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GROWTH AND PHYSIOLOGICAL ATTRIBUTES OF *Ceiba pentandra* (L.) GAERTN. SEEDS AND SEEDLINGS UNDER SALT STRESS

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ABSTRACT

Establishing salt tolerant multipurpose tree plantations on saline soils may improve fertility status of the soil and uplift the status of farmers in semiarid environments. Because of wide range of uses of *Ceiba pentandra* (L.) Gaertn**.**, it has been cultivated for a long time, but issues related to suitability on salinity are less documented. Thus, to study the salt tolerance of *Ceiba pentandra*, the effect of salinity on germination, vigour index of germinated seedlings, growth, chlorophyll stability index (CSI) and ionic uptake of seedlings were examined. The seed germination, morphological and physiological parameters were slightly affected by 3 to 9 dSm^{-1} salinity concentration, but were markedly reduced on the 12 and 15 dsm^{-1} salinity concentrations. Higher salinity concentration shows lower chlorophyll stability index this leads to decrease photosynthetic rate and less dry matter production. Rising of salinity in soil solution increased ionic concentration in the leaf tissue leading to reduction in leaf size leaf chlorosis, scorching of leaves, withering and finally death of seedling was occurred. However the *Ceiba pentanda* seeds germinate and tolerate the salinity variant of up to $9dSm^{-1}$, which can be regarded as a LD_{50} value for severe damages and classified as moderately saline tolerant multipurpose tree species in seedling stage.

Keywords: trees, multipurpose, salt, tolerance, CSI, seeds, germination, growth, salinity, ionic concentration.

INTRODUCTION

Soil salinization is a wide spread and acute problem in arid and semi arid regions of the world. Throughout the world, 100 million hectares of the arable land is adversely affected by high salt concentration [1], which reduces crop growth and yield. In India, the area with potential saline soil is about 20 million ha, and about 7 million ha are severely affected by salinity [2]. In the semiarid environment of Tamilnadu, India, the soil salinity affects 8-12 percent of arable lands. The factor of high evaporation, transpiration and concentration of salts on soil surface coupled with greater inherent sensitivity to salt are responsible for most emergence failures on saline soils. Afforestation of these salt affected lands requires careful selection of tree species that tolerate salts [3]. There is evidence that high concentrations of salts have detrimental effects on retardation of germination and growth of seedlings at high salinity and differ in their sensitivity or tolerance to salts [4].

In semiarid regions of Tamilnadu, India, *Ceiba pentandra* (L.) Gaertn**.**, (Bombacaceae) is one of the dominant tall, deciduous multipurpose tree generally propagated through seeds, and can also be raised by cuttings. The fruit is collected for the valuable kapok floss and used for stuffing pillows, mattresses and cushions. Due to its water repellent and buoyant, making it ideal for life jackets, lifeboats and other naval safety apparatus. It is an excellent material for insulating iceboxes, refrigerators, cold-storage plants, offices, theatres and aeroplanes. It is a good sound absorber and is widely used for acoustic insulation; it is indispensable in hospitals, since mattresses can be dry sterilized without losing original quality. The flowers are important honey source for beekeepers. The seed contains 20-25 percent non-drying oil, used as a lubricant and in soap manufacturing. The pressed cake is used as cattle feed containing about 26 percent protein. The wood is very light, with specific gravity of 0.25 g cc^{-1} and is used for preparation of plywood, packaging, lumber core stock, light construction, pulp and paper products, match splint, canoes and rafts, etc. Because of its wide range of uses, it has been cultivated in the boundaries of farmlands and social forestry plantations [5]. However, the potential of this tree species to grow and survive in the saline environment is not well known. Therefore, the present investigation was carried out to understand the adequate features of *Ceiba pentandra*, which allow it to grow and survive in saline semiarid environments.

MATERIALS AND METHODS

The present study was carried out at Annamalai University Experimental Farm (11^0 23' N Latitude and 79^0 41' E Longitude with an altitude of + 5.71 m MSL) in Tamilnadu, India. The seeds of *Ceiba pentandra* were collected in May 2003 from a plus tree in the experimental farm. To study the emergence and growth of seedlings, the top 5cm layer of soil was collected from the near by field. The soil was sandy clay loam in texture and the organic content was 0.29 with the pH of 6.9 and ECe 1.8. Soil fertility was low in available nitrogen (123 kg ha^{-1}), medium in available P_2O_5 (12 kg ha^{-1}) and high in K_2O (285 kg ha^{-1}).

