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Evaluation of NaCl salinity tolerance of Artocarpus altilis (Parkinson) Fosberg and Treculia africana Decne for climate change adaptation in agroecosystems

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Abstract— The success of agroforestry in climate change adaptation especially in coastal communities experiencing salt-water intrusion will to a large extent depend on the identification of salt-tolerant tree species that can be integrated in vulnerable agro-ecosystems. This study evaluated the salinity tolerance of Treculia africana and Artocarpus altilis. The experiment was laid out in a Completely Randomized Design (CRD) replicated three times. Poly-bags were filled with bulked topsoil collected from a common source. Viable seeds of T. africana and A. altilis from the same mother trees were each sown (10 seeds in three replicates) per treatment. Equal volumes of NaCl solution of different concentrations (0.0mg/l (control), 60mg/l, 120mg/l, and 240mg/l) were administered to the respective poly-bags before sowing and morning/evening after sowing until a period of two months. Germination percentage reduced with increased salinity levels in both species, although, T. africana had higher germination percentages than A. altilis. Commencement of germination of T. africana seeds was delayed for two days in 60.00, 120.00 and 240.00 mg/l NaCl. In A. altilis, germination was delayed for three days in 60.00 and 120.00 mg/l NaCl, and for five days in 240.00 mg/l NaCl. There was no significant difference ($p > 0.05$) in average number of leaves and seedling height between the control and other treatments in T. africana while significant difference ($p < 0.05$) was observed between control and other treatments in all the evaluated attributes in A. altilis except collar diameter. T. africana appears to be more tolerant to increased salinity levels than A. altilis; hence, T. africana is recommended for the diversification of agro-ecosystems prone to salt-water intrusion. Screening of more tree species for salinity tolerance is also recommended.

Index Terms— Climate change, salinity, adaptation, agroforestry, coastal communities

1 Introduction

Soil salinity as observed by [1] is becoming an increasingly serious constraint to plant growth and development in many parts of the world, particularly in arid and semi-arid regions of the world. In the coastal regions, however, rapid and palpable environmental and social degradation, due to climate change, have become serious menace. One of the environmental challenges posed by climate change is increase in salinity of arable lands which stems from salt water intrusion into agrarian communities due to rising water levels. Salinity affects 7% of the world's land area for around 930 million ha [2]. Increase in salinity level of water body and soil has negative impact on these ecosystems because it causes inability of seeds to germinate or delay in germination, reduces crop yield, affects the aquatic world and vegetative infrastructure, etc [3]. The implications of increase in salinity are quite grave especially for agrarian communities.

Given the reality of climate change and its consequences, there is need for adaptation. One possible way to climate change adaptation in agriculture is to diversify agroecosystems through agroforestry.

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Agroforestry stands to maximize the use of available lands through increased productivity, and provision of environmental services like carbon sequestration, provision of shade for man and crop, and sheltering of companion crops against stormy winds. The success of agroforestry in climate adaptation, especially in the areas prone to salt water intrusion like the Niger Delta Region of Nigeria, will to a large extent, depend on the identification and use of tree species that have high tolerance to salinity. However, such species are yet to be identified.

A. altilis and *T. africana* are two key livelihood tree species that will easily by adopted by rural dwellers in most places due to their usefulness. *A. altilis* is a better source of protein than cassava; and a relatively good source of iron, calcium, potassium and riboflavin [4]. Protein content of 6.19% and 3.28% were reported by [5] and [6] for *A. altilis* flour respectively. Crude fat contents reported for *A. altilis* were 2.26% and

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2.82% by [5] and [6] respectively; while the carbohydrate content reported for *A. altilis* pulp flour is 81.70% [5] and 82.84% [6]. The leaves are also eaten by livestock and can be fed to cattle, goats, pigs and horses.

T. africana on the other hand, tolerates wind and shade and has the ability to coppice and be pollarded. Medicinal uses of *T. africana* have been reported by [7]. Its seed is a rich source of vegetable oil (10%), protein (17%) and carbohydrates (40%), as well as several minerals and vitamins [8]. The seeds provide an important food item which is very popular and consumed as main dish especially in South-Eastern Nigeria [9, 10]. The fat and oil content makes it a potential commercial raw material for the production of vegetable oil, in pharmaceuticals, soaps, perfumes and paints [11]. Fresh seeds of *T. africana* have 38.3% carbohydrate, 17.7% crude-protein, 3.8% moisture, 15.9% crude fibre, 4.0% ash and 15.9% ether extract [12].

