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Response of Growth and Chemical Constituents in *Khaya sengalensis* to Salinity and Gypsum under Calcareous Soil Conditions

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Abstract: A pot experiments were conducted during 2010–2011 seasons at the greenhouse in Nubaria farm as well as laboratories of National Research Centre, Dokki, Giza, Egypt. The aim of this work is to study the effect of salinity levels and different rates of gypsum on vegetative growth and chemical constituents of *Khaya sengalensis* grown under calcareous soil conditions. Results showed that, increasing salinity levels significantly gradually decreased plant height, stem diameter, number of leaves/plant, root length and fresh and dry weight of leaves and shoots. The same behavior was noticed concerning chlorophyll a, b and carotenoids as well as N, P and K percentage in shoots. On the contrary, proline content as well as calcium and sodium percentage was increased with increasing salinity levels. On the other hand, all previous growth parameters and chemical constituents tended to increase with increasing gypsum rates, except the proline content and Na % tended to decrease with increasing gypsum rates. These applications may be recommended that for overcoming the harmful effect on growth and chemical constituents of *Khaya sengalensis* seedlings under salinity levels.

Key words: *Khaya sengalensis* · Calcareous soil · Salinity · Gypsum · Growth · Chemical constituents

INTRODUCTION

African mahogany (*Khaya sengalensis* Desr.) Family Meliaceae is a tree. The natural distribution area of khaye tree is from Senegal to Sudan and Uganda. Khaya tree can reach (15 to 24 m) in height with a stem diameter of about (1.0 m), it is semi-deciduous. *Khaya sengalensis* wood used for many purposes, as furniture, cabinets veneers interiors, turning and interior accent. Khaya plant is an important timber tree industry, in addition to its medicinal values, especially the bark, which is used to treat a number of diseases, such as fever, Lumbagos, cough, rheumatism and stomach ache and also gastric pains [1]. Salinity is considered a significant factor affecting plant production and agricultural sustainability in any regions of the world as it reduces the value and productivity of the affected land. Salinity problems can also occur in irrigated agriculture, particularly when poor quality water is used for irrigation as reported previously by Shehata *et al*. [2] on *Ficus nitida*, Bondok *et al*. [3] on peach, El-Mahrouk *et al*. [4] on *Thevitia mereiifolia*, Roussas and Pontikis [5] on *Simmondsia chinensis* and Mazhar *et al*. [6] on *Sesbaina aegyptiaca* reported that, salinity caused reduction in seedling height, stem diameter, fresh and dry weight of stem and roots. The reduction due to increasing salinity levels also was reported by Asmaael [7] on *Casurina equisetifolia* and Mazhar *et al*. [6] on *Sesbaina aegyptiaca* declared that saline water decreased the various chemical constituents such as chlorophyll and N, P, K % but increased Na %. Gypsum is calcium sulfate dehydrate ($CaSO_4$ $2H_2O$) and is a mineral form the evaporate family [8].Gypsum effectively changes the structure and fertility of heavy clay soils, especially those that are heavily weathered or subject to intensive crop production. Gypsum also sodic by removing sodium form the soil and replacing it with calcium. Therefore, one can see improvement in clay soil structure and fertility and desalinization of sodium-rich soils, by using. Gypsum would also improve drainage, decrease acidity and eliminate soil salts [9].

MATERIALS AND METHODS

This study was carried out during 2010 – 2011 growing seasons in the greenhouse in Nubaria farm as well as laboratories of National Research Centre, Dokki, Giza, Egypt. The aim of this study was to investigate the effect of salinity levels and different rates of gypsum on

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vegetative growth and chemical constituents of *Khaya sengalensis* under calcareous soil conditions. Homogenous seedlings of African mahogany *Khaya sengalensis* (one -year-old 20-25cm height and 4-6 compound leaf/plant in average. The seedlings were introduction from Forestry Department, Agricultural Research Centre, Giza, Egypt. The seedlings were planted in April 2010 and 2011 seasons, respectively. Seedlings were planted in 30 cm plastic pots (one seedling/pot) filled with 10 kg calcareous soil. The physical and chemical properties of soil were determined according to Chapman and Pratt [10] and the following results were: 39.93 % coarse sand, 37 % fine sand, 9.85 % silt, 19.72 clay, pH 7.4, EC 8.4 dS/m, $CaCO_3$ 50.91 %, OM 0.19%, Ca 37.71, Mg 13.53, Na 12.8, K 1.66,C 142.30, HCO_3 3.35 and SO_4 2.31 meq/L.

