

BIOCHEMICAL, PHYSIOLOGICAL AND MORPHOLOGICAL RESPONSES OF SUGAR BEET TO SALINIZATION

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ABSTRACT

Biochemical, physiological and morphological responses of sugar beet grown in sandy soil under three levels of NaCl salinity in irrigation water, i.e. control, 3000 and 6000 ppm were studied in pot experiment. Results showed that, root fresh weight linearly decreased by increasing NaCl salinity levels up to 6000 ppm, but sucrose percentage in root was significantly increased. On the other hand, increasing NaCl levels resulted in significant increase of Na content in both of shoot and root. Meanwhile, K content in shoot was sharply decreased but K content in root didn't significantly differ by increasing NaCl levels. Also, under salinity results indicated a strongly negative correlation between shoot osmotic potential and shoot Na content while it was mainly with sucrose concentration in root. Thus, sugar beet plant has an active mechanism to include higher amount of Na in leaves and utilizes it to regulate leaves osmotic potential under saline condition. Despite of this mechanism the transpiration rate and stomatal conductance showed significant decrease by increasing NaCl levels up to 6000 ppm. Moreover, stomatal behavior and stomatal morphology revealed a gradual response to the level of NaCl salinity used. Stomatal density, stomatal area and stomata pore area significantly decreased by adding the first saline level (3000 ppm) but no response was detected for stomatal closure at the same saline level. No further response was shown for stomatal area by increasing NaCl from 3000 to 6000 ppm, while stomatal closure recorded 60% in lower & 30% in upper leaf surface at 6000 ppm NaCl level. Generally it could be pointed out that, the decrease of sugar beet root fresh weight at low salinity level (3000 ppm) might be due to osmotical stress. While at high level of NaCl (6000 ppm) it was attributed to toxic effect of higher NaCl accumulated on photosynthesis tissues which led to close the stomata in order to inhibit more Na transporting into leaves.

INTRODUCTION

Salinity is one of the principal abiotic factors affected crop yields in arid and semi-arid areas. Because sugar beet has halophytic ancestors, *Beta vulgaris ssp. maritima*, which is found in salt marshes, moreover, sugar beet root has an affective mechanism to avoid salt stress by uptaking Na from the salt medium and immediately transported into leaves. Therefore, sugar beet is a good target crop for studying in such salt-affected areas. Until now reduction of sugar beet root yield under salinization is unclear. However, many investigations suggested that this reduction is caused by inhibition of photosynthesis or nutrient deficiency or by mineral toxicity. Brugnoti and Bjorkman (1992) reported that the lowering of conductance to CO₂ diffusion caused by stomatal closure accounts for much of the reduction in photosynthesis under moderate salt stress. Also, Delfine *et al.* (1998) found that salt accumulation caused a drop of the Ca and Mg content in spinach leaves that might have decreased membrane stability and chlorophyll content respectively. Moreover, they concluded that salinity reduced photosynthesis primarily by reducing the diffusion of CO₂ to the chloroplast both by stomatal

closure and changes in mesophyll structure, which decreased the conductance to CO₂ diffusion within the leaf.

However, Very *et al.* (1998) reported that the halophyte *Aster tripolium* partially closes its stomata in response to high Na concentrations. Despite the fact that *Aster tripolium* possesses no specific morphological adaptation to salinity, its stomatal responses preventing excessive accumulation of Na within the shoot via control of the transpiration rate, is probably a principal feature of observed salt tolerance within the shoot. On the other hand, Ali *et al.* (2000) summarized some salt tolerance mechanisms of sugar beet such as replacing most of K in leaves by Na and selectivity of K over Na in young leaf as compared with the old one. Moreover, Flowers (1988) found that in genotypes with salt inclusion, the predominant strategy of osmotic adjustment is achieved by the accumulation of salts (mainly NaCl) in the leaf tissue. This is also indicated for *Chenopodium rubrum* (Warne *et al.*, 1990) and for *Spartina townsendii* (Koyro and Huchzermeyer 2004) who reported that osmotic adjustment under salinity is achieved by accumulating electrolytes in leaves.

