Salinity Stress on Growth, Nutrients and Carbon Distribution in Seedlings Parts of *Heritiera fomes*

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Abstract- Present study was conducted to evaluate the effect of salinity on survival and growth of Heretiera fomes Buch.-Ham seedling. It was also examine the distributional pattern of nitrogen, phosphorus, potassium, sodium, and carbon in seedlings parts in relation to salinity. This experiment was carried out in hydroponic media for six months. All the seedlings (100%) found to survive at non saline (0 ppt) to moderate (10 ppt) saline conditions and lowest (40%) survival was observed at 35 ppt salinity. Significant ($p<0.05$) negative correlations were observed among salinity and different indicators of growth (collar diameter, height and oven-dried biomass increment). Significant ($p<0.05$) difference in nitrogen, phosphorus, potassium, sodium, and carbon concentration was observed for different parts of seedlings at different salinity levels. Comparatively ($p<0.05$) highest concentration of nitrogen (16 to 21 mg/g), phosphorus (2.9 to 3.7 mg/g), potassium (11 to 26 mg/g) and carbon (44.60 to 46.40%) were found in leaves. Conversely, significantly ($p<0.05$) highest concentration (8 to 48 mg/g) of sodium was observed in roots followed by stem. Potassium and carbon concentration in different parts of seedlings, and nitrogen in leaves and roots showed significant ($p<0.05$) negative correlation with salinity. Similarly, sodium concentration in plant parts showed significant ($p<0.05$) negative correlation with potassium and carbon concentration in the respective plant parts. The findings of this study indicated that survival and growth of H. fomes seedling were strongly influenced by salinity. This influence was reflected through the nutrients and carbon distributional pattern in seedling parts; and antagonistic relationship among sodium concentration; and potassium and carbon concentration.

Keywords- Growth, *Heritiera fomes*, Nutrients, Salinity, Seedling, Survival

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I. Introduction

Heritiera fomes (Buch.-Ham.) is a medium sized to tall large evergreen mangrove tree. This species has shown narrow distribution in the world and almost restricted in South Asian countries of Bangladesh, India, Myanmar, Thailand, and Peninsular Malaysia (Spalding et al. 1997). In Bangladesh, this species found to occur in the Sundarbans, Chakaria-Sundarbans and other coastal areas (Das and Alam 2001). This species is quickly disappearing in many parts of its range due to a number of localized threats like coastal development, habitat destruction and removal of mangrove areas, top-dying disease, reduction of freshwater flow, and sea level rise (Rahman 1996; Spalding et al. 1997). *Heretiera fomes* is the most important and dominant tree species in the Sundarbans. It covers about 52.7 percent of the forest area and constitutes about 63.8 percent of the standing volume (Rahman et al. 1983). However, the co-dominant species of the Sundarbans are *Excoecaria agallocha*, *Xylocarpus mekongensis*, *X. granatum*, *Sonneratia apetala*, *Avicennia* spp. (Iftekhar and Saenger 2008). It is reported that *H. fomes* dominated areas are replaced by *E. agallocha* and other more salt tolerant species (Das and Alam 2001). Species composition and vegetation dynamics of the Sundarbans mangrove forest of Bangladesh are heterogeneous that seems to be controlled by hydrology, tidal inundation and salinity (Pethick 2011). This change in species composition may be due to the changed scenario of salinity regime and tidal inundation (Mahmood et al. 1998; Iftekhar and Saenger 2008). Salinity is one of the major parameters that influence productivity, germination, survival, growth and nutrient distribution in plant parts (Rubio Casal et al. 2003; L'opez-Hoffman et al. 2006; Elumalai and Manikandan 2013).