The seedlings were fertilized with different rates of NPK (4,4 and 2 g/plant) of mixture containing (ammonium nitrate 33.5 % N + calcium super phosphate 15.5 % P_2O_5+Potassium sulphate 48-52% K_2O). Plants were fertilized three times during the two growing seasons. Gypsum was added to soil at the rates of 0, 20 and 40g/pot after 30 and 60 days from transplanting. Plants were irrigated during the first three weeks with tap water as necessary to prevent water stress and to keep the soil around field capacity. Four salinity levels were prepared (0 (tap water), 2000, 4000 and 6000 ppm) by adding a mixture of sodium chloride and calcium chloride at the ratio of 1:1 (w/w). The experiment included 12 treatments. Each treatment was replicated five times under three salinity levels, in addition to control and tow treatments of gypsum addition the control. After six months from transplanting the data were recorded: Plant height (cm), stem diameter (cm), leaves number/plant, root length (cm), fresh and dry weight of shoots (g), fresh and dry weight of roots, chlorophyll a, b and carotenoids content in the leaves (mg/g F.W.) were determined according to Saric *et al*. [11]. The proline concentration was determined using fresh material according to Bates *et al*. [12]. Calcium, sodium, nitrogen, phosphorus and potassium were determined according to the method described by Cottenie *et al*. [13].

Statistical Analysis: Data recorded on vegetative growth were statistically analyzed and separation of means was performed using the least significant different (L.S.D) test at the 5% level, as described by Snedecor and Cochran [14].

RESULTS AND DISCUSSION

Vegetative Growth: The results presented in Table 1 showed that the vegetative growth including plant height, stem diameter, leaves number/plant and root length were gradually decreased as salinity levels increased up to 6000ppm salinity in comparison to control treatment. The reduction in stem length, plant height or stem diameter might be due to that salinity which decreased each cell division, cell elongation and meristemic activity as indicated by Rug *et al*. [15] and Bolus *et al*. [16]. Also, under salinity conditions, the reduction in leaves number/plant might cause a disturbance in natural hormones leading to unbalanced growth of the plants. Bernstien *et al*. [17] found that, the decrease in root length due to salinity treatments might be attributed to the inhibition of water absorption, specific ions concentration in the saline media. On the other hand, the previous characters were gradually increased with increasing the rates of gypsum. Application of gypsum led to significant increase, the highest values was obtained due to gypsum at the rate of 40 g. The increments were 39.2, 27.6, 27.4 and 29.1% in plant height, stem diameter, leaves number/plant and root length, respectively, compared with control. These results were confirmed by Shtikan *et al*. [18] on Flax and Messenger *et al*. [19] on *Phytophthora cinnamomi*. Regarding the effect of the interaction between gypsum rates and salinity levels, applications at the rate of 40 g alone and without salinity treatments gave the highest increment in plant height, stem diameter, leaves number/plant and root length. The same trend was observed in fresh and dry weight of shoots and roots (Table 2). All vegetative growth parameters fresh and dry weight of shoots or roots were gradually decreased with increasing salinity in irrigation water up to high concentration. Moreover, the decrease in fresh and dry weight of all plant organs due to Cl^- or Na^+ accumulation in leaves might cause injury interfering with normal stomata closure causing excessive water loss and leaf injury symptoms like those of drought and CO_2 fixation might be reduced under high level of salinity which led to lower metabolism [5]. Such reduction was estimated by 25.8, 32.1, 38.8 and 37.6 % in fresh and dry weight of shoots and roots, respectively compared with untreated plants. In this respect, such reduction in fresh and dry weight of shoots might be due to the inhibition of water absorption, distribution of mineral balance, absorption and utilization under salinity conditions [6]. At the same

Table 1: Effect of salinity levels and different rates of gypsum and their interaction on plant height, stem diameter, leaves number/plant and root length of *Khaya sengalensis* (Means of two seasons 2010 & 2011).