Finally, not enough knowledge of the biochemical and physiological basis of the salt detrimental effect on growth and root yield of sugar beet are the main reasons for the limited success of sugar beet planting under high salt condition. Therefore, this study was carried out to understanding the biochemical and physiological basis of sugar beet salt tolerance mechanisms in order to improve those mechanisms and consequently achieving salt tolerance not only of sugar beet but also of other conventional field crops.

MATERIAL AND METHODS

The present study was carried out at Faculty of Agriculture, Ain Shams University, Cairo, Egypt. Ten seeds of sugar beet (*Beta vulgaris* L. ssp. Maritime (L.) Arang. var. altissima Doell) were sown on November 15th 1999 in Pots (30 cm diameter with a bottom drainage hole) that were filled with 9.5 kg sandy soil (97.0% sand, 1.6% silt and 1.4% clay).

Plants were thinned after 4 weeks to one plant per pot. Complete randomized design with ten replicates was used. Each replicate included three levels of NaCl salinity namely, control (tap water), 3000 and 6000 ppm. Salt treatments were added to irrigation water after 4 weeks from the sowing date and continued till the end of the experiment. Modified nutrient solution after Arnon and Hoagland (1940) was used till 15 weeks from sowing. Plants were harvested 23 weeks after sowing, then immediately separated into shoot and storage root (root & crown at the lowest leaf scar). Fresh weights of shoot and root were determined. Sucrose and glucose concentrations were determined in root and shoot fresh weight according to the method of Shaffer and Hartmann (1921). Sodium and potassium contents in sugar beet shoot and root were measured using flame photometer Petracoourt PFP1. Osmotic potential of root and shoot was estimated by osmometer 800 cl. Leaf temperature, transpiration rate and stomatal conductance were measured by a Porometer L1-1600 (Licorginc USA) on the leaf No.10 (from top to bottom of the plant). The morphological changes of stomata for leaf No.10 from

different treatments were examined and calculated through a Joel Scanning Electron Microscopy (T.330A) linked with SemaFour software program in Central Laboratory Fac. of Agric. Ain Shams University.

Statistical analysis

Statistical analysis was performed using Statgraphics plus program, version 7). Means were compared using the least significant difference, which is developed by Duncan (1955) at 5% level of probability.

RESULTS

Data in Table (1) show that, first level of NaCl (3000 ppm) resulted in a significant reduction of sugar beet root fresh weight to about 37% less than control. While, shoot fresh weight was not significantly affected. Raising the NaCl level to 6000 ppm led to a significant reduction in both root and shoot fresh weight to 70.5 and 45.5%, respectively less than control treatment. Consequently, root/shoot ratio was decreased linearly by increasing NaCl levels up to 6000 ppm.in the nutrient medium.

Responses of sucrose and glucose content for both root and shoot to increase NaCl levels illustrated in Table 1 & Fig.3. On the one side increasing NaCl levels up to 6000 ppm significantly increased root sucrose percentage but on the other, sucrose percentage in shoots showed no significant response. Interesting results were shown for the glucose percentage in both shoot and root as affected by increasing NaCl levels in nutrient media. Whereas, glucose concentration increased in the roots, it was reduced in the shoots by increasing NaCl level. These inverse responses of root and shoot glucose concentration to increase NaCl levels resulted in an obvious increase of root/shoot glucose concentration ratio (Fig.3). Meanwhile, sucrose root/shoot ratio was not affected.

Table (1): Effect of different levels of NaCl on sugar beet root and shoot fresh weight, root/shoot fresh weight ratio and sucrose concentration in root (fw = fresh weight).

