using compost alone was the least effective treatment. These results were in agreement with those reported by El-Baha *et al.* (2003) on *Acacia saligna*, *Casuarina cunninghamiana* and *Eucalyptus camaldulensis*, Gars (2004) on *Bombax ceiba* and Assefat (2006) on *Khaya senegalensis*.

Number of leaves / plant

The data in Table 4 showed that the different salinity levels had a significant effect on the average of number of leaves/plant of *Agave sisalana*. The highest number of leaves (13.86 and 14.47 leaves /plant in the first and second seasons, respectively) was found on control plants (no salts used). The values were gradually decreased as a result of raising the salt concentration in the irrigation water. Accordingly, the lowest number of leaves recorded in the two seasons (8.50

Table 4: Effect of irrigation water salinity levels, and fertilization treatments on number of leaves /plant of *Agave sisalana* during the 2004/2005 and 2005/2006 seasons.

Fertilizers (F)	(2004-2005) Salinity (ppm) (S)						Mean (F)
	0	1000	2000	3000	4000	5000	
0	11.95	11.38	11.15	10.93	8.92	6.00	10.05
Compost	13.07	12.32	12.33	12.32	10.27	7.08	11.23
NPK	14.68	14.67	13.32	13.12	12.32	11.13	13.21
Compost+ NPK	15.73	15.23	14.73	15.05	13.13	9.80	13.94
Mean(S)	**13.86**	**13.40**	**12.88**	**12.86**	**11.16**	**8.50**	
L.S.D. at 0.05	F : 0.68	S : 0.30	F X S : 0.60				

Fertilizers (F)	(2005-2006) Salinity (ppm) (S)								Mean (F)
	0	1000	2000	3000	4000	5000	6000	7000	
0	12.57	11.87	11.65	11.43	9.57	6.50	6.30	4.50	9.30
Compost	13.57	12.83	12.83	12.83	10.53	7.57	6.58	5.50	10.28
NPK	15.17	14.93	13.83	13.65	13.43	11.67	8.43	6.27	12.17
Compost+ NPK	16.55	15.63	15.37	15.30	13.37	10.13	9.30	7.37	12.88
Mean(S)	**14.47**	**13.81**	**13.42**	**13.30**	**11.73**	**8.97**	**7.65**	**5.91**	
L.S.D. at 0.05	F : 0.23	S : 0.23	F X S : 0.47						

leaves / plant and 5.91 leaves / plant in the first and second seasons, respectively) was obtained from plants irrigated using the highest salinity level (5000 or 7000 ppm in the two seasons, respectively). These values indicate reductions of 38.67% and 59.16% in the number of leaves/plant, compared to that of control treatment. These results are in harmony with those of Reda *et al.* (2000) on *Leucaena leucocephala*, Aslam *et al.* (2002) on *Eucalyptus camaldulensis* and Sharma *et al.* (2002) on *Acacia nilotica, Azadirachta indica, L. leucocephala, P. cinerea* and *P. juliflora*.

From the results presented in Table (4) it can also be concluded that the fertilization treatments had a significant effect on the average of number of leaves /plant. In both seasons, the lowest number of leaves (10.05 and 9.30 leaves /plant in the first and second seasons, respectively) was found on unfertilized control plants. On the other hand, plants fertilized using compost+ NPK gave the highest number of leaves (13.94 and 12.88 leaves /plant in the two seasons, respectively), followed by plants fertilized using NPK alone (with 13.21 and 12.17 leaves/plant in the two seasons, respectively).

These results are in accordance with those reported by Gars (2004) on *Bombax ceiba* and Assefat (2006) on *Khaya senegalensis*.

Leaf area (cm^2)

Table 5 showed salinity concentrations of 1000-7000 ppm were associated with considerable decreases in the leaf area. In the first season, the leaf areas in plants

Table 5: Effect of irrigation water salinity levels, and fertilization treatments on leaf area (cm^2) of *Agave sisalana* during the 2004/2005 and 2005/2006 seasons.

Fertilizers (F)	(2004-2005) Salinity (ppm) (S)						Mean (F)
	0	1000	2000	3000	4000	5000	
0	57.62	53.81	41.34	33.82	25.94	23.59	39.35
Compost	66.98	61.14	48.74	38.16	30.38	24.44	44.97
NPK	68.61	64.38	50.73	39.35	34.50	26.45	47.34
Compost+ NPK	70.51	66.81	52.58	32.37	36.17	28.23	47.78
Mean (S)	**65.93**	**61.54**	**48.35**	**35.92**	**31.75**	**25.68**	
L.S.D. at 0.05	F : 2.99	S : 3.44	F X S: N.S.				