Characters Treatments	Plant height (cm) Gypsum (g) (A)				Stem diameter (cm) Gypsum (g) (A)				Leaves number/plant Gypsum (g) (A)				Roots length (cm) Gypsum (g) (A)			
Salinity %(B)	0	20	40	Mean	0	20	40	Mean	0	20	40	Mean	0	20	40	Mean
0	62.3	73.6	85.9	73.9	0.86	0.99	1.15	1.0	39.7	46.3	51.5	45.8	34.4	37.6	42.7	38.2
2000	60.0	68.7	79.3	69.3	0.81	0.92	0.98	0.9	34.7	39.5	43.8	39.3	30.1	33.3	38.4	33.9
4000	53.5	62.3	73.6	63.1	0.73	0.81	0.90	0.8	31.6	35.6	39	35.4	26.4	29.6	34.1	30.0
6000	43.7	55.6	66.7	55.3	0.65	0.71	0.83	0.7	26.7	31.6	34.7	31.0	21.7	25.5	30.2	25.8
Mean	54.9	65.1	76.4	--	0.76	0.86	0.97	--	33.2	38.3	42.3	--	28.2	31.5	36.4	--
L.S.D.at 5%																
(A)	1.3				0.11				1.12				1.2			
(B)	1.5				0.15				1.5				1.4			
(A) × (B)	2.6				0.24				2.4				2.5			

Table 2: Effect of salinity levels and different rates of gypsum and their interaction on fresh and dry weights of shoots and roots of *Khaya sengalensis* (Means of two seasons 2010 & 2011).

Characters Treatments	Shoots fresh weight (g) Gypsum (g) (A)				Shoots dry weight (g) Gypsum (g) (A)				Roots fresh weight (g) Gypsum (g) (A)				Roots dry weight (g) Gypsum (g) (A)			
Salinity %(B)	0	20	40	Mean	0	20	40	Mean	0	20	40	Mean	0	20	40	Mean
0	79.8	87.5	95.7	87.7	23.3	26.1	30.2	26.5	35.3	39.6	46.6	40.5	15.6	17.7	20.1	17.8
2000	73.7	78.0	83.6	78.4	20.1	23.5	27.7	23.8	31.7	35.5	38.7	35.3	13.1	15.5	18.0	15.5
4000	63.5	71.6	76.4	71.2	16.8	19.0	23.4	19.7	25.4	28.8	33.6	29.3	11.3	12.6	14.6	12.8
6000	60.1	64.9	70.2	65.1	14.3	17.9	21.9	18.0	20.7	24.3	29.5	24.8	9.7	11.3	12.4	11.1
Mean	69.8	75.5	81.5	--	18.6	21.6	25.8	--	28.3	32.1	37.1	--	12.4	14.3	16.3	--
L.S.D.at 5%																
(A)	2.3				1.5				1.7				0.21			
(B)	3.2				2.1				2.4				0.36			
(A) × (B)	4.9				3.2				3.5				0.81			

Table 3: Effect of different rates of gypsum, different salinity levels and their interaction on chlorophyll (a),(b) and carotenoids in leaves of *Khaya sengalensis* seedlings (Means of two seasons 2010 & 2011).

Characters Treatments	Chlorophyll a (mg/g F.W) Gypsum (g) (A)				Chlorophyll b (mg/g F.W) Gypsum (g) (A)				Carotenoids (mg/g F.W) Gypsum (g) (A)			
Salinity %(B)	0	20	40	Mean	0	20	40	Mean	0	20	40	Mean
0	1.315	1.398	1.756	1.490	0.531	0.596	0.695	0.607	0.631	0.637	0.671	0.646
2000	1.212	1.256	1.631	1.366	0.426	0.493	0.543	0.497	0.617	0.621	0.637	0.625
4000	0.835	0.915	1.351	1.034	0.413	0.435	0.512	0.453	0.551	0.571	0.573	0.565
6000	0.619	0.815	0.975	0.803	0.367	0.388	0.437	0.397	0.513	0.519	0.535	0.522
Mean	0.995	1.096	1.428	--	0.442	0.478	0.547	--	0.578	0.587	0.604	--

