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Growth Performance of Beach Bean (*Canavalia maritima* Thouars) on Three Soil Types Irrigated with Saline Water

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Author's contribution

This whole work was carried out by the author OK.

Original Research Article

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ABSTRACT

Beach bean (*Canavalia maritima* Thouars) is a wild legume distributed exclusively on coastal sand dunes, with potential of being domesticated for its nutritional attributes and utility in agriculture. A pot experiment was conducted to investigate its seedling performance under sand, loam and clay soils irrigated with 0 (control), 25, 50, 100, 150 and 200 mM NaCl saline water. In sand, mortality occurred only at 200 mM with 70% survival. Survival reduced at 150 and 200 mM to 80.48 and 56.34% respectively in loam. In clay, 61.8 and 43.14% plants survived at 100 and 150 mM while no plants survived at 200 mM. Growth parameters including number of nodes, internode length, plant height, number of leaves and branches, root length, root number and relative growth rate increased significantly (P=0.05) at 25-150 and 25-100 mM NaCl in sand and loam respectively, but decreased significantly (P=0.05) at higher concentrations, compared to the control. Fresh and dry mass of plant parts and total biomass in sand and loam followed similar trends with the growth parameters. All the variables decreased significantly (P=0.05) in clay with increasing concentration of saline water. Stem girth increased while leaf area and leaf total chlorophyll decreased significantly (P=0.05) in all the soil types irrigated with saline water. Root/shoot ratio also increased but was significant (P=0.05) only in sand. Salinity induced leaf and stem succulence, led to a significant (P=0.05) reduction in pre-dawn xylem water potential and caused accumulation of Na^+ and Cl^- in the plant tissues. *Canavalia maritima* can be propagated in sand and

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loam soils, with optimal growth when irrigated with saline water containing 25-150 mM and 25-100mM NaCl respectively.

Keywords: Beach bean; wild legume; domestication; salinity; soil types.

1. INTRODUCTION

Coastal sand dunes are ecologically important as they provide niches for a variety of distinct flora, fauna and microbiota. *Canavalia maritima* (beach bean) is a pioneer plant species widely distributed exclusively on coastal sand dunes along seashores in the tropical areas all over the world [1-2]. It is a trailing, herbaceous vine that forms mats of foliage. Stems reach a length of more than 6 m and 2.5 cm in thickness. Each compound leaf is made up of three leaflets 5.1–7.6 cm in diameter. The flowers are purplish pink and 5.1 cm long. The flat pods are 10.2–15.2 cm long and become prominently ridged as they mature [1]. The coastal sand dunes of the Southwest coast of Nigeria are rich niches for this under-exploited legume. This wild legume is more attractive due to its in-built traits such as fast growth, tolerance to adverse environmental conditions and resistance to diseases and pests [2]. *Commelina maritima* is an important plant species that is used for different purposes. It is a strand plant that forms mat and serves to stabilize soil and control soil erosion. The leaves of *C. maritima* are a potent alternative for other more popular smoking herbs already popping up in several popular smoke blends in many countries like the Gulf Coast of Mexico, following the ban on marijuana [3]. Mature seeds are roasted and used as a coffee substitute in the West Indies. An infusion can be made with the crushed roots and rubbed over the skin for rheumatism, general pain, skin disorders and cold [4]. Seeds of beach bean are consumed by both humans and animals and are an important source of dietary protein in West Africa [5].

Much research on coastal legumes has focused on their nutritional and chemical composition [5-8]. Raw *Canavalia* seeds possess adequate amount of proteins (31.2–35.5%), which is one of the desirable traits essential to combat poor nutrition. It was reported that animal proteins tend to possess high fat and their consumption should be reduced in favour of legumes such as *Canavalia* maritima, as the fat content is low [8]. The fiber content of raw seeds of *Canavalia* ranges between 1.7 and 10.2%, which is essential as it regulates digestion, detoxifies and normalizes bowel function, reduces blood cholesterol and prevents colon cancer [9]. Carbohydrates of raw seeds of *Canavalia* are 50.5–61.4% and easily provide the energy required for oxidative metabolism. Protein, fibre, ash and energy of *Canavalia* seeds were higher than that of wheat [3]. Proteins of *Canavalia* seeds were lower than those in soybean only by 5%, indicating their richness next to soybean [3]. The essential amino acids (EAA) of the raw seeds surpassed FAO/WHO recommended pattern [10]. This under-explored plant is therefore an ideal plant for breeding programmes, mass cultivation, domestication and conservation.

Unfortunately, the exploration of *C. maritima* has depended solely on the wild [3-4,9]. It is not being cultivated because adequate information specific to its cultivability and domestication outside the beach is largely unavailable in the scientific literature. In view to meet the plant growing traditional knowledge, nutritional need and utility in agriculture, information pertaining to soil conditions for successful domestication is important. The objective of this study, therefore, was to determine the influence of varied concentrations of saline water irrigation of three soil types (loam, clay and sand) on the growth potential of *C. maritima* seedlings under greenhouse conditions. This was hoped top reveal the soil conditions for the optimal growth of the plant in an attempt to domesticate it outside the beach.

2. MATERIALS AND METHODS

2.1 Plant Material

Dried pods of beach bean, *Canavalia maritima* Thouars were obtained from coastal sand dunes at Arogbo Ijaw Seaside Beach, Ondo State, Nigeria (6º 11'N latitude, 4º 29'E Longitude). Seeds extracted from the pods were sun-dried and stored under dry condition.