Increased levels of salinity is primarily stunted the seedling growth in association of other environmental factors such as humidity, temperature, light, tidal inundation. While, plant growth is directly depends on the availability of nutrients (Shannon et al. 1994; Hoppe-Speer et al. 2011). Salinity affects nutrient availability to plants through modification of binding, retention and transformation of nutrients in the soil and finally affects the uptake and/or absorption of nutrients by the root system (Wahome 2001). Moreover, higher concentration of Na showed antagonistic relationship to the uptake of the other nutrients (Cramer et al. 1991; Grattan and Grieve 1999). There are few studies on salinity and seedling growth of mangroves at different areas of the world e.g. *Ceriops tagal* from Gujarat and Tamil Nadu of India (Patel et al. 2010a; Sivasankaramoorthy 2012); *Avicennia marina* from Gujarat and Tamil Nadu of India (Patel et al. 2010b; Sivasankaramoorthy 2012) and Fujian, China (Yan et al. 2007); *Rhizophora mucronata* from South Africa (Hoppe-Speer et al. 2011) and Tamil Nadu, India (Sivasankaramoorthy 2012). **S**alt tolerance ranges of different mangrove species were found to vary significantly and this range of salt tolerance is an important determinant of plant growth in mangroves (Nandy Datta et al. 2007). The influence of salinity on survival, growth and distribution of different species of the Sundarbans are not known. The relationships among salinity and growth; nutrients, carbon and sodium in plant parts are important to understand the growth dynamics of mangrove plants and species composition in the Sundarbans mangrove forest at different salinity levels. The aims of this study were to examine the effect of salinity on seedling survival and growth; and nutrients (N, P, and K), sodium and carbon distribution in different parts of *H. fomes* seedlings in relation to salinity.

II. Materials and methods

A. *Seed collection and seedling raising*

The mature seeds of *H. fomes* were collected during the month of July 2011 from the Sundarbans mangrove forest of Bangladesh. The Collected seeds were sorted manually and the seeds with visible defect were discarded. Seeds were sown on in a germination bed of coarse sand layer of 30 cm at non saline condition. This allowed pulling off the seedlings with their intact root system for the next experiment.

B. *Experiment setup*

A total of 96 pet bottles with 9 cm in diameter and 20 cm in height were taken. Six month old seedlings were planted in each bottle with coarse sand. Collar diameter, height and green biomass of each seedling were measured and recorded. Some of the seedlings were taken to the laboratory to calculate the green weight to oven-dried weight conversion ratio at 80 ^{o}C for 4 days. A total of 12 pet bottles with seedlings were placed in a plastic box (46 cm x 30 cm x 24 cm) and thus 8 boxes were prepared. In sea water and thus in mangrove environment NaCl represents the highest proportion of salts and others are present only in trace amount. In this study salt means NaCl. This experiment was carried out in hydroponic media with Modified Hogland solution to avoid the complication of Na^+ and Cl^- from the original Hogland nutrient solution. Eight litter of modified Hoagland nutrient solution was added to each box to get the upto mark of solution with desired salinity treatments (0, 5, 10, 15, 20, 25, 30 and 35 ppt). Initially the salinity of the nutrient solution was zero. At the second week, the salinity of the first treatment was remained zero and all other treatment were increased to 1 ppt. At the 3rd week, the salinity of the first treatment was remained zero and other treatment were increase to 2 ppt. Salinity of the solution was increased gradually from 0 to 35 ppt to the respective treatments following the above method. Gradual increase of salinity levels was followed to cope the seedlings with the sudden shock of increased salinity. The nutrient solution was replaced weekly and salinity levels were checked regularly. This experiment was conducted for six month in a glass house of Forestry and Wood Technology Discipline of Khulna University.

C. *Survival and growth of seedlings*

Number of survived seedlings in each salinity treatments was counted at the end of the experiment and survival percentage was estimated. At the end of the experiment, all the seedlings were harvested and their collar diameter, height and green weight were measured according to salinity treatments. The growth increment in term of diameter, height and oven-dried biomass were estimated from the initial and final values.

D. *Nutrients (N, P and K), sodium and carbon in seedling parts*

Subsamples (100 g) of seedling parts (leaf, bark, stem and root) were randomly collected from the harvested seedlings of each treatment and oven-dried at 80 ^{o}C for 4 days. The oven-dried samples were processed and acid digested according to Allen (1989) to measure nitrogen, phosphorus, potassium and sodium in the respective parts. Nitrogen and phosphorus in the sample extract were measured according to

Baethgen and Alley (1989) and Olsen and Sommers (1982), respectively. Potassium and sodium in the sample extract were measured by Flame photometer (PFP7, Jenway LTD, England). Carbon concentrations in samples were measured according to Allen (1989).