Fertilizers (F)	(2005-2006) Salinity (ppm) (S)								Mean (F)
	0	1000	2000	3000	4000	5000	6000	7000	
0	63.45	51.40	44.04	33.20	26.17	19.60	15.49	11.30	33.08
Compost	70.57	61.20	52.37	40.23	33.95	25.69	17.33	13.87	39.40
NPK	70.47	61.42	53.78	43.10	35.84	28.43	19.34	14.37	40.84
Compost+ NPK	75.41	67.02	56.73	45.89	38.94	30.28	22.21	15.93	44.05
Mean (S)	**69.97**	**60.26**	**51.73**	**40.61**	**33.73**	**26.00**	**18.59**	**13.87**	
L.S.D. at 0.05	F : 2.45	S : 2.39	F X S : N.S						

receiving these treatments ranged from 25.68 to 61.54 cm^2, while control plants had a leaf area of 65.93 cm^2. A similar trend was recorded in the 2nd season: control plants had a leaf area of 69.97 cm^2, while plants receiving the highest salt concentration (7000 ppm) had the smallest leaves, with an area of 13.87 cm^2. This decrease in leaf area as a result of increasing salinity levels is in agreement with the findings of Awan *et al.* (2002) on *Eucalyptus camaldulensis*, ChuanHong *et al.* (2002) on *Populus euramericana* [*P. canadensis*] and Parida *et al.* (2004) on *Bruguiera parviflora*.

The data presented in Table 5, also indicated that, in both seasons, all fertilization treatments increased the leaf area, compared to the control, with plants fertilized using compost + NPK giving the largest leaves. Similar findings were reported by Gars (2004) on *Bombax ceiba* and Assefat (2006) on *Khaya senegalensis*. These increases in leaf area as a result of fertilization were statistically significant.

Leaf thickness (mm)

Data presented in Table 6 showed that in both seasons, irrigating the seedlings with tap water gave significantly thicker leaves than those of plants receiving the different salinity levels (1000-7000 ppm). These results are similar to those mentioned by Gonzalez *et al.* (2000) on 9 forage legumes (*Sesbania emerus*, *Leucaena leucocephala*, *Macroptilium lathyroides*, *Clitoria ternatea*, *Stylosanthes guianensis*, *Crotalaria juncea*, *Macroptilium atropurpureum*, *Teramnus labialis* and *Centrosema pubescens*).

Table 6 : Effect of salinity levels, and fertilization on leaf thickness (mm) *Agave sisalana* during the 2004/2005 and 2005/2006 seasons.

Fertilizers (F)	(2004-2005) Salinity (ppm) (S)						Mean (F)
	0	1000	2000	3000	4000	5000	
0	3.11	2.74	2.59	2.42	1.04	0.87	2.13
Compost	3.17	2.68	3.08	2.57	1.35	1.06	2.32
NPK	3.25	2.71	2.57	2.47	1.31	1.20	2.25
Compost+ NPK	3.24	2.59	2.54	2.50	1.38	1.27	2.25
Mean(S)	**3.19**	**2.68**	**2.69**	**2.49**	**1.27**	**1.10**	
L.S.D. at 0.05	F: 0.07 S : 0.07 F X S : 0.15						

Fertilizers (F)	(2005-2006) Salinity (ppm) (S)								Mean (F)
	0	1000	2000	3000	4000	5000	6000	7000	
0	3.19	2.80	2.24	2.11	1.05	0.90	0.44	0.325	1.63
Compost	3.42	3.08	2.49	2.03	1.38	1.17	0.65	0.440	1.83
NPK	3.53	3.17	2.63	2.33	1.45	1.30	0.75	0.482	1.95
Compost+ NPK	3.55	3.15	2.64	2.37	1.46	1.29	0.80	0.488	1.97
Mean(S)	**3.42**	**3.05**	**2.498**	**2.21**	**1.33**	**1.17**	**0.66**	**0.43**	
L.S.D. at 0.05	F : 0.06 S : 0.08 F X S : N.S								

As for fertilization treatments on leaf thickness, it was observed that in the first season, plants fertilized with compost gave the thickest leaves (2.32 mm), followed by the other treatments. However, the thickest leaves formed in the second season (1.97 mm) were obtained by using compost+ NPK. On the other hand, unfertilized control plants had the thinnest leaves in both seasons (2.13 and 1.63 mm in the first and second seasons, respectively). This means that fertilization had a significant effect on increasing leaf thickness. These results are in agreement with those obtained by Xie *et al.* (2000) on *Ginkgo biloba* and WenYuan *et al.* (2001) on *Kandelia candel*.