time, the reduction in fresh and dry weight of root might be due to the reduction in water and minerals absorption and/or the reduction in upper ground growth under salinity condition [20]. On the contrary, the same Table showed that application of gypsum led to a significantly increased in fresh and dry weights of shoots and roots compared with control. The highest values were obtained by using 40g gypsum. These results were confirmed by Messenger *et al*. [19] and Shimizu *et al*. [21]. Regarding the effect of the interaction between gypsum applications at the rate of 40g alone and without salinity treatments gave the highest increment in fresh and dry weight of shoots and roots.

Chemical Composition: Photosynthetic Pigments Content: Results in Table 3 indicated that, increasing salinity levels decreased chlorophyll a, b and carotenoids content compared to control treatment. The lowest photosynthetic ability under salt stress condition was due to stomata closure, inhibition of chlorophyll synthesis, a decrease of carboxylase and due to high chlorophylls activity as reported by Patil [22] and Batanouny *et al*. [23]. These results are in agreement with those obtained by Mazher *et al*. [24] on *Taxadium disticum* and El-Khateeb *et al*. [25] on *Cebia pentandora* L. Regarding to gypsum application, the effect of various treatments on photosynthetic pigments content is presented in Table 3.

The increase in gypsum rate gradually increased chlorophyll a, b and carotenoids content. The increments estimated by 43.5, 23.8 and 4.50 %, respectively, compared with control treatment. Concerning, the interaction between gypsum rates and salinity levels, data in Table 3 indicated that application of 40g gypsum under non-saline treatment increased all photosynthetic pigments content compared to other treatments. These results are in agreement with those obtained by Linda [9] who mentioned that the adding gypsum to sandy or non-sodic soils improved pigments content.

Proline Content: Data presented in Table 4 showed that, irrigation with different salinity levels increased proline content in the leaves, stems and roots as compared to untreated plants. Ackerson [26] pointed that, cellular osmotic adjustment occurs in response to stress via an active or passive accumulation of salutes. It has been assumed that salt stress enhanced the production of proline, which causes osmotic adjustment [27]. The response of different plants to salt stress depends on the degree of their tolerance and on type, level and duration of osmotic substrate as reported by Afiah *et al*. [28] and Kwon *et al*. [29]. Concerning, the application of gypsum, it can be noticed that, increasing gypsum rates decrease proline content in the leaves, stems and roots (Table 4). However, gypsum application at zero rates in addition of 6000 ppm salinity level increased the proline content in the leaves, stems and roots compared with other treatments. Similar results were obtained by Linda [9].

Calcium and Sodium Percentages: The results of calcium and sodium percentage are presented in Table 5. Calcium and sodium percentage under salinity conditions were increased compared to control. These results run parallel with those obtained by Farahat [30] *on Scinus molle* L. *Myoprum acumination* and El –Etantawy *et al*. [31] on *Eucalyptus camoldulensis*. The increase in calcium and sodium concentrations in plant with salinity may be a result of the ability of plant to use Ca^{++} and Na^{+} maintain an adequate osmotic potential gradient between the plant tissues and external solution [32]. On the contrary, calcium and sodium percentage was influenced by gypsum treatments (Table 5). It can be concluded that, increasing gypsum rates increased calcium content, while decreased sodium percentage. Application of 40g gypsum and 6000 ppm salinity gave the highest values of calcium percentage. Whereas, the highest values of sodium percentage were obtained from the plants treating with salinity 6000 ppm without gypsum. These results are in accordance with those obtained by Linda [9].