2.2 Planting Soils

Three soil types: sand, loam and clay were used for planting. Loam soil was collected from Adekunle Ajasin University experimental farm, clay soil from a farmland near the University Botanical garden and sand from a building site in the University campus. Soil samples collected from each soil type were sieved to pass through a 2-mm sieve, shade-dried and analyzed for soil particle distribution, pH and organic content using the using the standard method of the Association of Official Analytical Chemists [11] in the Central Laboratory of The National Institute for Oil Palm Research (NIFOR), Nigeria. Leaching fraction (LF), defined as the proportion of applied water that leaches from a container after an irrigation effect, was calculated following the formula: LF = leachate volume/total irrigation volume x 100 [12].

2.3 Irrigation Saline Water

Concentrations of 25, 50, 100, 150 and 200 mM NaCl saline solutions were prepared in plastic kegs just before each treatment by dissolving weighed amount of commercially available salt in tap water to make the desired concentrations. One molar solution was prepared by dissolving 58.5 g (molar mass of NaCl) in water to make 1 litre. This quantity (58.5 g) was divided by 1000 to make 1 mM solution, and was subsequently multiplied by the desired value of mM and number of litres to be prepared, to account for the quantity of salt to be dissolved in water. Some quality parameters of the water were analyzed. Electrical conductivity was measured with conductivity meter while pH was by pH meter. Sodium adsorption ratio (SAR) was calculated using the commonly used formula [13]:

$$SAR = Na^{+} / \sqrt{\{(Ca^{2+} + Mg^{2+})/2\}}.$$

2.4 Experimental Set Up

The seeds were mechanically scarified to break dormancy, and sown in perforated plastic pots containing sand, loam and clay soils respectively. Prior to beginning salt treatments, five plants grown in the experimental site but not for the experiment were randomly selected for the determination of initial growth parameters. Plants in each soil type were irrigated with saline water at 0 (control), 25, 50, 100, 150 and 200 mM NaCl. Salt treatments commenced at 20 days after seedling emergence and were carried out 3 times/week from 9:00 to 10:00 on each day. Saline water treatment was initiated by gradual 25 mM increments at 2-day intervals to reach the maximum salinity level of 200 mM NaCl at 14 days, to prevent osmotic chock [14,15]. Irrigation was done at the root zone of the plant to ensure that the relative level of soil salinity would be the primary cause of any observed effect rather than combined effect of soil and air-borne (salt spray) salinity. Each pot was treated with 150 ml (volume enough to keep the soil moist) per treatment; thus each pot received 450 ml of NaCl solution per week. The treatments lasted for 12 weeks; thus, each pot received a total of 4.5 litres of saline solution before the experiment was terminated. Meanwhile, pots were saturated with water and allowed to drain once per week to flush out excess salt and prevent salt build-up in the soil above the treatment levels [14,15]. The experiment was carried out from January to April 2014 in the Greenhouse of Plant Science & Biotechnology Department, Adekunle Ajasin University, Akungba Akoko, Ondo State, Nigeria (7º37[1]N latitude, 5º 44'E Longitude and 100 m above the mean sea level). Survival, growth, water status and salt accumulation in the seeds of the plants were measured in the different soil types and salt treatment levels.

2.5 Survival and Growth Determination

Plant survival was monitored till the end of the experiment (12 weeks after treatment), which was equivalent to 118 days after seedling emergence. Shoot length, leaf area and collar diameter were measured with meter rule, leaf area meter (LI-COR 300 model) and digital vernier caliper (model 0-200 mm) respectively. The leaves and primary branches on individual plants were counted. At maturity, plants were destructively harvested and partitioned into leaves, stems, roots and pods. Monolith samples were washed on pinboards to measure root length, root number and number of nodules. Root/shoot ratio (root mass/shoot mass) and the relative growth rate (RGR) = (ln $mass_2$-ln $mass_1$)/ time were estimated, where $mass_1$ = biomass at the commencement of treatments while $mass_2$ = biomass at the end of the experiment and time = period interval between $mass_1$ and $mass_2$ in days.

2.6 Chlorophyll Content and Water Status Determination

Leaf total chlorophyll was extracted with 80% acetone and calculated with the formula: $(20.2 \times D_{645}+8.02 \times D_{663}) \times (50/1000) \times (100/5) \times ½$, where D=absorbance [16]. Two aspects of water status (moisture content and xylem water potential) were determined. Moisture content was calculated with the commonly used formula: [(fresh mass– dry mass)/dry mass] x100 while plant xylem water potential was measured with a plant moisture-stress instrument (PMS Instrument Co., Oregon, USA) on 5 randomly selected stems from each treatment between 06.00 and 07.00 am.

2.7 Phytochemical Analyses

Dry plant samples were assayed using the standard method of the Association of Official Analytical Chemists [11] in the Central Laboratory of The National Institute for Oil Palm Research (NIFOR), Nigeria. Na^+ was determined by flame photometry while Cl^- was by silver nitrate titration.

2.8 Experimental Design and Statistical Analysis

The experiment was completely randomized with 5 single-plant replicates per salinity treatment. Data on the treatment levels in each soil type were subjected to single factor ANOVA and means were separated with Tukey Honest Significant Difference (HSD) test using SPSS version 17.0 software (SPSS Inc., Chicago, IL, USA) at 95% level of significance.

3. RESULTS

3.1 Planting Soil and Irrigation Water Quality

The different soils differed in their properties. Loam had the highest organic content, followed by clay and the least was sand. Leaching fraction (LF) of the soil was highest in sand followed by loam, and the least was obtained in clay (Table 1). The electrical conductivity of the irrigation water increased with increasing salinity, and was higher than in control (Fig. 1). Saline water was also more alkaline than the control. Sodium adsorption rate (SAR) also increased with increasing salinity. EC of saline irrigation water ranged from 2.29-18.31, while SAR ranged from 2.5-30.12.