NaCl levels (ppm)	Root Shoot		Root/ Shoot Ratio	Root sucrose Shoot sucrose		Sucrose root/ shoot ratio
	(g plant ⁻¹ fw)			(g 100 g ⁻¹ fw).		
Control	373 _a	110 _a	3.7	16.21 _c	0.55 _a	29.4
3000	235 _b	100 _a	2.7	18.03 _b	0.58 _a	31.1
6000	110 _c	60 _b	1.8	19.70 _a	0.62 _a	31.8

Means with the same letter at the same column are not significant different at 5% probability level.

The data in Table 2 show that, increasing NaCl levels up to 6000 ppm significantly increased Na content for both root and shoot. However, increasing NaCl levels had no significant effect on root K content but, shoot K content was significantly reduced. Another aspect of NaCl salinity effects on distribution of K and Na between root and shoot is shown in Table 2. It's clear that higher amounts of K, and Na in shoots than in roots were found even

under salinization. However, the replacement of K by Na was more effective in leaves than in root. Moreover, the selectivity of K in root is more evident than in leaves, nevertheless K/Na ratio was decreased by increasing NaCl levels for both roots and shoots. In addition, the osmotic potential in either roots or shoots was significantly decreased as associated with increasing NaCl level in nutrient medium. However, in roots a lower osmotic potential (more negative value) was recorded than in shoot as shown in Table 2.

Table (2): Effect of different levels of NaCl on sodium and potassium content, potassium/sodium ratio and osmotic potential of sugar beet roots and shoots. (OP = Osmotic Potential, MPa = mega pascal).

Plant organ Parameters	Root				Shoot			
	K (mg g ⁻¹ dry weight)	Na (mg g ⁻¹ dry weight)	K/Na Ratio	OP (MPa)	K (mg g ⁻¹ dry weight)	Na (mg g ⁻¹ dry weight)	K/Na ratio	OP (MPa)
NaCl levels (ppm):								
Control	8.0 _a	0.2 _c	40	-1.2 _c	52 _a	2.2 _c	24	-0.32 _c
3000	9.2 _a	2.4 _b	3.8	-1.5 _b	40 _b	38 _b	1.05	-0.49 _b
6000	10.0 _a	3.4 _a	2.9	-1.7 _a	30 _c	65 _a	0.46	-0.58 _a

Means with the same letter at the same column are not significant different at 5% probability level.

The data in Table 3 show that the application of NaCl was followed by reduction in both transpiration rate and stomatal conductance of 10th leaf. On the other hand, leaf temperature did not show any response to increasing salinity. However, the highest reduction of transpiration rate and stomatal conductance occurred at the higher level of NaCl. Whereas, decreasing the values of transpiration rate and stomatal conductance at 3000 ppm NaCl recorded 34 and 37% respectively below control treatment. For higher level such reduction was 47.5 and 50%.

Table (3): Effect of different levels of NaCl on temperature, transpiration rate and stomatal conductance of sugar beet leaf No.10 (from top to bottom).

NaCl levels (ppm)	Leaf temperature (°C)	Transpiration rate (mmol m ⁻² s ⁻¹)	Stomatal conductance (mmol m ⁻² s ⁻¹)
Control	34 ^a	0.61 ^a	427 ^a
3000	34 ^a	0.40 ^b	270 ^b
6000	34 ^a	0.32 ^c	212 ^c

Means with the same letter at the same column are not significant different at 5% probability level.

Concerning the morphological changes of stomatal criteria to salinity (Table 4), it is quite evident that each parameter observed exhibited its individual response to increase NaCl levels. Whereas, stomatal density linearly decreased by increasing NaCl levels up to 6000 ppm, significant reduction of stomatal area was detected up to 3000ppm and no further