Seedling emergence

Surface soil was collected, air dried and well powdered and six lots of soil of 10kg were separately spread over polyethylene sheets. The quantity of salts needed to bring the soil to the given salinity level (ECe) were prepared by according to the methods described by Jackson [6]. The calculated amounts of NaCl, $CaCl_2$ and $MgSO_4$ in the ratio of 5:3:2 was thoroughly mixed with soil to gives an electrical conductivity of 3, 6, 9, 12 and 15 dSm^{-1} in the five lots of soil, respectively. There was no addition of salt to one lot of soil, which was maintained as control. Six germination trays for each level of salinity and control were filled with 2kg of soil. After the addition of salt, the soil was subjected to the wetting and drying cycles by using tap water (pH 6.8) for one week to attain proper equilibrium. Soils were then racked using fingers and seeds were sown at a depth of 2cm on 15th July 2003. Immediately after sowing, soils were watered and there after watering were carried out on alternate days. Emergence of seedlings was recorded every day and the seedling vigour index was worked out the method given by Bhattacharya *et al*. [7].

Seedling growth

Second set of experiment was conducted to study the effects of salinity on growth of seedlings. For these three months old well grown seedlings were selected for uniformity according to leaf number and plant height and transferred to 16cm x 30cm x 300 gauge polyethylene bag filled with 2.5kg of salt added soil. The polythene containers were kept in plastic dishes to enable collection of leachates caused by watering which are retuned to the seedlings. The watering was done in alternate days and the seedlings were organized in a randomized block design with ten plants per treatment. The experiment was conducted over a period of 90 days and morphological characteristics of each seedling were recorded.

Physiological measurements

Plants were harvested after 90 days and dry matter production was determined after oven drying the samples at 80^{o} C to a constant mass. Chlorophyll Stability Index (CSI) in the leaf was estimated using a spectrometer following the method of Kaloyereas [8]. Leaves are analyzed for Sodium (Na), Potassium (K), Calcium (Ca), Chloride (Cl) and Magnesium (Mg) content. Na, K, Ca and Mg concentration was determined from dry, powdered plant tissue digestion with HNO_3 and $HClO_4$ using an atomic absorption spectrophotometer and Cl was determined by silver ion filtration.

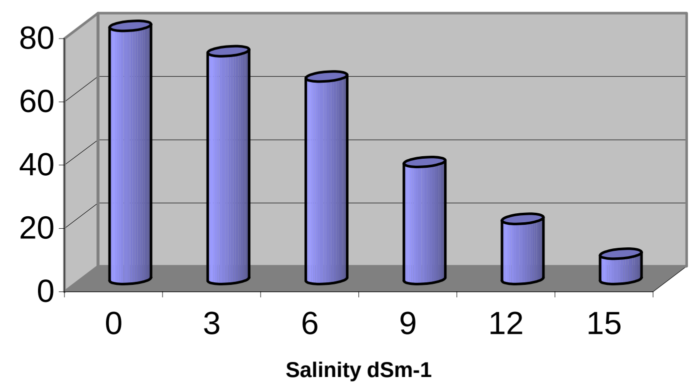
The experiment was laid out in randomized block design with 5 replications. The data's were subjected to analysis of variance and significant differences between treatment means and control were compared by the least significant differences test (LSDT) (P = 0.05).

RESULTS AND DISCUSSION

Effect of salt concentration on seedling emergence

The results of the effect of salinity levels on the percentage of germinated seeds of *Ceiba pentandra* are shown in Figure-1. Seedlings began to emerge 9 days after sowing and 80 percent seed germination was obtained over a period of 14 days under control treatment. Seedling emergence was occupied a period of 9, 9, 10, 14 and 17 days in soils with salinities of 3, 6, 9, 12 and 15 dSm^{-1} and percentage seed germination was 72, 64, 47, 29 and 08, respectively. There was a significant reduction in germination of seeds with increasing salt stress when compared to control. The seed germination of salt tolerant *Ceiba pentandra* reduced to less than 50 percent when the concentration exceeding 9 dSm^{-1}. As a result, this plant species is moderately salt tolerant at seed germination phase. Salinity stress could operate by inactivating some hormone or enzymes systems and moreover membrane permeability may be affected in the seeds leading to a loss of germinability [9]. It was observed that seeds began to shrink within few days in the soil with high salt concentration. It can be attributed due to decreasing osmotic potential of the soil solution with increasing concentration of salt and inhibition of the translocation of hydrolysis products leads to reduction in protein hydration [10]. High salt concentrations inhibit enzymes by impeding the balance of forces controlling the protein structure [11].