However, the successful use of these species in agro-ecosystems for climate change adaptation, especially in coastal areas vulnerable to salt water intrusion, will to a large extent depend on their salinity tolerance levels. However, this knowledge is lacking. This study therefore, evaluated the ability of *Artocarpus altilis* and *Treculia africana* to cope with increased salinity. The specific objectives were to determine the effect of increased salinity on the germination of seeds of *A. altilis* and *T. africana;* and to ascertain the effect of increased salinity on early growth of seedlings of the two tree species. Germination and seedling stage are predictive of plant growth responses to salinity [13, 14]. Thus, seeds with more rapid germination under salt stress may be expected to achieve a rapid seedling establishment and more salt tolerance, and hence higher yields [2, 15].

2 MATERIALS AND METHODS

2.1 Study Area

The study was carried out at the experimental nursery of the Department of Forestry and Wildlife Management, Choba Park, University of Port Harcourt, Port Harcourt, Rivers State, Nigeria. The University of Port Harcourt is located on latitude 40 53' 14''N through 40 54' 42''N and longitude 60 54' 00''E through 60 55' 50''E. Figure 1 is the map of University of Port showing its three campuses and their landmarks.

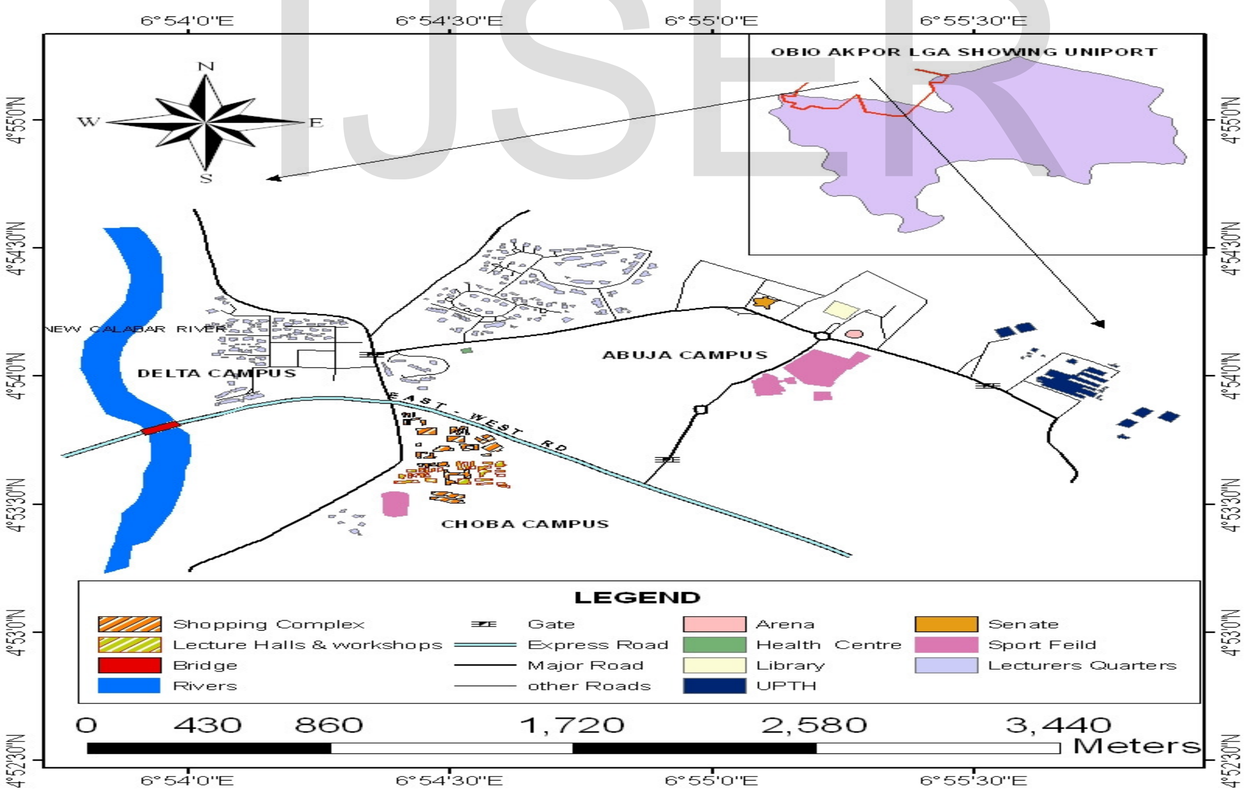

Fig.1. Map of University of Port Harcourt showing the three campuses

Source: Department of Geography and Environmental Management, University of Port Harcourt.

2.2 Seed Collection, Viability Test, and Processing

Mature fruits of *A. altilis* and *T. africana* were collected from selected healthy mother-trees growing within the same locality in Rivers State. Floatation method of seed viability test was employed to detect the viable seeds. The viable seeds

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were soaked in water for three days and exposed to moderate sunlight before sowing into poly-bags. One seed was sown per poly bag.

2.3 Experimental Design and Treatments

The experiment was laid out in a Completely Randomized Design (CRD) replicated three times. Poly-bags filled with bulked topsoil collected from the same source. Viable seeds of *T. africana and A. altilis* were each sown (10 seeds in three replicates) per treatment for the four treatments: 0.0mg/l (control), 60mg/l, 120mg/l, and 240mg/l of NaCl. This gave rise to a total of 30 seeds sown per treatment and a total of 120 seeds for the four treatments. Equal volume (250ml^3) of the treatments was administered to the respective poly-bags before sowing. Administering of treatments continued with 100ml^3 of each of the treatments morning and evening after sowing until a period of two months when the experiment was terminated. The experimental layout is shown in Figure 2 below.