response was shown even at 6000 ppm. Stomatal closure showed another different response along with increased NaCl levels. This parameter showed no effective response with increasing NaCl up to 3000 ppm but, stomata were closed at the highest NaCl level (6000 ppm). More focusing to the effect of salinity on stomatal closure for the upper (adaxial) and the lower (abaxial) leaf surface are shown in Table 4. The distribution of stomatal density between the abaxial and adaxial leaf surfaces was decreased in a much more pronounced way for the abaxial than for the adaxial leaf surface as the NaCl level increase. Accordingly, the adaxial/abaxial distribution ratio of stomatal density was obviously decreased from 71.7 to 63.7% by increasing NaCl level up to 6000 ppm. The opposite trend was true for stomatal pore area. Consequently, the closing of stomatal pores was more evident for abaxial than for the adaxial leaf surface. Results of stomatal closure (Table 4) supported the previous conclusion. The stomatal closure was firstly detected for the abaxial leaf surface at the lower level of NaCl (3000 ppm) while at 6000 ppm, stomatal closure was detected for both abaxial and adaxial leaf surfaces. However, stomatal closure was two times higher at the abaxial than at the adaxial leaf surface at the high NaCl level (6000 ppm).

Table (4): Effect of different levels of NaCl on stomatal density, stomatal area, stomatal pore area and stomatal closure for upper and lower surfaces of sugar beet leaf No.10 (from top to bottom). Stomatal closure (%) = No. of stomata closed : No. of total stomata x 100. ND: Not detectable.

NaCl levels (ppm)	Stomatal density (No. mm ⁻²)		Stomatal area (. m ²)		Stomatal pore area (. m ²)		Stomatal closure (%)					
	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper			
	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper			
Control	81.0 ^b	113 ^a	71.7	530 ^a	510 ^a	104	40.0 ^a	41.9 ^a	0.95	ND	ND	ND
3000	60.0 ^c	90.6 ^b	66.8	364 ^b	322 ^b	113	29.8 ^b	18.0 ^c	1.7	1.0	11.0	0.1
6000	41.7 ^d	65.5 ^c	63.7	3350 ^b	360 ^b	97	28.0 ^b	11.0 ^d	2.5	30	60	0.5

Means with the same letter for the same parameter are not significant different at 5% probability level.

DISCUSSION

Starting with the responses of sugar beet yield to increase NaCl levels up to 6000 ppm, it is clear that, despite of the linear decrease of root fresh weight nevertheless, root sucrose percentage was increased. At the same time, it was obvious that reduction of root/shoot ratio along with increasing NaCl levels might be a modificative adaptation to reduce root mass. Consequently, root sucrose percentage was concentrated and thus root osmotic potential was adjusted against high NaCl concentration around root system. However, the detrimental effects of salt on sugar beet yield have been already indicated by many investigators (Nassar 1989; El-Hawary 1990; Ali *et al.* 2000 and Eisa *et al.* 2001). They reported that reduction of shoot as well as root fresh and dry weights were associated with increasing salinity levels. On the other hand, the ability of sugar beet to change its osmotic potential as responses to salt stress was discussed by Lindhauer *et al.*

(1990), who reported that inorganic salts such as potassium, sodium and magnesium played the main role of osmotic potential adjustment in sugar beet leaves whereas sucrose dominated root osmotic potential. Also, results obtained in the present work revealed a more pronounced accumulation of both sucrose and glucose in the roots than in the shoots by increasing NaCl levels. Besides, higher concentrations of inorganic solutes (Na and K) were found in shoots than in roots. However, correlation analysis (Fig. 1) identified Na as the main solute for osmotic potential adjustment in sugar beet leaves under salinity conditions. Moreover, both of sucrose and K are the main solutes for osmotic potential adjustment in roots followed by glucose and Na. Accordingly, it may be concluded that high Na concentration plays an important role in leaves metabolic function such as turgor maintenance. This ability to adjust shoot osmotic potential by using Na under saline condition is in agreement with characterizing of sugar beet plants as salt inclusion species.