Minerals Content: Data presented in Table 6 indicated that increasing salinity levels up to 6000 ppm reduced the percentages of N, P and K in the two growing seasons. These results are in agreement with those reported by Mazher *et al*. [6] on *Sesbania aegyptiaca*. In this connection, Hanafy *et al*. [33] pointed out that salinization impaired N accumulation and incorporation into protein and raised total free amino acid accumulation in salinized plant. Also, it can be suggested that amino acids can act

Table 4: Effect of different rates of gypsum, different salinity levels and their interaction on proline in plants organs of *Khaya sengalensis* seedlings (Means of two seasons 2010 & 2011)

Characters Treatments	Proline (μmg⁻¹) in leaves Gypsum (g) (A)				Proline (μmg⁻¹) in stems Gypsum (g) (A)				Proline (μmg⁻¹) in roots Gypsum (g) (A)			
Salinity %(B)	0	20	40	Mean	0	20	40	Mean	0	20	40	Mean
0	6.81	5.12	3.02	4.98	7.12	6.51	6.11	6.58	8.31	7.03	6.12	7.15
2000	6.98	5.53	3.25	5.25	7.98	6.67	6.02	6.89	8.37	7.25	6.35	7.32
4000	8.31	6.11	3.76	6.06	9.31	7.75	7.21	8.09	9.76	8.12	7.37	8.42
6000	9.96	6.52	4.96	7.15	11.71	8.13	7.76	9.20	12.11	10.21	8.35	10.22
Mean	8.02	5.82	3.748	--	9.03	7.27	6.78	--	9.64	8.15	7.05	--

Table 5: Effect of different rates of gypsum, different salinity levels and their interaction on calcium and sodium percentage of *Khaya sengalensis* seedlings (Means of two seasons 2010 & 2011).

Characters Treatments	Calcium % Gypsum (g) (A)				Sodium % Gypsum (g) (A)			
Salinity %(B)	0	20	40	Mean	0	20	40	Mean
0	1.76	1.92	2.12	1.93	2.35	2.13	1.83	2.10
2000	2.02	2.16	2.32	2.17	2.53	2.35	2.11	2.33
4000	2.14	2.26	2.39	2.26	2.61	2.46	2.35	2.47
6000	2.21	2.35	2.54	2.37	2.69	2.55	2.45	2.56
Mean	2.03	2.17	2.34	--	2.55	2.37	2.19	--

Table 6: Effect of different rates of gypsum, different salinity levels and their interaction on nitrogen, phosphorus and potassium percentage of *Khaya sengalensis* seedlings (Means of two seasons 2010 & 2011).

Characters	Nitrogen %				Phosphorus %				Potassium %			
Treatments	Gypsum (g) (A)				Gypsum (g) (A)				Gypsum (g) (A)			
Salinity %(B)	0	20	40	Mean	0	20	40	Mean	0	20	40	Mean
0	1.63	1.85	2.11	1.86	1.31	1.42	1.51	1.41	0.88	0.95	1.07	0.97
2000	1.52	1.70	1.86	1.69	1.23	1.29	1.38	1.30	0.81	0.86	0.94	0.87
4000	1.36	1.55	1.69	1.53	1.16	1.23	1.29	1.23	0.70	0.77	0.83	0.77
6000	1.22	1.41	1.54	1.39	0.98	1.07	1.12	1.06	0.65	0.71	0.78	0.71
Mean	1.43	1.63	1.80	--	1.17	1.25	1.33	--	0.76	0.82	0.91	--

as components of salt tolerance mechanism and build up a favoutable osmotic potential inside the cell in order to combat the effect of which replaced nitrate in the vacuoles. Furthermore, the reduction in P uptake under saline condition could be explained on the fact that Na salt raised the pH of the soil, which in turn reduced the availability of P to the plant [34]. In this context, Gemea *et al*. [35] found an increase in Na concentration and a decrease in K concentration with salinity, these results may be due to a possible antagonism between K and Na. Regarding to gypsum application, data in Table 6 indicated that, increasing gypsum rates gradually increased N, P and K percentages. Application of 40g under non-saline treatment (tap water) increased N, P and K concentrations compared to other treatments. Similar results were obtained by Khare *et al*. [36]. Also Gaballah and Abu-Leilah [20] pointed out that, gypsum application at different rates increased the percentage of N, P and K.

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