Replicates	Treatments							
	0.0mg/l (Control)		60 mg/l		120 mg/l		240 mg/l	
R1	O	O	O	O	O	O	O	O
	O	O	O	O	O	O	O	O
	O	O	O	O	O	O	O	O
	O	O	O	O	O	O	O	O
	O	O	O	O	O	O	O	O
R2	O	O	O	O	O	O	O	O
	O	O	O	O	O	O	O	O
	O	O	O	O	O	O	O	O
	O	O	O	O	O	O	O	O
	O	O	O	O	O	O	O	O
R3	O	O	O	O	O	O	O	O
	O	O	O	O	O	O	O	O
	O	O	O	O	O	O	O	O
	O	O	O	O	O	O	O	O
	O	O	O	O	O	O	O	O
TOTAL	30 Seeds		30 Seeds		30 Seeds		30 Seeds	

Fig. 2. Experimental layout for each species

2.3 Data Collection

The germination trial for *T. africana* lasted for two weeks while that of *A. altilis* lasted for four weeks. Data collection on the effect of different salinity levels on early seedling growth lasted for two months after sowing in each of the species. Data collected covered: time (days) before commencement of germination under the different treatments; duration of germination under different treatments; germination percentage under different treatments; seedling height; leaf production (number of leaves); seedling collar diameter; and leaf length and diameter.

2.4 Data Collection

2.4.1 Analyysis of Variance

One-way analysis of variance was used to test for significant differences in growth attributes of seedlings under different treatments for each species. The Least Significant Difference (LSD) test was used for mean separation where significant difference occurred. The analysis of variance was performed using Statistical Package for Social Sciences (SPSS) as described by [16].

2.4.2 Germination Percentage

Germination percentage (GP) was computed for the two tree species under the different treatments after [17] using the equation below.

$$GP = \frac{n}{N} X\, 100$$

Where: n = number of germinated seeds

N = number of broadcasted seeds

3 RESULTS

3.1 Effect of different Salinity Levels on Germination of *T. africana and A. altilis*

3.1.1 Germination Percentage

The germination percentages of *T. africana* and *A. altilis* under different salinity levels are presented in Figure 3. Germination percentage reduced with increased salinity levels in both species. However, *T. africana* had higher germination percentages than *T. altilis*.