Dry weight of foliage (g /plant)

It is clear from the data in Table 7 that adding the different salt concentrations (1000-7000 ppm) in the irrigation water caused significant reductions in D.W. of *Agave sisalana* foliage in both seasons. As the salt concentration was increased, the foliage dry weight showed a steady decrease. The decrease was more pronounced in the second season at salt concentrations of 6000 and 7000 ppm. These results are similar to those reported by ChuanHong *et al.* (2002) on *Populus euramericana* , El-Baha *et al.* (2003) on *Acacia saligna*, *Casuarina cunninghamiana* and *Eucalyptus camaldulensis*, Parida *et al.* (2004) on *Bruguiera parviflora*, and Renault (2005) on *Cornus stolonifera.*

Table (7): Effect of salinity levels, and fertilization on dry weight of foliage (g /plant) in *Agave sisalana* during the 2004/2005 and 2005/2006 seasons.

Fertilizers (F)	(2004-2005) Salinity (ppm) (S)						Mean (F)
	0	1000	2000	3000	4000	5000	
0	8.98	7.05	5.93	6.17	5.57	5.46	6.52
Compost	9.15	8.02	7.08	7.13	5.69	4.93	6.99
NPK	9.40	8.11	7.08	6.23	5.76	5.47	7.01
Compost+ NPK	9.87	8.27	6.78	6.22	6.20	5.66	7.17
Mean(S)	**9.34**	**7.86**	**6.72**	**6.43**	**5.80**	**5.38**	
L.S.D. at 0.05	F : 0.35	S : 0.56	F X S : N.S				

Fertilizers (F)	(2005-2006) Salinity (ppm) (S)								Mean (F)
	0	1000	2000	3000	4000	5000	6000	7000	
0	9.41	8.29	6.55	6.52	4.44	3.62	2.74	1.38	5.37
Compost	9.25	7.42	6.43	6.08	5.98	4.31	3.51	1.45	5.56
NPK	10.16	9.28	7.45	6.67	6.30	5.77	3.78	1.59	6.38
Compost+ NPK	10.57	9.37	7.28	5.86	6.42	5.90	3.21	1.83	6.31
Mean(S)	**9.85**	**8.59**	**6.93**	**6.29**	**5.78**	**4.90**	**3.31**	**1.56**	
L.S.D. at 0.05	F : 0.37	S: 0.65	F X S : N.S						

The data on the effect of fertilization on D.W. of foliage indicate that, in both seasons, plants fertilized with NPK or compost + NPK had significantly heavier foliage dry weights than the unfertilized control plants. Also, fertilization using compost alone increased foliage dry weight significantly in the first season (compared to the control), but not in the second season. In both seasons, no significant difference was recorded between the fresh weights of plants fertilized using NPK or compost + NPK. Similar findings were reported by Gars (2004) on *Bombax ceiba* and Assefat (2006) on *Khaya senegalensis*.

Dry weight of fibrous roots (g /plant)

It is clear from Table 8 that, in both seasons, all the tested irrigation water salt concentrations significantly decreased the fibrous roots dry weight/plant, and that the rate of reduction increased steadily as the salinity level increased. It is worthy to note that the significant decrease in D.W. of fibrous roots per *Agave sisalana* plant was detected at salinity levels of 1000 up to 7000 ppm. These results are in agreement with conclusions reached by El-Baha *et al.* (2003) on *Acacia saligna*, *Casuarina cunninghamiana*, *Eucalyptus camaldulensis*, Agarwal and Pandey (2004) on *Cassia angustifolia*, and Renault (2005) on *Cornus stolonifera.*

The results presented in Table 8, also show that the effect of fertilization treatments on the dry weight of fibrous roots was insignificant in both seasons. These results are in line with those demonstrated by Gars (2004) on *Bombax ceiba* and Assefat (2006) on *Khaya senegalensis*.