E. Statistical analysis

The survival percentage values of each salinity treatments were transformed to arcsine and comparison among the treatments was performed by one-way Analysis of Variance followed by Duncan Multiple Range Test. Moreover, correlation among the survival of seedlings and salinity treatments was also conducted by using SAS statistical software. Diameter, height and oven-dried biomass increment in different salinity treatments were compared by one-way Analysis of Variance followed by Duncan Multiple Range Test; and correlation among the salinity treatment and the growth parameters were evaluated by using SAS statistical software. Nitrogen, phosphorus, potassium, sodium and carbon concentration in different parts of seedlings at different salinity treatments were compared by Two-way Analysis of Variance followed by Duncan Multiple Range Test. Relationships among salinity and nitrogen, phosphorus, potassium, sodium and carbon were evaluated through correlation analysis. Irrespectively, correlation among sodium; nitrogen, phosphorus, potassium, and carbon were conducted using SAS statistical software.

III. Results

A. Survival and growth of seedlings

All the seedlings (100%) found to survive at non saline condition (0 ppt) to moderate (10 ppt) saline condition. The survival of seedling showed significant ($p<0.05$) strong negative correlation ($r=-0.97$) with salinity and lowest (40%) survival was reported at salinity of 35 ppt. Similar ($p>0.05$) increment of collar diameter (5.87 - 5.19 mm) was observed at 0 ppt to 15 ppt salinity. While, similar ($p>0.05$) increment in height (5.33 - 5.18 cm) and oven-dried biomass (9.86 - 9.96 g) was found at 0 ppt to 5 ppt salinity. Comparatively ($p<0.05$) lower diameter (2.43 mm), height (1.2 cm) and biomass (1.47 g) increment were observed at the highest salinity of 35 ppt. However, collar diameter, height and oven-dried biomass increment showed significant ($p<0.05$) strong negative correlation with salinity (Fig. 1).

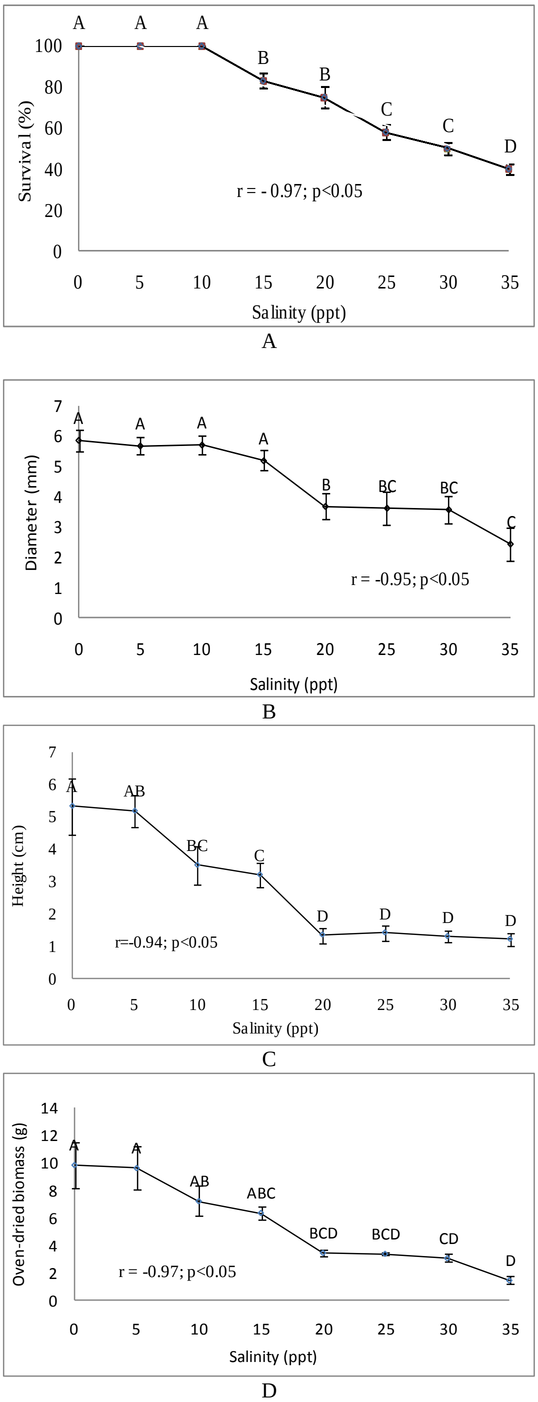
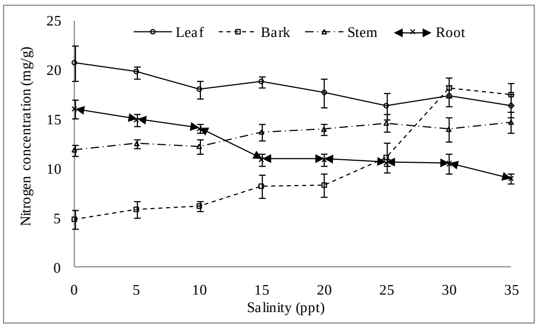