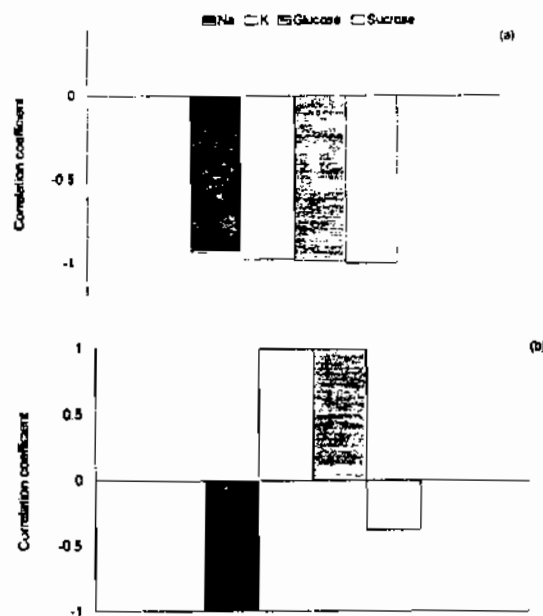


Fig. 1. Correlation coefficient between root (a) and shoot (b) osmotic potential and sodium, potassium, glucose and sucrose of sugar beet root and shoot under different concentrations of NaCl levels.

Concerning the effect of increasing NaCl levels on sodium and potassium content, the present results show that increasing NaCl levels up to 6000 ppm greatly increased Na content in both shoots and roots, but sharply decreased K content in shoots (Table 2). On the other hand, root potassium content was not significantly affected by increasing NaCl levels. Accordingly, K/Na ratio, particularly for the shoot was obviously decreased. This pointed out a mechanism for replacing most of the potassium by sodium. As

indicating by the higher amounts of Na accumulation in the shoots, an elimination of Na from the root by transporting it to the shoot where it replaces most of the K in leaves must be assumed. This mechanism (salt inclusion) has been detected by several investigators in some natrophylic plants to achieve salt tolerance [Greenway and Munns (1980); Gorham *et al.* (1985); Marschner (1995); Haneklaus *et al.* (1998); Ali *et al.* (2000) and Eisa *et al.* (2001)].

On the other hand, correlations presented in Fig.(2) illustrated that, both of K/Na ratio and osmotic potential in root and shoot were inversely correlated with stomatal closure whereas Na and sucrose content correlated proportionally with stomatal closure. It is clear that, Na and sucrose content in both root and shoot led to a decrease of the osmotic potential, which resulted in elevation of stomatal closure under saline condition. However stomatal closure correlated better with root osmotic potential ($r = -0.9$) than with that of the shoot ($r = -0.8$) and that may accentuate that stomatal closure was more a response to root osmotic potential than to that of the shoot under saline condition.

As for biochemical aspects, it was evident that leaves glucose concentration sharply decreased by increasing NaCl up to 6000 ppm while, the opposite response was observed for root glucose concentration (Fig.3). However, decreasing glucose concentration in the shoot and increasing concentration in the root as affected by salinity may favor sucrose transport and accumulation in the root. This might be reflected by a lower activity of acid invertase associated with high activity of sucrose-P synthesis in leaves but the reverse was true in roots. Thus, it seems that under salinity stress sugar beet leaves are mainly a source while roots seem to be a main or a single sink as the formation of new leaves was strongly reduced or even inhibited. On the other hand, control plants have two sinks namely, young growing leaves and the root. This might be the second reason for increasing sucrose concentration in the root at increased salinity levels. Salt stress could be considered a factor helping plant leaves to shift from functioning as a sink to be become a source by aforementioned mechanism. Consequently, sucrose concentration increases in sugar beet root. In this regard, Eschrich (1984) and Marschner (1995) reported that in sugar beet leaves the shift from sink to source is closely correlated with changes in enzyme activities associated with carbohydrate metabolism, namely a decrease in acid invertase activity (sucrose hydrolysis) and a sharp increase in sucrose-P synthase activity (sucrose synthesis). They added that, sinks like young leaves and roots are characterized by high activities of acid invertase in the apoplasm. This enzyme hydrolyzes sucrose to form hexoses and there by maintains a low sucrose concentration in the apoplasm. Consequently sucrose transporting is enhanced by phloem unloading into the sink. Moreover, inhibited invertase activity in response to salinity was reported in sugar beet leaves (Rathert 1982a), in cotton (Rathert 1982b), and soybean (Rathert and Doring 1983).