Table 8 : Effect of salinity levels, and fertilization on dry weight of fibrous roots /plant (g) of *Agave sisalana* during the 2004/2005 and 2005/2006 seasons.

Fertilizers (F)	(2004-2005) Salinity (ppm) (S)						Mean (F)
	0	**1000**	**2000**	**3000**	**4000**	**5000**	
0	2.42	1.52	1.57	1.53	1.18	1.17	1.56
Compost	2.80	2.43	1.46	1.43	1.36	1.43	1.82
NPK	2.38	2.28	1.60	1.47	1.40	1.31	1.74
Compost+ NPK	2.70	2.53	1.66	1.53	1.49	1.23	1.86
Mean(S)	**2.58**	**2.19**	**1.58**	**1.49**	**1.36**	**1.28**	
L.S.D. at 0.05	F : N.S S : 0.11 F X S: 0.22						

Fertilizers (F)	(2005-2006) Salinity (ppm) (S)								Mean (F)
	0	**1000**	**2000**	**3000**	**4000**	**5000**	**6000**	**7000**	
0	2.47	1.55	1.52	1.45	1.18	1.07	0.39	0.25	1.24
Compost	2.60	2.33	1.43	1.29	1.64	1.26	0.70	0.28	1.44
NPK	2.44	2.20	1.60	1.51	1.48	1.44	0.67	0.30	1.45
Compost+ NPK	2.87	2.68	1.70	1.63	1.44	1.64	0.98	0.46	1.67
Mean(S)	**2.59**	**2.19**	**1.57**	**1.46**	**1.44**	**1.35**	**0.69**	**0.32**	
L.S.D. at 0.05	F : N.S S : 0.16 F X S : 0.32								

From the above results it can be concluded that, in both seasons, all the tested concentrations of salinity in irrigation water decreased the measured morphological characteristics of *Agave sisalana* plants (plant height, number of leaves, leaf area, leaf thickness, and dry weights of foliage and fibrous roots. Moreover, the rate of reduction increased steadily as the salinity level increased, and reached its maximum with a salinity level of 7000 ppm.

In general, the depressing effect of salinity on plant growth, as expressed by changes in the morphological characters under salinity conditions, could be attributed to many reasons. Excess of salt in irrigation water usually affects many metabolic aspects of plants and induces changes in their physiological behaviour; Schulze *et al.* (2005) mentioned that secondary damage occurs that is caused by severe salt stress; growth by cell division and elongation is particularly affected; also young tissues often become necrotic. Stress also influences cell wall metabolism. The cell wall of salinity-stressed cells contains less cellulose and fewer cell wall proteins.

In contrast, all the tested fertilization treatments increased extensively plant growth compared, to the unfertilized control plants. Fertilization treatments slightly reduced the inhibiting effect of salinity, particularly the compost + NPK treatment.

II- Effect on anatomical structure

Anatomical studies aimed at describing the major anatomical features of the fleshy leaf of *Agave sisalana*, as well as explaining the morphological outcomes of the salinity treatments on leaf structure characteristics, i.e., leaf thickness, leaf area and leaf fresh and dry weight. The inhibitory effects that occurred due to salinity treatments may be related directly to the changes that can be found in the anatomical measurements and counts of different leaf tissues, compared to those of control plants.

Leaf anatomical features of the control Agave plants

The means of measurements (μ) and counts of different leaf lamina tissues of the studied *Agave* plant, as shown in the transverse sections, are represented in Table 9 and Figure 1. It can be seen in the cross section in the leaf lamina that *Agave sisalana* has a typical monocotyledon leaf structure. The upper and lower epidermis is covered with a very thick waxy cuticle layer. The cuticle thickness varied between the upper and the lower epidermis (11.5 μ and 4.0 μ for the upper and lower epidermis, respectively). Also, the upper and lower epidermal cells showed a considerable difference in thickness (with values of 22.5 μ and 15.0 μ for upper and lower epidermis, respectively). These cells are barrel shaped, with relatively numerous amounts of green plastids as well as a dense cytoplasm.