Fig. 1: Effect of salinity levels on seedlings of *Heritiera fomes* A) Survival of seedling B) Collar diameter increment C) Height increment D) Oven-dried biomass increment. Similar alphabet along the line are not significantly ($p>0.05$) different

B. Nutrients (N, P and K), sodium and carbon in seedling parts

Significant difference in nitrogen (F=26.78, p=0.0001), phosphorus (F=2079.00, p=0.0001), potassium (F=194.15, p=0.0001), sodium (F=98.56, p=0.0001), and carbon (F=166.30, p=0.0001) concentration was observed for different parts of *H. fomes* seedlings with different salinity levels. Comparatively ($p<0.05$)

highest concentration of nitrogen (16 to 21 mg/g) was observed in leaves followed by roots (11 to 16 mg/g) at 0 ppt to 15 ppt salinity. Highest concentration (2.9 to 3.7 mg/g) of phosphorus was observed in leaves followed by stem and roots at different salinity. Comparatively ($p<0.05$) highest concentration (11 to 26 mg/g) of potassium was observed in leaves followed by stem and lowest (2 to 10 mg/g) was detected in roots. Comparatively ($p<0.05$) higher concentration of carbon was measured in leaves (44.60 to 46.40%) followed by bark and lowest (38.32 to 41.69%) was detected in roots. Conversely, significantly ($p<0.05$) highest concentration (8 to 48 mg/g) of sodium was observed in roots followed by stem and lowest concentration (2 to 13 mg/g) was measured in leaves (Fig. 2, Table 1). Potassium and carbon concentration in different parts of seedlings, and nitrogen in leaves and roots showed significant ($p<0.05$) negative correlation with salinity. But, phosphorus concentration in leaves, stems, and roots showed not significant ($p<0.05$) correlation with salinity (Table 2). Similarly, sodium concentration in plant parts showed significant ($p<0.05$) negative correlation with potassium and carbon concentration in the respective plant parts. While, not significant ($p>0.05$) correlation was observed for phosphorus concentration in leaves and roots (Table 3).



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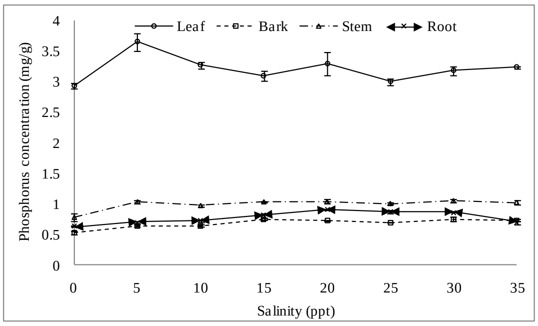

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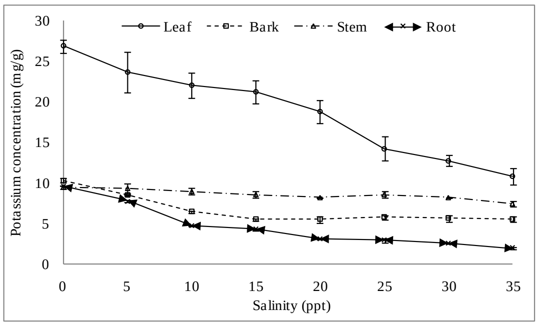

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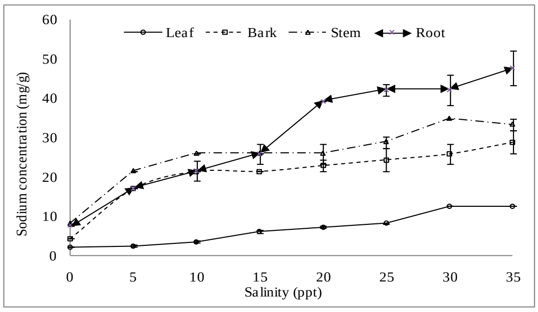