Fig 1: Germination percentage of *Ceiba pentandra* seeds as influenced by various salinity levels



Effect of salinisation on vigour index of the *Ceiba pentandra* seedlings

A perusal of data on vigour index (Table-1) would clearly indicate that salinity concentration increment reduce the vigour index of the *Ceiba pentandra* seedlings. The reduction in shoot and root elongation resulted low vigour index value. Growth of plants under moderate salts stress was affected primarily a reduction in cell elongation and stop or slow down the root development [12]. In early stages plants are subjected to higher salt concentration show a reduction in shoot, root elongation and influence all aspect of plant metabolism [13].

Table-1. Seedling vigour index, survival and growth attribute of *Ceiba pentandra* seedlings as influenced by various salinity levels.

Salinity concentration (dSm^{-1})	**Seedling vigour index**	**Survival** (%)	**Pl. height increment** (cm)	**DMP** (g)	**Average leaf area** (cm^2)
0	1400.0	100	28.87	28.21	70.55
3	1245.6	100	24.22	23.68	62.52
6	883.2	85	19.67	18.42	49.00
9	618.0	56	16.50	14.52	42.81
12	304.0	35	05.47	08.59	26.37
15	059.2	10	03.63	06.87	19.89
LSD (P = 0.05)	-	17	3.40	0.39	4.60

Effect of salinisation on seedling survival percentage and morphological growth of *Ceiba pentandra*

The survival of *Ceiba pentandra* adversely affected due to increment in salinity concentrations. Up to 9 dSm^{-1} salinity concentrations, it recorded more than 50 percent survival rate, and there was no injury symptoms recorded. In the sixth week of the experiment, the chlorosis on mature leaves was observed in 12 and 15 dSm^{-1} treatment. At the end of the experiment chlorosis progressed from the tips to the leaf let margins and was accompanied with scorching and finally scorched leaves are withered and mortality of seedlings occurred. Higher salt concentrations are often responsible for leaf injuries in salt stressed plants. The scorching of leaves and mortality of seedlings was due to specific ionic effect. The ions, which are absorbed by plants, are accumulated in leaf tissues and other plant parts that damaged the plants and become a cause of death [14]. Chlorosis in the tips along the leaf margins of seedlings can be characterized as typical Cl^- induced symptoms [15].

The vegetative growth was affected in all salt treatments significantly and the data on growth parameters are the average of surviving seedlings only. The control treatment attained maximum height increment of 38.87cm and the height reduction ranged between 12 to 65 percent due to increment in salt concentration. In low to moderate salinity (3-9 dSm^{-1}) concentrations, salt exclusion is the strategy and can be done through permeable membrane, by ion pumps, or by dilution of ions in the tissue of the plant [14]. The greatest reduction in plant height occurred in plants of the 12 and 15 dSm^{-1} treatment. At low salt concentrations, growths are mildly affected [16] and reduction in the growth of seedlings under increasing salt stress was through osmotic effects, specific ion effect and imbalance of uptake of essential nutrients. These modes of action may operate on the cellular as well as on higher organizational levels and influence all aspects of plant metabolism [4]. Osmotic stress and ion toxicity are the problems stemming from salt stress, and the resulting decrease in chemical activity causes cells to lose turger and implies danger of cell survival [11].

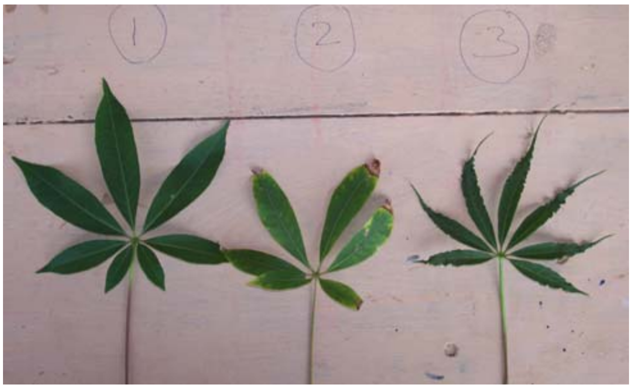


Plate-1. Effect of salinity on *Ceiba pentandra* seedlings at 12 dSm^{-1} concentration: (1) control, (2) older leaves showing chlorosis and scorching of leaves, (3) young leaves showing reduction in leaf area.