The mesophyll occupied the central part of leaf lamina, and consisted of large polygonal parenchyma cells with intercellular spaces. Multilayered chlorenchyma was found adjacent to both the upper and lower epidermis Figure 1, and consisted of 4 to 6 rows of well-developed angular chlorenchyma cells. In transverse section, the leaf blade showed numerous closed lateral vascular bundles, arranged in nearly parallel rows within the leaf ground tissue. Each vascular bundle has a vigorous sclernchymatous bundle sheath that resembles a bundle cap. The vascular bundle showed weakly developed phloem tissue mixed with fibrous cells. The above-mentioned leaf features are similar to those described by Kubitzki *et al.* (1998) and Pandey (2004).

The effect of salinity on leaf lamina structure

Microscopical measurements recorded on transverse sections of *Agave* leaves from plants affected by different levels of salinity are presented and illustrated in Table 9 and Figure 1. It is worth mentioning that salinity treatments generally, caused reductions in the measurements and counts of the histological traits of leaf structure: thickness of upper cuticle, average diameter of parenchyma and chlorenchyma cells, length and width of vascular bundles, thickness of vascular bundle sclernchymatous bundle sheath and the average diameter of xylem. These reductions tend to increase with raising salinity level from 1000 to 7000 ppm, and reached its maximum reduction with 7000 ppm salinity. It can be stated that a linear negative relationship was found between the increase in salinity treatments and the measurements and counts recorded on internal tissues of leaf lamina. Relative to the control, the lamina thickness was reduced by 0.46% and 66.82% at salt concentrations of 2000 and 7000 ppm, respectively. The leaf upper epidermis thickness was also reduced by 33.33 % at

Table 9: Microscopical counts and measurements (μ) of *Agave sisalana* leaf histological features in transverse sections through the median leaf of control plants, and plants irrigated with different salt concentrations.

Characters		Salinity (ppm)							
		0	**1000**	**2000**	**3000**	**4000**	**5000**	**6000**	**7000**
(Lamina) Blade thickness (μ)		2170	1980	2160	1215	1110	870	810	720
Cuticle thickness (μ)	**Upper**	11.5	11.5	11.5	7.5	7.5	11.5	11.5	15
	Lower	4	4	4	4	4	4	7.5	7.5
Epidermis thickness (μ)	**Upper**	22.5	22.5	15	11.5	26	26	26	18.5
	Lower	15	15	18.5	22.5	15	18.5	22.5	18.5
Average of diameter	**Chlorenchyma cells (μ)**	250	225	225	135	150	75	75	60
	Parenchyma cells (μ)	105	97.5	80	77.5	70	63	52.5	52.5
Vascular bundle (v.b.) dimension	**length (μ)**	300	225	210	180	165	165	150	150
	Width (μ)	165	120	105	105	90	90	90	90
No.of v.b. in field 1500*1500 μ		75	60	65	75	105	150	165	180
Distance between	**Upper v.b. (μ)**	352.5	337.5	337.5	547.5	555	240	285	259.5
	Lower v.b. (μ)	330	360	300	424.5	360	270	405	292.5
No. of cells between	**Upper v.b.**	127.5	120	120	130.5	150	105	120	137.5
	Lower v.b.	124.5	135	105	118.5	88.5	124.5	139.5	132
v.b. sclerenchyma sheath thickness (μ)	**Upper**	60	37.5	45	30	52.5	41	30	30
	Lower	18.5	18.5	12.5	12.5	12.5	15	18.5	18.5
Phloem thickness (μ)		15	15	15	15	15	15	15	15
Av. xylem vessels diameter (μ)		75	67.5	62.5	60	56.25	63	39	43

salt concentration of 2000 ppm, whereas the lower epidermis thickness was increased by 23.33 at the same salt concentration. This contrast in the responses of the upper and lower epidermis thickness occurred to varying extents with the different salinity treatments. It is also clear that some other anatomical traits such as average thickness of chlorenchyma and parenchyma cells as well as the vascular bundle dimensions showed a relative decrease due to salinity treatments. This reduction in parenchyma and chlorenchyma cells diameter may be related to the increase that occurred in the number and density of vascular bundles (number of bundles in a square area measuring 1500 x1500 μ). This decrease squeezed together cells that found between vascular bundles. Data presented in Table 9 proved that salinity treatments resulted in a remarkable decrease in vascular bundles dimensions that may be due to decreases in the thickness of the vascular sheath and the xylem vessels diameter, whereas the phloem diameter showed a constant size with all salinity treatments. The reductions in amount and size of xylem vessels that detected in the present work due to salinity treatments are in agreement with the findings of Mohamed (2002). This reduction in size and amount of xylem vessels might affect the conducting of water and minerals in the plant. From the above results, it could be concluded that as the salinity treatments affected the morphological traits of *Agave* leaves, the anatomical features of the leaf were also greatly affected by salinity treatments. This supports and explains the recorded responses of morphological parameters (leaf thickness, leaf area and foliage fresh and dry weight). These results also indicate that, contrary to the common belief that succulent zerophytes plants are tolerant to salinity treatments, it is