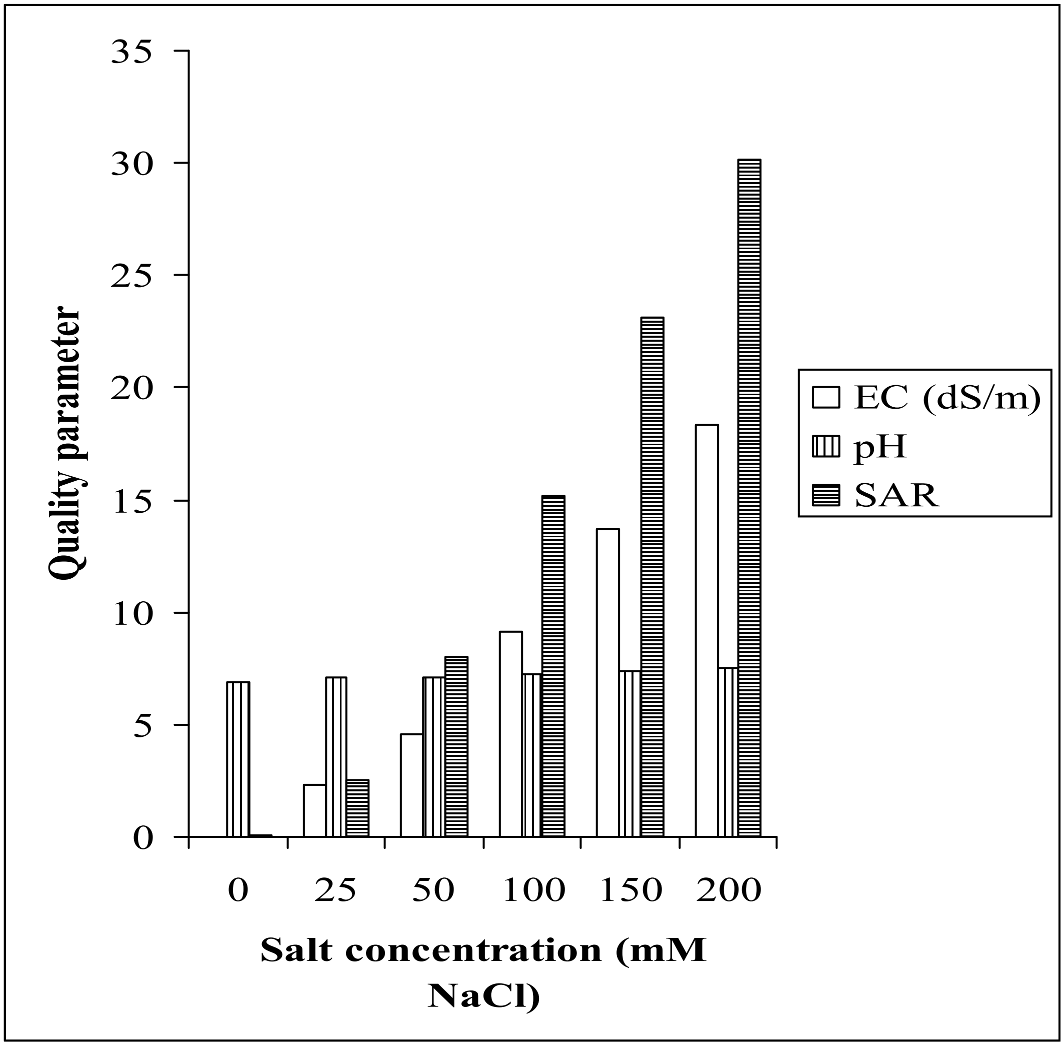

Fig. 1. Some quality parameters of saline irrigation water
EC=electrical conductivity, SAR=sodium adsorption ratio

Table 1. Particle distribution, pH, organic content and leaching fraction of the soils used for planting

	Sand	Loam	Clay
Sand (%)	96.50	26.50	26.50
Clay (%)	1.00	15.00	70.00
Silt (%)	2.50	58.50	3.50
pH (%)	7.36	7.54	7.34
Organic content (%)	0.60	1.63	0.89
Leaching fraction (%)	62.12	59.05	48.21