3.1.2 Trend in Germination

The trend in germination varied with different salt concentrations in both *T. africana* and *A. altilis*. In *T. africana* (Figure 4), germination started on the sixth day after sowing in the Control

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(0.00mg/l NaCl) but was delayed till the 8th day in 60.00, 120.00 and 240.00 mg/l NaCl. On the eight day, 57.67% of the seeds had germinated in the Control while 20.00%, 6.67% and 10.00% germinated in 60.00, 120.00 and 240.00 mg/l NaCl respectively on the same day. Two weeks after sowing, 0.00, 60.00, 120.00 and 240.00 mg/l NaCl had 100%, 93.30%, 86.67%, and 83.33% germination respectively.

In *A. altilis* (Figure 5), germination started on the 12th day after sowing in the Control (0.00mg/l NaCl) but was delayed till the 15th day in 60.00 and 120.00 mg/l NaCl, and till the 17th day in 240.00 mg/l NaCl. Four weeks after sowing, 86.67, 63.33, 60.00 and 56.67 % germination was recorded in 0.00, 60.00, 120.00 and 240.00 mg/l NaCl respectively.

Generally, germination was better in *T. africana* than in *A. altilis* when both the inception of germination and germination percentage were considered.

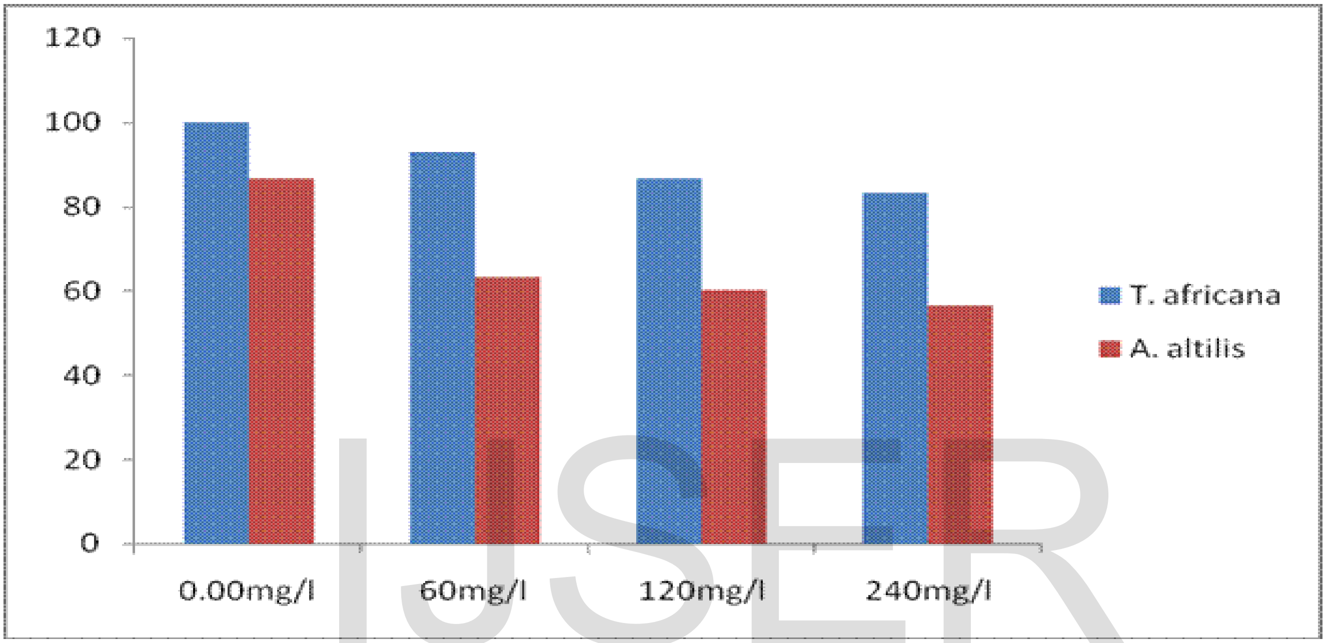

Fig. 3. Germination percentages for *T. africana* and *A. altilis* in different salt (NaCl) concentrations