Here again, concerning the effect of increasing NaCl levels on the K content in the root, the present data show slight accumulation of K content in the roots due to increased NaCl levels.

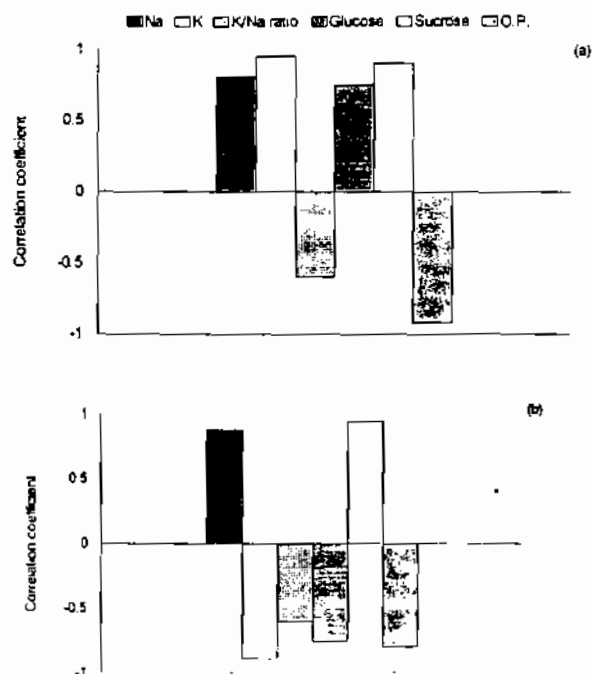


Fig. 2. Correlation coefficient between stomatal closure and sodium, potassium, K/Na, glucose and sucrose of sugar beet root (a) and shoot (b) under different concentrations of NaCl levels.

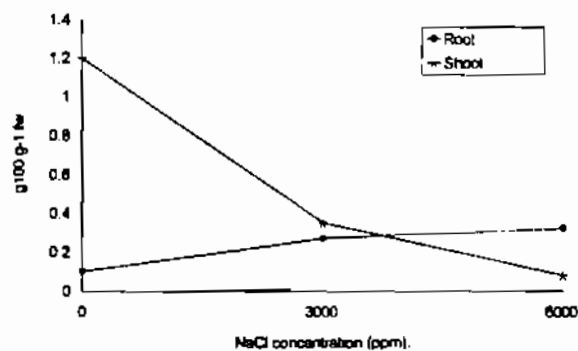


Fig. 3. Glucose concentration in root and shoot of sugar beet plant under two levels of salinity (3000 and 6000 ppm NaCl)

Whereas K in the shoots decreased linearly at increasing NaCl levels. However, the accumulation of a suitable amount of K in root despite the increasing NaCl levels in the nutrient medium may have occurred due to a restricted transport of K from the root (sink) to shoot (source). This result was found to be in agreement with Wolf *et al.* (1991) who assumed that the high K and low Na concentration in young barley leaves and productive organs

(sinks) were achieved by low xylem import of both K and Na but high phloem import of K from the mature leaves (source). However, the restriction of K transport into the shoot at increasing NaCl levels may be the second reason for K accumulation in the roots. Accordingly, maintaining K in a suitable level in roots may be important for some essential metabolic functions in root such as enzyme activities. In this regard, Saftner and Wyc (1980) and Willenbrink *et al.* (1984) reported that in storage cells of sugar beet roots accumulation of sucrose is stimulated by potassium. Also, they added that sodium has an even greater stimulatory effect on sucrose accumulation.

Regarding the physiological and morphological responses to increasing NaCl levels, greatly reduce transpiration rate and stomatal conductance were observed by applying lower salinity level (3000 ppm NaCl) while, slightly further decrease for both parameters was recorded at the higher NaCl level (6000 ppm).