3.2 Survival and Growth

Soil salinity affected plant survival in all the soil types, but with varied degrees (Table 2). In sand, survival was not affected until at 200 mM (70% survival). Plant survival was reduced at 150 and 200 mM to 80.48 and 56.34 respectively in loam, while 61.8 and 43.14% survived at 100 and 150 mM respectively, with 100% mortality at 200 mM in clay. Growth parameters including number of nodes, internode length, plant height, number of leaves, number of branches, root length, root number and relative growth rate significantly (P=0.05) increased in sandy soil irrigated with saline water at 25-150 mM NaCl, but declined significantly (P=0.05) at higher concentrations as compared to the control (Table 2). The growth parameters were likewise favoured by loam soil irrigated with saline water, but at salt concentrations of 25-100 mM, while higher concentrations also significantly (P=0.05) suppressed growth. The growth stimulation at moderate salinity measured by these variables was higher in sand than in loam soil. For instance, plant height increased over the control by 0.57, 0.55, 0.56 and 0.44% at 25, 50, 100 and 150 mM respectively in sandy soil, but increased by 0.47, 0.31 and 0.15% at 25, 50 and 100 mM respectively in loam. Likewise, number of leaves increased over the control by 0.42, 0.46, 0.40 and 0.39% at 25, 50, 100 and 150 mM respectively in sand, but increased by 0.42, 0.46 and 0.26 at 25, 50 and 100 mM respectively in loam. In clay soil however, the variables decreased with increasing concentration of saline water, which significantly (P=0.05) differed from the control treatment. In all the soil types, values of stem girth were significantly (P=0.05) higher in plants irrigated with saline water than in those irrigated with non-saline water. Leaf area in all the soil types were reduced by saline irrigation. The highest leaf area reduction of 25.25 and 37.27% occurred at 200 mM in sand and loam respectively, while 55.07% reduction was obtained in clay at 150 mM. Data were not available in clay at 200 mM because plants did not survive. Fresh and dry mass of leaf, stem, root and shoot as well as total biomass increased in sandy soil irrigated with 25-150 mM NaCl water, but decreased significant (P=0.05) at higher concentrations (Table 3). Loam soil irrigated with saline water between 25-100 mM also increased the variables but lowered them at higher concentrations. Clay soil irrigated with saline water however lowered the values of the variables with increasing salt concentration. In sand, loam and clay soils, salinity increased root/shoot ratio values over the control, but one-way ANOVA showed that the increase was significant (P=0.05) only in sandy soil, when compared to the control (Table 3).

3.3 Leaf Total Chlorophyll and Water Status

Leaf total chlorophyll in all the soil types were reduced by saline irrigation; the highest reduction of 29.87 and 48.72% occurred at 200 mM in sand and loam respectively, while 49.35% reduction was obtained at 150 mM relative to the control treatment (Table 3). Relative to the control, salinity had no effect on root moisture content but significantly

(P=0.05) increased that of leaf and stem (Table 4). Plants responded to salinity stress in similar ways in all the soil types as pre-dawn plant xylem water potential was lower under saline irrigation than did control plants, and they significantly (P=0.05) differed from control (Fig. 2).

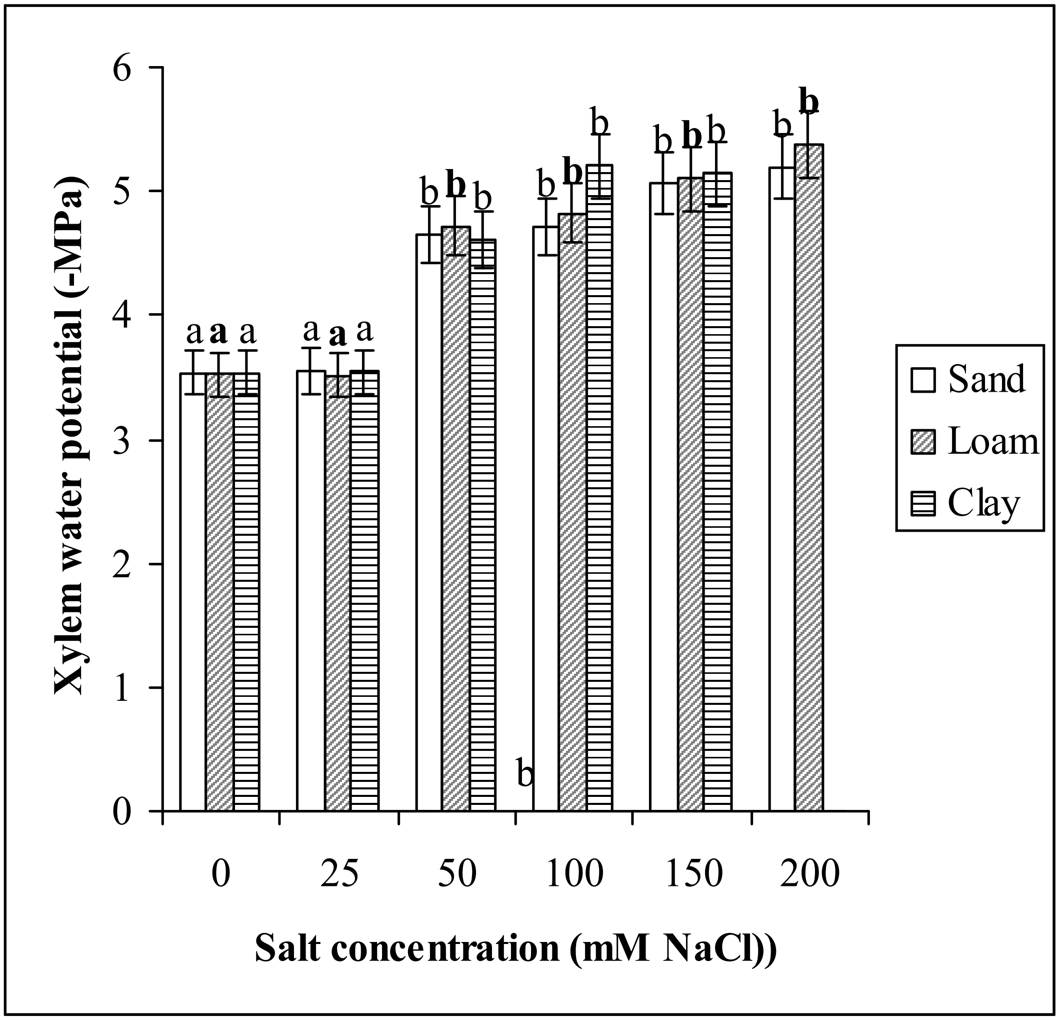

Fig. 2. Plant xylem water potential (-MPa) of *Canavalia maritima* on 3 soil types irrigated with different concentrations of saline water for 12 weeks

Each bar represents mean±standard error of 5 replicates. For each plant part, bars with the same letter(s) are not significantly different at P =0.05 (Turkey HSD)

3.4 Phytochemical Analysis

Irrespective of the soil type, soil salinity led to accumulation of Na^+ and Cl^- in the plant tissues, which were significantly (P=0.05) higher than in control treatments (Fig. 3).