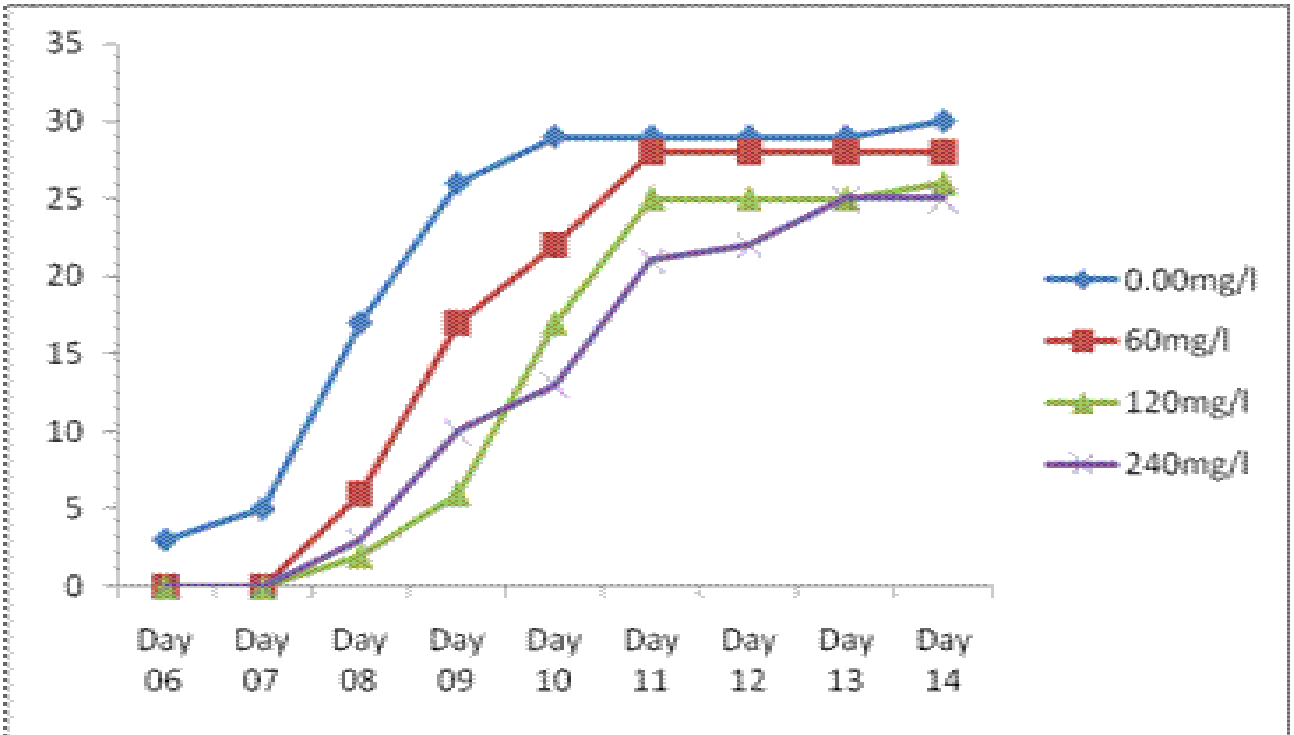

Fig. 4. Germination trend in *T. africana* in different salt (NaCl) concentrations