In the same regard, stomatal conductance was found to be sensitive even under mild salt stress either in salt sensitive beans (Gale *et al.*, 1967) or resistant spinach (Robinson *et al.*, 1983) and sugar beet plants (Heuer and Plaut 1981). However, concerning the reduction of transpiration rate and stomatal conductance in the present work at the lower NaCl level (3000 ppm) was attributed to decrease in stomatal density, size and pore area but stomatal closure didn't play an important role at this level. On the other hand, higher NaCl level (6000 ppm) accounted for sudden increase of stomatal closure. This sensitivity of stomatal closure at high NaCl level (6000 ppm) may be the last mechanism for sugar beet plants to avoid the injurious effect of salt. In this regard, it could be suggested that the photosynthesis seems to be strongly affected at high NaCl (6000 ppm) may be due to excessive accumulation of Na in leaves excreting toxic influence on this process. In other word, high transpiration rates lead to more accumulation of Na in leaves via xylem import which reaches the toxic level for active photosynthesis tissues and at this point stomata will be closed as the last way to avoid toxic effects of salt stress. Therefore, it may be concluded that plant has been finished off its aforementioned biochemical mechanisms such as replacement of K by Na in leaves. Additional support that validates this suggestion can be obtained from an earlier report by Eisa (1999) who studied distribution and redistribution of Na in single cells of sugar beet leaf under various salinity levels, i.e. control (distilled water), 2000 and 6000 ppm NaCl. The authors also reported that at the lower salt level (2000 ppm), Na accumulates in higher amount in both upper and lower epidermis cells than in mesophyll cells. Thus, this partitioning mechanism within the leaf tissue eliminates the deleterious effect of Na from photosynthetically active tissues and this, in turn, reflects the insignificant effect of salt stress on the activity or concentration of CO₂ fixation enzymes. He added that, raising NaCl level up to 6000 ppm Na accumulates greatly in mesophyll cells because the epidermal cells were saturated which lead to a significant decrease in Rubisco concentration and increase PEPCase activity. From results presented it could be concluded that, increasing PEPCase enzyme activity may be an additional clue at limited CO₂ due to closed stomata at high NaCl level (6000 ppm).

CONCLUSION

The present work has pointed out some salt tolerance mechanisms for sugar beet plant which could be summarized as following: firstly, sugar beet plants have an effective inclusion mechanism through which, sodium was readily translocated into the shoot where it replaced most potassium. Secondly, sugar beet plants have an ability to change the osmotic potential of shoot and root under saline condition. While sodium was mainly used for adjustment of shoot osmotic potential under saline condition, sucrose played a main role in the regulation of root osmotic potential followed by potassium, glucose and sodium against low osmotic potential in the nutrient medium. Therefore, increasing sucrose concentration in the root under saline condition may be attributed to the following: A) Decreasing glucose concentration in the shoot increased it in the root in order to orient sucrose translocation into the root. B) Preventing the induction of new leaves will keep the root to be the main sink. C) As a consequence of reduced root mass formation sucrose was concentrated in the root. Thirdly, the ability to regulate leaf transpiration rate and stomatal conductance by gradual control of stomatal behavior according to salinity level in nutrient medium; primarily at low level of NaCl (3000 ppm) the reduction of transpiration rate was caused by reducing stomata density, size and pore area but not attributed to stomatal closure while at a higher NaCl (6000 ppm), it was predominantly attributed to stomatal closure. Accordingly, it can be pointed out that the reduction of root fresh weight yield at low NaCl (3000 ppm) may be due to osmotic stress but at high level of NaCl (6000 ppm) to the toxic effect of the higher Na content on photosynthesis. Moreover, another ability to regulate leaf transpiration rate was detected as stomata started to close firstly at lower leaf surface at low level of NaCl (3000 ppm) and then in both leaf surfaces at the higher NaCl level (6000 ppm). However, at high salinity stomatal closure at the lower surface was two times more than at the upper leaf surface.