Table 2. Percentage survival, leaf total chlorophyll and some growth parameters of *Canavalia maritima* on 3 soil types irrigated with different concentrations of saline water for 12 weeks

Growth parameter	Salt concentration (mM NaCl) in sand						Salt concentration (mM NaCl) in loam						Salt concentration (mM NaCl) in clay					
	0	25	50	100	150	200	0	25	50	100	150	200	0	25	50	100	150	200
Survival at harvest (%)	100	100	100	100	100	70	100	100	100	100	80.48	56.34	100	100	100	61.8	43.14	-
Number of nodes/plant	2.27^{b}	21.10^{a}	21.47^{a}	18.65^{a}	16.93^{a}	7.48^{c}	11.52^{b}	17.51^{a}	17.86^{a}	16.36^{a}	9.29^{c}	4.72^{c}	10.35^{a}	10.76^{a}	10.04^{a}	8.90^{ab}	5.49^{b}	-
Internode length (cm)	3.23^{b}	5.30^{a}	5.23^{a}	5.20^{a}	4.68^{a}	1.81^{c}	3.23^{b}	4.97^{a}	4.91^{a}	2.81^{c}	2.33^{c}	1.49^{cd}	2.18^{a}	2.27^{a}	1.85^{b}	1.57^{b}	1.31^{b}	-
Plant height (cm)	8.97^{b}	45.48^{a}	44.90^{a}	45.19^{a}	41.72^{a}	20.57^{c}	26.39^{b}	38.79^{a}	38.27^{a}	32.16^{a}	20.06^{c}	17.71^{c}	24.65^{a}	26.13^{a}	19.23^{ab}	14.30^{ab}	10.85^{c}	-
Stem girth (cm)	3.53^{a}	4.19^{a}	4.26^{a}	4.05^{a}	4.62^{a}	4.37^{a}	3.55	4.78^{a}	4.79^{a}	4.77^{a}	4.63^{a}	4.01^{a}	3.08^{a}	4.23^{b}	4.29^{b}	4.43^{b}	4.76^{b}	-
Leaf area (cm^2)	3.82^{a}	31.51^{a}	30.17^{a}	30.89^{a}	26.29^{b}	25.28^{b}	30.78^{b}	47.09^{a}	47.71^{a}	28.17^{a}	24.01^{a}	19.30^{c}	30.48^{a}	30.47^{a}	25.35^{a}	18.23^{bc}	13.39^{c}	-
Number of leaves/plant	4.97^{b}	21.26^{a}	21.86^{a}	20.96^{a}	20.81^{a}	8.83^{c}	14.21^{b}	20.18^{a}	20.75^{a}	17.89^{a}	9.80^{c}	8.38^{c}	10.34^{a}	10.34^{a}	9.00^{a}	6.10^{b}	5.17^{b}	-
Number of branches/plant	6.44^{b}	10.11^{a}	9.98^{a}	10.05^{a}	9.27^{a}	4.57^{c}	5.34^{b}	7.32^{a}	7.21^{a}	4.26^{b}	4.33^{b}	3.20^{bc}	4.11^{a}	4.36^{a}	3.78^{a}	2.55^{ab}	1.60^{b}	-
Number of roots/plant	5.65^{a}	17.12^{a}	17.14^{a}	17.08^{a}	16.96^{a}	16.32^{a}	15.20^{ab}	19.30^{a}	19.61^{a}	12.24^{ab}	14.74^{ab}	9.58^{c}	12.61^{a}	12.86^{a}	9.96^{ab}	6.18^{b}	4.41^{b}	-
Root length (cm)	4.93^{a}	25.89^{a}	25.39^{a}	24.14^{a}	26.15^{a}	23.96^{a}	21.84^{ab}	29.40^{a}	29.00^{a}	18.75^{b}	17.48^{b}	8.37^{c}	18.85^{a}	19.60^{a}	16.59^{a}	12.63^{ab}	10.18^{ab}	-
Relative growth rate (RGR) ($gg^{-1}d^{-1}$)	.061^{b}	0.10^{a}	0.10^{a}	0.09^{a}	0.09^{a}	0.05^{b}	0.06^{b}	0.09^{a}	0.09^{a}	0.04^{bc}	0.04^{bc}	0.02^{c}	0.057^{a}	0.06^{a}	0.05^{a}	0.02^{b}	0.02^{b}	-
Leaf total chlorophyll (LTC) (mgg^{-1} fresh leaves)	1.54^{a}	1.49^{b}	1.47^{b}	1.48^{b}	1.38^{b}	1.08^{bc}	1.56^{a}	1.57^{a}	1.54^{a}	1.12^{ab}	0.86^{c}	0.80^{c}	1.54^{a}	1.55^{a}	1.54^{a}	1.06^{ab}	0.78^{b}	-

For each parameter, means with the same letter(s) in superscript in the same row are not significantly different at P =0.05 (Tukey HSD). In the result, – represents where data could not be taken due to total mortality

Table 3. Biomass accumulation of *Canavalia maritima* on 3 soil types irrigated with different concentrations of saline water for 12 weeks