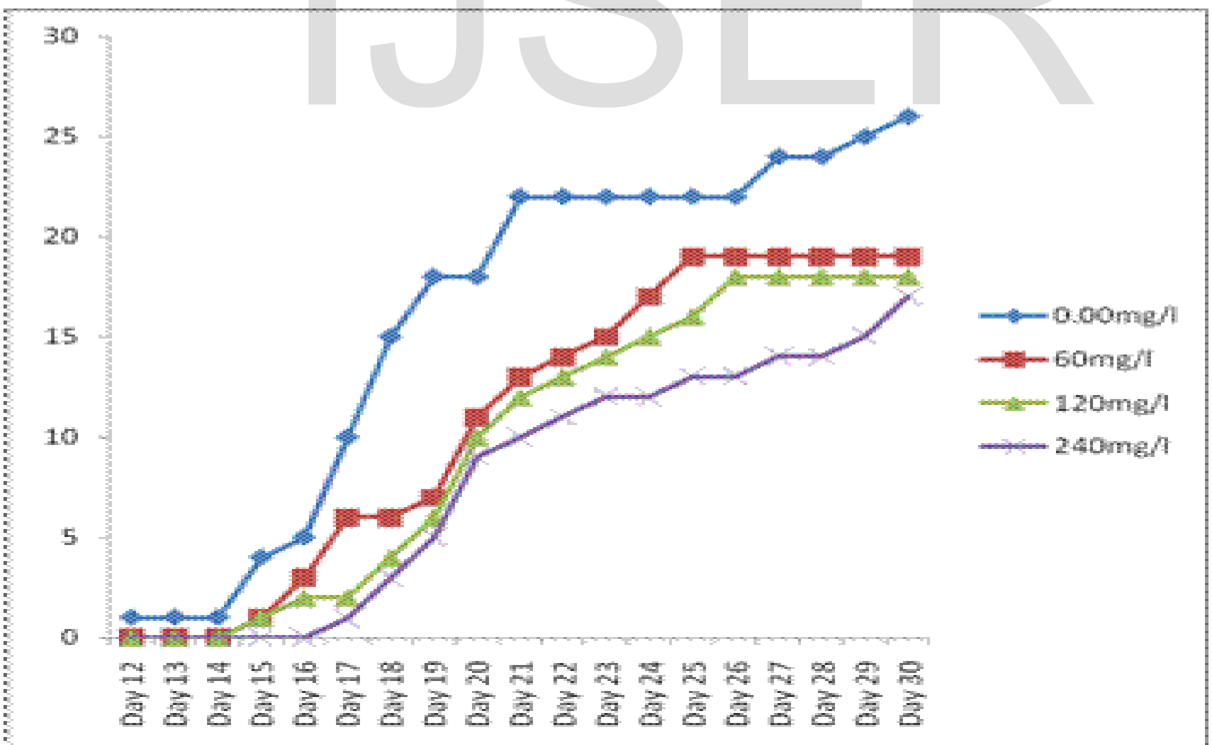

Fig. 5. Germination trend in *A. altilis* in different salt (NaCl) concentrations

3.2 Effect of different Salinity Levels on early Growth of *T. africana and A. altilis*

Mean separation for the different growth attributes for *T. africana* and *A. altilis* is presented in Tables 1 and 2 respective-

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ly.

In *T. africana* (Table 1), average leaf length and collar diameter of seedlings varied significantly between the Control (0.00mg/l NaCl) and the various salinity levels. Significant difference in average leaf length was also observed between the different salinity levels except for 120.00 and 240.00 mg/l NaCl. There was no significant difference in average leaf width between the Control and 60.00 mg/l NaCl. No significant difference was also observed in both average number of leaves and average seedling height between Control and different salinity levels in *T. africana*.

In *A. altilis* (Table 2), average leaf length, number of leaves, and seedling height varied significantly between the Control and different salt concentrations while there was no significant difference in average collar diameter. There was no significant difference in average leaf width between Control and 60.00mg/l NaCl and between 120.00 and 240.00 mg/l NaCl. Average leaf length did not also vary significantly between 120.00 and 240.00 mg/l NaCl.

TABLE 1
EXTENT OF VARIATION IN GROOWTH ATTRIBUTES OF *T. africana* SEEDLING UNDER DIFFERENT SALINITY LEVELS

Growth variable	NaCl concentrations			
	0.00mg/l	60mg/l	120mg/l	240mg/l
Leaf length (cm)	5.06 ± 0.18^{a}	4.23 ± 0.16^{b}	3.41 ± 0.21^{c}	3.06 ± 0.14^{cd}
Leaf width (cm)	4.05 ± 0.13^{a}	4.08 ± 0.17^{ab}	3.28 ± 0.21^{c}	2.85 ± 0.15^{cd}
No. of leaves	3.30 ± 0.09^{a}	3.25 ± 0.08^{a}	3.15 ± 0.07^{a}	3.20 ± 0.08^{a}
Collar diameter (cm)	0.24 ± 0.009^{a}	0.18 ± 0.002^{b}	0.15 ± 0.002^{c}	0.11 ± 0.000^{d}
Seedling height (cm)	6.57 ± 0.20^{a}	7.09 ± 0.22^{a}	7.09 ± 0.34^{a}	7.06 ± 0.31^{a}