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الاستجابات البيوكيميائية والفسيولوجية والمورفولوجية لنباتات بنجر السكر المتأثرة بالملوحة

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قيمت تجربة أصص لدراسة استجابة نباتات بنجر السكر المنزرعة في تربة رملية وتروى في ثلاث مستويات ملوحة مع ماء الري (كنترول ٣٠٠٠ ppm ، ٦٠٠٠ ppm كلوريد صوديوم) أضيفت الملوحة بعد أربعة أسابيع من الزراعة وحتى الحصاد. أظهرت النتائج انخفاض محتوى في الوزن الطازج للجنور مصحوبا بزيادة خطية في تركيز السكروز بها مع زيادة مستوى الملوحة في ماء الري حتى ٦٠٠٠ ppm. كذلك ازداد محتوى الصوديوم معنويا في كل من الجذر والمجموع الخضري بينما انخفض محتوى البوتاسيوم معنويا في المجموع الخضري دون الجذور بزيادة مستوى الملوحة. وقد أوضحت علاقة الارتباط وجود معنوية شديدة بين الحدب الأزموزي في المجموع الخضري ومحتوى الصوديوم به تحت تأثير الملوحة بينما كان الارتباط في الجذور قوى المعنوية مع تركيز السكروز. يتضح من ذلك أن نباتات بنجر السكر لها القدرة على تغيير أو تنظيم جهدها الأزموزي تحت الاجهاد الملحي كآحدى الميكانيكيات الفسيولوجية لمقاومة الاجهاد الملحي ويتم ذلك بطريقتين مختلفتين، الأولى في الجذر بزيادة تركيز السكروز بينما في المجموع الخضري يتم التحكم في الجهد الأزموزي بتوظيف الصوديوم. وبدل ذلك على فكرة نباتات البنجر في احوال الصوديوم بدلا من البوتاسيوم في إحدى الميئات الفسيولوجية لهامة مثل تنظيم الجهد الأزموزي. كما أظهرت النتائج أنه على الرغم من انخفاض معدل النتج والتوصيل الثغري بزيادة مستوى الملوحة حتى ٦٠٠٠ جزء في المليون إلا أن دراسة مورفولوجيا الثغور بالميكروسكوب الإلكتروني أوضحت نتائج ذات دلالة، ففي حين انخفض كل من عدد الثغور في المليمتر ومساحة الثغر وكذلك مساحة فتحة الثغر بأضافة المستوى الأول من الملوحة (٣٠٠٠ جزء في المليون) لكن لم تتأثر نسبة الثغور المنفتحة / المفتوحة عند هذا المستوى بالمقارنة بالكنترول. بينما عند زيادة مستوى الملوحة من ٣٠٠٠- ٦٠٠٠ جزء في المليون تحدث زيادة معنوية في نسبة الثغور المنفتحة / المفتوحة بينما لا تتأثر باقي الصفات المورفولوجية للثغور. من هذه النتائج الفسيولوجية والمورفولوجية يمكن اقتراح أن بنجر السكر يتدرج في مقاومته للملوحة على حسب مستوى الملوحة في ماء الري ففي مستوى الملوحة المتوسط (٣٠٠٠ جزء في المليون) لا يعاني النبات من عطش فسيولوجي بظليل عتم لفجالت الثغور في هذه الحالة يتطلب على زيادة محتوى الصوديوم بخالته محل البوتاسيوم في المجموع الخضري وكذلك زيادة محتوى السكروز في الجذر لمقاومة انخفاض الجهد الأزموزي للماء الأرضي في وجود الملوحة بمعنى أن النبات له القدرة على امتصاص الماء والملح والمحتوى على كلوريد الصوديوم واستخدام الصوديوم في الميئات الفسيولوجية. بينما عند المستويات المرتفعة ٦٠٠٠ جزء في المليون يبدأ النبات في علق الثغور وهنا يبدأ الضرر الناتج عن العطش الفسيولوجي.