	Salt concentration (mM NaCl) in sand						Salt concentration (mM NaCl) in loam						Salt concentration (mM NaCl) in clay					
	0	25	50	100	150	200	0	25	50	100	150	200	0	25	50	100	150	200
Leaf fresh mass	7.45^{b}	10.95^{a}	11.10^{a}	10.65^{a}	9.76^{a}	4.99^{c}	7.04^{b}	10.84^{a}	10.70^{a}	10.49^{a}	5.07^{c}	3.24^{bc}	5..02^{a}	5.32^{a}	3.92^{b}	2.91^{bc}	2.21^{bc}	-
Stem fresh mass	5.98^{b}	8.49^{a}	8.73^{a}	8.37^{a}	8.31^{a}	3.53^{c}	5.13^{b}	6.91^{a}	6.92^{a}	6.89^{a}	3.80^{c}	2.91^{c}	3.47^{a}	3.71^{a}	3.09^{a}	2.22^{bc}	1.63^{c}	-
Root fresh mass	4.88^{b}	8.00^{a}	7.91^{a}	7.86^{a}	7.08^{a}	2.73^{bc}	4.12^{b}	6.30^{a}	6.39^{a}	6.18^{a}	3.21^{c}	2.58^{bc}	3.11^{a}	3.11^{a}	2.71^{bc}	1.83^{c}	1.56^{c}	-
Shoot fresh mass	13.43^{b}	19.44^{a}	19.83^{a}	19.02^{a}	18.07^{a}	8.52^{c}	12.17^{b}	17.75^{a}	17.62^{a}	17.38^{a}	8.87^{c}	6.15^{c}	8.49^{a}	9.03^{a}	7.01^{a}	5.13^{ab}	3.84^{b}	-
Leaf dry mass	3.53^{b}	4.37^{a}	4.31^{a}	4.02^{a}	3.92^{ab}	2.06^{c}	3.43^{b}	4.62^{a}	4.46^{a}	4.32^{a}	2.31^{bc}	1.49^{c}	2.43^{a}	2.32^{a}	1.65^{b}	1.27^{b}	0.98^{c}	-
Stem dry mass	2.90^{b}	4.71^{a}	4.55^{a}	4.58^{a}	4.18^{a}	1.62^{c}	3.05^{b}	4.11^{a}	4.06^{a}	4.04^{a}	2.23^{bc}	1.70^{c}	2.05^{a}	2.20^{a}	1.83^{b}	1.32^{b}	0.96^{bc}	-
Root dry mass	2.85^{b}	4.65^{a}	4.68^{a}	4.62^{a}	4.16^{a}	1.62^{c}	2.45^{ab}	3.74^{a}	3.79^{a}	3.64^{a}	1.92^{c}	1.52^{c}	1.83^{a}	1.84^{a}	1.61^{a}	1.08^{a}	0.92^{b}	-
Shoot dry mass	6.43^{b}	9.07^{a}	8.86^{a}	8.60^{a}	8.10^{a}	3.68^{c}	6.48^{b}	8.72^{a}	8.52^{a}	8.36^{a}	4.54^{c}	3.19^{c}	4.48^{a}	4.52^{a}	3.49^{a}	2.59^{b}	1.94^{c}	
Total biomass	9.28^{b}	13.73^{a}	13.54^{a}	13.22^{a}	12.26^{a}	5.30^{c}	8.93^{b}	12.47^{a}	12.30^{a}	12.00^{a}	6.46^{bc}	4.71^{bc}	6.31^{a}	6.36^{a}	5.10^{a}	3.67^{bc}	2.86^{bc}	-
Root/shoot ratio	0.44^{b}	0.51^{a}	0.53^{a}	0.54^{a}	0.51^{a}	0.45^{b}	0.38	0.43^{a}	0.44^{a}	0.44^{a}	0.42^{a}	0.48^{a}	0.41^{a}	0.43^{a}	0.46^{a}	0.42^{a}	0.47^{a}	-

For each parameter, means with the same letter(s) in superscript in the same row are not significantly different at P =0.05 (Tukey HSD). In the result, – represents where data could not be taken due to total mortality

Table 4. Relative moisture content of leaf, stem and root of *Canavalia maritima* on 3 soil types irrigated with different concentrations of saline water for 12 weeks

Plant part	Salt concentration (mM NaCl) in sand						Salt concentration (mM NaCl) in loam						Salt concentration (mM NaCl) in clay					
	0	25	50	100	150	200	0	25	50	100	150	200	0	25	50	100	150	200
Leaf	52.61^{b}	60.12^{a}	61.2^{a}	62.23^{a}	59.87^{a}	58.74^{a}	51.24^{b}	57.42^{a}	58.35^{a}	58.85^{a}	54.46^{a}	54.07^{a}	51.57^{b}	56.45^{a}	57.83^{a}	56.34^{a}	55.67^{a}	-
Stem	41.51^{bc}	44.57^{bc}	47.87^{b}	45.28^{b}	49.68^{b}	54.05^{a}	40.57^{a}	42.56^{ab}	42.34^{ab}	42.36^{ab}	43.28^{ab}	42.51^{ab}	40.88^{a}	43.58^{ab}	42.68^{ab}	42.67^{ab}	42.03^{ab}	-
Root	41.67^{a}	41.84^{a}	40.82^{a}	41.19^{a}	41.16^{a}	40.62^{a}	40.57^{a}	40.57^{a}	40.74^{a}	41.07^{a}	40.22^{a}	41.02^{a}	41.21^{a}	40.78^{a}	40.45^{a}	40.86^{a}	41.01^{a}	-