Means with the same alphabet on the same row are not significantly different ($p > 0.05$)

TABLE 2
EXTENT OF VARIATION IN GROWTH ATTRIBUTES of *A. altilis* SEEDLINGS UNDER DIFFERENT SALINITY LEVELS

Growth variable	NaCl concentrations			
	0.00mg/l	60mg/l	120mg/l	240mg/l
Leaf length (cm)	8.49 ± 0.37^{a}	6.28 ± 0.34^{b}	5.40 ± 0.25^{bc}	4.41 ± 0.30^{cd}
Leaf width (cm)	6.21 ± 0.31^{a}	5.14 ± 0.32^{b}	4.23 ± 0.29^{c}	2.87 ± 0.22^{d}
No. of leaves	4.38 ± 0.16^{a}	3.83 ± 0.09^{b}	2.94 ± 0.13^{c}	2.79 ± 0.19^{cd}
Collar diameter (cm)	0.56 ± 0.012^{a}	0.55 ± 0.011^{a}	0.54 ± 0.017^{a}	0.53 ± 0.018^{a}
Seedling height (cm)	12.69 ± 1.24^{a}	9.51 ± 0.87^{b}	8.19 ± 0.76^{bc}	8.39 ± 1.01^{bcd}

Means with the same alphabet on the same row are not significantly different ($p > 0.05$)

4 DISCUSSION

Germination represents a dynamic phase in the life cycle of plants as the seed makes the transition from a metabolically quiescent to an active growing entity, and the sequence follows events such as imbibing of water, enzyme activation, hydrolysis of stored material, initiation of growth, rupture of seed coat and emergence of seedlings [18]. Higher concentrations of NaCl were found to delay the process of germination in *T. africana and A. altilis*, although the delay was longer in *A. altilis* where the application of NaCl was also longer before the commencement of germination probably due to the nature of their seeds. It has been observed by [19] that salinity adversely affects germination by decreasing the osmotic potential of the soil solution to such a point that it retards or prevents the intake of water. Salt-induced inhibition of seed germination could be attributed to osmotic stress or specific ion toxicity [20]. Salinity could also produce toxic effects on the embryo and the seedlings which result in delayed germination and or reduced percentage germination, as observed in this study. Although, there are no available literatures on the effects of increased salinity on germination and early growth of seedlings of tree species, varying NaCl concentrations have been observed to reduce the percentage germination in selected leafy vegetables [21, 22, 23].

The height of the seedling is considered as a useful criterion to understand the effect of salinity at seedling establishment stage. It has been suggested that seedling height is a very sensitive trait related to salinity [24]. Seedling height varied significantly in *A. altilis* while no significant difference was observed in seedling height of *T. africana*. Apart from seedling height, other evaluated growth attributes in *A. altilis* (number of leaves, leaf width, and leaf length) were also significantly affected by increased salinity except collar diameter. Accord-

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ing to [25], salt stress reduces the ability of plants to absorb water which leads to reduction in growth. However, [26] following their experiments on *Helianthus annuus* suggested that reduction in plant growth is due to decreasing turgor pressure in the cells under saline environment. It was also observed by [3] that high salt concentration hampers vital processes such as seed germination, seedling growth and vigor, vegetative growth, flowering as well as fruit set. Therefore, greater stability in growth attributes of *T. africana* in this study is indicative of its less sensitivity and more tolerance to increase in salinity.

5 CONCLUSION

The study has shown that that *A. altilis* is more sensitive to NaCl salinity than *T. africana*. Increasing concentrations of NaCl in the growth medium adversely affected germination, leaf production, and seedling height in *A. altilis* more than it did in *T. africana*.

6 RECOMMENDATIONS

It is recommended that *T. africana* be integrated in agroecosystems vulnerable to salt water intrusion for climate change adaptation. More studies to ascertain salinity- tolerance of more forest tree species should be conducted.

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