evident that *Agave* plants showed strong reductions in its characteristics as a result of the physiological drought caused by the salinity treatments. It is, therefore, evident that most anatomical features under investigation proved to be xeroplastic characters as they showed distinctive responses to the environmental conditions. These outcomes are in harmony with those mentioned by Pandey (2004).

The above results are also in harmony with conclusions reached by Reda *et al.* (2000) who mentioned that on *Leucaena leucocephala*, salinity mainly affected the leaf anatomy, since the thickness of vascular bundles and the distance between bundles and number of vascular bundles was decreased significantly by increasing salinity. Also, the salinity-induced reduction in thickness of lamina and mid-vein of leaflets of the median compound leaf is in agreement with the findings of Reinoso *et al.* (2004), who reported that salinity induced anatomical changes in leaflets on *Prosopis strombulifera*.

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دراسات على بعض النباتات الشوكية والعصارية، واستخدامها فى الحدائق النباتية المصرية

١ـ تأثير مستويات الملوحة والتسميد على النمو الخضرى والتركيب التشريحى للورقة، لنباتات السيسال

حازم عبد الجليل منصور-طارق أبو دهب محمد أبو دهب ـ * أشرف عبد الرازق إبراهيم أحمد
قسم بساتين الزينة- كلية الزراعة - جامعة القاهرة – ج.م.ع.
*شركة جرين بارادايس للمقاولات الزراعية- ج.م.ع.

أجرى هذا البحث لدراسة مدى تحمل نبات السيسال للرى بالمستويات المختلفة من الماء المالح . وقد أجريت التجربة فى اصص بالمشتل التجريبى بقسم بساتين الزينة بكلية الزراعة جامعة القاهرة خلال الموسمين ٢٠٠٤ /٢٠٠٥ ، ٢٠٠٥/٢٠٠٦ وقد استخدمت أملاح كلوريد الصوديوم وكلوريد الكالسيوم (١ :١ ، بالوزن) بتركيز ١٠٠٠ ، ٢٠٠٠ ، ٣٠٠٠ ، ٤٠٠٠ ، ٥٠٠٠ ، ٦٠٠٠ أو ٧٠٠٠ جزء فى المليون مع استخدام الماء العادى لرى نباتات المقارنة . بالاضافة الى دراسة تاثير معاملات التسميد المختلفة (بدون تسميد ، تسميد عضوى بالكمبوست " ٥٠ جم / اصيص " ، السماد الكيماوى NPK المركب " ٢ جم / اصيص " ، و اضافة السماد الكيماوى المركب مع الكمبوست) وذلك لتقليل الآثار الغير مرغوبة للملوحة على النمو الخضرى والتركيب التشريحى.

أوضحت النتائج المسجلة أن زيادة مستويات الملوحة قد قلل معظم الصفات محل الدراسة (ارتفاع النبات ، عدد الأوراق / نبات ، مساحة الورقة ، سمك الورقة ، و الوزن الجاف لكل من المجموع الخضرى والمجموع الجذرى).

وقد أكدت وفسرت الدراسة التشريحية النقص فى معظم الصفات المورفولوجية تحت الدراسة نتيجة لمعاملات الملوحة، حيث تاثرت الصفات التشريحية للورقة إلى حد كبير. وعموما تلاحظ أنه بزيادة ملوحة ماء الرى تدريجيا أدى ذلك الى انخفاض فى متوسط قيم جميع الصفات المدروسة فى كلا الموسمين . وكان الانخفاض ملحوظا بدرجة كبيرة مع مستوى ملوحة ٧٠٠٠ جزء فى المليون .

و من ناحية أخرى قللت معاملات التسميد الى حد ما التأثير السلبى للملوحة.

الكلمات الدالة: النباتات الشوكية، النباتات العصارية، السيسال ، الملوحة ، التسميد ، النمو الخضرى ، تشريح الورقة