For each parameter, means with the same letter(s) in superscript in the same row are not significantly different at P =0.05 (Tukey HSD). In the result, – represents where data could not be taken due to total mortality

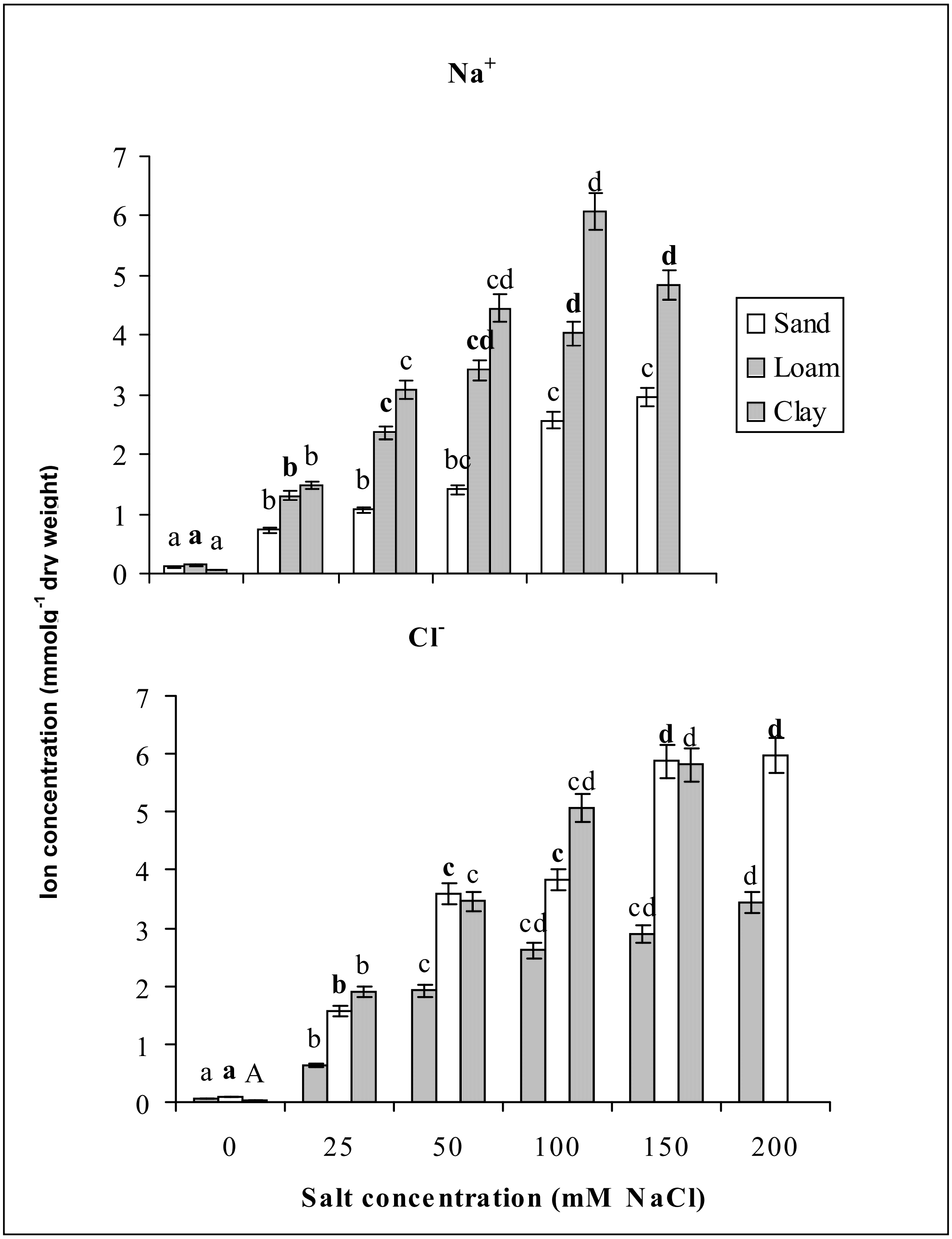

Fig. 3. Na^+ and Cl^- accumulation in leaf, stem and root of *Canavalia maritima* on 3 soil types irrigated with different concentrations of saline water for 12 weeks

Each bar represents mean ± standard error of 3 replicates. For each plant part, bars with the same letter(s) are not significantly different at P = 0.05 (Turkey HSD)

4. DISCUSSION

Plants grown in sandy and loamy soils at low salinity significantly considerably enhanced growth at low and moderate salinity but growth was however better in sand than loam. This can be attributed to the variations in soil conditions [17-19]. Leaching fraction of soil has a significant role to play in the retention of ions supplied by water of irrigation [12]. Sandy soil has the largest particles among the different soil types, thus the particles have large spaces between them, the soil is porous, leaching rate is high and salt does not accumulate in the root zone due to high leaching fraction. Loamy soil retains water longer than sandy soil, and because of its lower leaching fraction, the soil drains poorly and retains higher level of salt. On the other hand, due to the tiny size of clay particles and its tendency to settle together, little air passes through its spaces, it drains slowly and has relatively low leaching fraction. Because of low leaching fraction, salt is accumulated in soil, which becomes available to the plants at a toxic level [12,20]. Generally, most exotic plant species with either taproot or fibrous root systems grow poorly on clay soil, probably due to their sensitivity to waterlogging conditions [21].