Effect of salinity on physiological attributes of *Ceiba pentandra*

The salinity stress reduced the development of new leaves, which led to significant differences in leaf area between the control and the treatments. In the 3 dSm^{-1} treatment the leaf area was only reduced by 11.4 percent when compared to the control. But in 12 and 15 dSm^{-1} concentrations the leaf area reduction was 62.62 and 71.81 percent, respectively. Dry weight significantly decreased in response to increasing concentration of salt in soil compared with the control. Seedlings in the 12 and 15 dSm^{-1} concentration were reduced in dry biomass by 69.55 and 75.85 percent. The results for reduction in leaf area of *Ceiba pentandra* with increasing salt concentration are in conformity with the finding of Curtis and Lauchi [17], who stated that plants under salt stress were affected through reduction in leaf area development. The salt causes a slower rate or shorter duration of expansion of cells and this compromises the size of the leaves [18]. The overall effect of the salinity on plants is the eventual shrinkage of leaf size, which leads to death of the leaf, and finally the plant. After 12 weeks of salinity treatment, Chlorophyll Stability Index (CSI) of the leaves in all treatments was greatly reduced in response to salt increment compared with control (Table-2). The CSI was higher (84.2%) in control treatment and afterwards salinity increment greatly reduced the CSI percent (47.6%). This CSI is an indication of the stress tolerance capacity of plants [2]. A high CSI value indicates that the stress did not have much effect on chlorophyll content of plants and helps to withstand stress through better availability of chlorophyll, leads to increased photosynthetic rate and more dry matter production. The increased salinity reduced the chlorophyll content and thus affects the photosynthetic rate [19] leads to poor growth.

Table-2. CSI and ionic concentration of leaves of *Ceiba pentandra* seedlings as influenced by salinity 12 weeks after initiation of the treatment.

Salinity concentration (dSm^{-1})	**CSI** (%)	**Na** (%)	**K** (%)	**Ca** (%)	**Mg** (%)	**Cl** (%)
0	84.2 a	0.58 a	0.75 a	1.65 a	0.28 a	0.61 a
3	82.9 a	0.65 a	0.90 a	1.67 a	0.35 a	0.68 a
6	78.7 b	0.76 b	1.12 b	1.77 a	0.36 a	0.77 a
9	73.4 b	1.20 c	1.27 b	2.04 a	0.39 a	1.05 b
12	57.2 c	1.25 c	1.35 b	2.16 a	0.48 b	1.04 b
15	46.8 d	1.37 d	1.29 b	2.25 a	0.47 b	1.25 c

Means followed by the same letter(s) in the same column do not vary significantly at $P < 0.05$ according to Duncan's Multiple Range Test (DMRT).

Ionic composition of leaves

The ionic concentrations of Na, K, Ca, Mg and Cl response to salinity after 12 weeks of treatment are presented in Table-2. Increment in salt concentration significantly increased ion concentration in leaf tissues. The stress caused by ion concentrations allows the water gradient to decrease, making it more difficult for water and nutrients to move through the root membrane. As older cells lose their capacity to grow, the new growth cannot handle the burden of collecting all the salt ions. This leads to premature death in the cells of leaves, and the plant will quickly succumb to the decreasing ability to compartmentalize the salt [18]. The Calcium, Magnesium and Potassium uptake and transport to the leaves were not significantly reduced with increasing salinity. This may be due to higher Na^+ ions in soils or solutions reduces Ca^+ and K^+ uptake by plants and or affects the internal distribution of these elements [20]. The leaf tissue shows high K/ Na ratio. Due to similar structures of Na and K the competition for binding sites causes potassium deficiency with in the cell [21]. The Na competing for potassium binding sites in the cytoplasm inhibits metabolic processes that depend on potassium; there fore the plant must maintain a high potassium level to counter balance the excess of salt [18]. In lesser salt concentrations, seedlings did not show any salinity symptoms. Depending on the concentration ratio, sodium and calcium can replace each other from the plasma membrane, and calcium might reduce salt toxicity [22].

CONCLUSIONS

The study indicates that *Ceiba pentandra* seeds germinate and seedlings tolerate the salinity concentration of up to $9dSm^{-1}$, which can be regarded as a LD_{50} value (the maximum degree of salinity at which 50 percent of the plants died) for severe damages in seedling stage and classified as a moderately salt tolerant multipurpose tree species.

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