Also, soil water salinity can affect soil physical properties by causing fine particles to bind together into aggregates (flocculation), which is beneficial in terms of soil aeration, root penetration, and root growth [13]. Although increasing soil solution salinity has a positive effect on soil aggregation and stabilization, at high levels salinity can have negative and potentially lethal effects on plants. All these accounted for growth reduction obtained at high salinity in sand and loam soils. The major implications associated with decreased infiltration due to effect of sodicity (SAR) include reduced plant available water and increased runoff and soil erosion [13]. The effects of sodicity and its dispersive effects influence whether or not soil will stay aggregated or become dispersed under various salinity levels. The forces that bind clay particles together are disrupted when too many large sodium ions come between them. When this separation occurs, the clay particles expand, causing swelling and soil dispersion. Soil dispersion causes clay particles to plug soil pores, resulting in reduced soil permeability [13]. Thus, high SAR at high salinity level was responsible for its negative effect on growth. The variations in the properties of the soil were responsible for the differences observed in the responses of the test plant irrigated with saline water under the different soil types.

4.1 Survival and Growth

Reduced plant survival in this study agrees with the previous research that revealed that rye (*Secale cereale*) growth was reduced in the presence of salt, but 110 mmol/L NaCl was the highest concentration allowing its growth to the three-leaf stage [22]. When the percentage of dead leaves in *Hordeum* species reached about 20% of the total, the rate of leaf production slowed down dramatically and some plants died [23]. *Blutaparon portulacoides* seedlings likewise showed a gradual decrease in survival under salinity stress [24].

Growth stimulation in this study conforms with *Atriplex nummularia* growth, which was optimal at 100 to 200 mM NaCl [24]. *Atriplex* spp. showed a stimulation of growth at NaCl concentrations that are inhibitory to the growth of non-halophytes [25]. Growth stimulation at low saline conditions was reported on several strandline species: *Atriplex glabriuscula*, *Cakile maritima* and *Salsola kali* [26]. Demonstration of growth stimulation of a grass, *Sporobolus virginicus* by NaCl qualifies it as euhalophytic according to the halophyte classification [27]. *Atriplex infata* and *A. nummularia* growth was greater at 600 mM NaCl than in nutrient controls [28]. Likewise, *Sporobolus virginicus*, accumulation of aboveground dry biomass was 4 times greater and tiller production was about 23 times greater in plants grown at 125 mmol/L NaCl than in those grown at 5 mmol/L [29]. They stated that 100–150 mmol/L NaCl was optimal for growth of *S. virginicus*. Similarly, optimum growth in *Rhizophora mucronata* was obtained at 50% seawater and declined with further increases in salinity [30]. *Cakile maritima* also exhibited a typical halophytic behaviour, requiring the presence of a moderate salt concentration (50 to 100 mM NaCl) to express its maximal growth potentialities, but growth activity was maintained up to 500 mM NaCl [31]. Also, *Kandelia cordel* seedlings grew at salinities up to 260 mM with optimal growth at 85 mM but growth was inhibited by salinities greater than 340 mM [32]. They showed an extremely efficient system for the re-distribution of photosynthates from the source (shoot) to the sink (root), thus enabling aggressive root production under saline conditions. The immediate response of salt stress is reduction in the rate of leaf surface expansion leading to cessation of expansion as salt concentration increases [33]. Leaf area reduction might serve as an adaptive mechanism for salt tolerance in plants by providing reduced area for transpiration water loss. Increase in stem diameter in the presence of salt in the soil concurs with the findings that stem diameter was higher at 0.4% NaCl than control in *Tagetes patula* and *Ageratum mexicanum*, which was an evidence of adaptation for ion dilution [30,34].

4.2 Leaf Total Chlorophyll and Water Status

Salinity disrupts water balance in plants, and only the tolerant species can adjust osmotically through reduced xylem water potential [14-15,35]. Increased succulence in the presence of salt is an adaptive mechanism for ion dilution [30,34]. Salinity has been reported to result in foliage-induced damage by Na^+ and Cl^- ions leading to reduction in chlorophyll content. Salinity usually results in foliage induced fragmented cuticles, disrupted stomata, collapsed cell walls, coarsely granulated cytoplasm, disintegrated chloroplasts and nuclei, and disorganized phloem in plants [35]. Decrease in certain elements such as Mg^{2+} and $Fe^{2+,}$ which are part of chlorophyll ultrastructure might have led to a decline in chlorophyll formation. Besides, reduction in total leaf chlorophyll was largely due to damage induced by salt, caused by Na^+ and Cl^- ions toxicity [35]. Growth reduction in *Rhizophora stylosa* under high salinity was attributed to reduced photosynthetic assimilation and increased leaf loss [36]. The reduction in the whole-plant photosynthesis under high salinity was accompanied by both reduced photosynthetic potential and smaller total leaf area. The integrated reduction of the number of leaves and components of the leaf under different soil types eventually resulted in poor overall plant biomass, since the leaf is the major source of carbohydrates required for growth.

4.3 Phytochemical Analysis

Na^+ and Cl^- ions accounted for almost half of the osmotic adjustment in *Triticum dicoccum farrum* (Triticum df) and Triticale T300, and up to 90 percent in rye, *Secale cereale* [22]. Thus, Na^+ and Cl^- accumulation contributed to the osmotic adjustment of *C. maritima* under salt stress. Halophytes are characterized by their capacity to adjust tissue water potential to a level that is more negative than that of the soil in which they grow [14-15,30].

5. CONCLUSION

Canavalia maritima requires sand and loam soils irrigated with water containing salinities of 25-150 mM and 25-100 mM NaCl respectively, to express its maximum growth potentials in number of nodes, internode length, plant height, number of leaves and branches, root length, root number, relative growth rate, fresh and dry mass of plant parts as well as biomass. Its domestication is however better in sandy soil conditions similar to its habitat.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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