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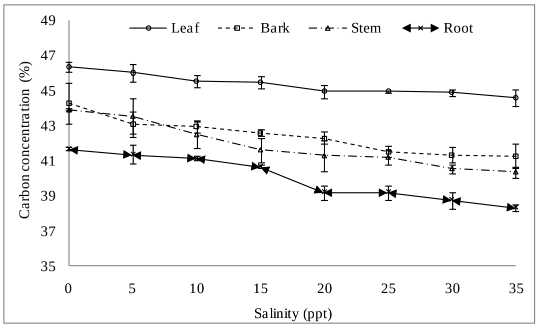

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Fig. 2: Effect of salinity levels on seedling parts of *Heritiera fomes* A) Nitrogen concentration B) Phosphorus concentration C) Potassium concentration D) Sodium concentration E) Carbon concentration

Table 1: Anova result (F-value and p-value) of nitrogen, phosphorus, potassium, sodium and carbon in different parts of *Heretiera fomes* seedlings

	Leaf	Bark	Stem	Root
Nitrogen	F=1.72 p=0.1755	F=24.07 p=0.0001	F=1.84 p=0.1477	F=14.19 p=0.0001
Phosphorus	F=4.83 p=0.0044	F=17.34 p=0.0001	F=7.63 p=0.0004	F=26.85 p=0.0001
Potassium	F=23.66 p=0.0001	F=38.26 p=0.0001	F=3.44 p=0.0193	F=380.29 p=0.0001
Sodium	F=254.72 p=0.0001	F=13.83 p=0.0001	F=31.07 p=0.0001	F=44.67 p=0.0001
Carbon	F=2.91 p=0.0364	F=2.96 p=0.034	F=4.43 p=0.0065	F=14.76 p=0.0001

Table 2: Correlation among salinity level and nitrogen, phosphorus, potassium, sodium and carbon in different parts of seedlings

	Leaf	Bark	Stem	Root
Nitrogen	-0.91	0.93	0.92	-0.94
Phosphorus	-0.17*	0.82	0.62*	0.53*
Potassium	-0.99	-0.81	-0.94	-0.93
Sodium	0.98	0.88	0.89	0.98
Carbon	-0.97	-0.97	-0.97	-0.97

* Values are not significant at 95% level

Table 3: Correlation among sodium; and nitrogen, phosphorus, potassium, sodium and carbon in different parts of seedlings

	Leaf	Bark	Stem	Root
Nitrogen	0.95	0.73	0.78	-0.94
Phosphorus	0.06*	0.90	0.85	0.65*
Potassium	-0.96	-0.93	-0.81	-0.95
Carbon	-0.91	-0.93	-0.90	-0.98

* Values are not significant at 95% level

IV. Discussion

Survival and growth of mangrove seedling depends on salinity levels and the range of salt tolerance is species specific (Gilles et al. 2001; Nandy Datta et al. 2007). Mangrove seedling involves most of the energy for their growth at the lower saline condition. Conversely, the majority energy found to engage for survival at the higher salinity (L´opez-Hoffman 2006). This could be the reason to observe comparatively higher survival and growth of *H. fomes* seedlings at lower salinity. Similar observation was reported with *Ceriops australis* and *C. decandra* at Australia (Ball 2002); *A. germinans* at Venezuela (Lopez-Hoffman 2007). Growth of some true mangrove species (*A. marina*, *Ceriops* spp., *Rhizophora* spp.) found to increase at moderate salinity (Yan et al. 2007; Patel et al. 2010a; Hoppe-Speer 2011). *Heretiera fomes* being a non-exclusive mangrove species may have the characteristics of affecting growth even at low saline condition. Higher salinity (>15 ppt) negatively influence the growth of mangrove seedlings (Smith 1992) through limiting the water uptake (Clough 1984), causing low leaf intercellular CO_2 concentrations (Andrews and Muller 1985), decreased photosynthetic rates (Pezeshki et al. 1990; Sobrado 1999).

Plant uptake nutrients from soil and translocate to leaves, and synthesized food thereafter is distributed to different parts. Nutrients are effective for different physiological function (such as respiration, transpiration and photosynthesis) and normal growth or metabolism of plants (Jones et al. 1991; Marschner 1995). Nutrients concentration not only varies from species to species but also varied among the plant parts and stages of growth (Jones et al. 19991; Mahmood et al. 2006). Nitrogen, phosphorus and potassium are more abundant in physiologically active and photosynthetic tissue like leaves (Marschner 1995). This could be the reason to observe comparatively higher concentration of N, P and K concentration in leaves compared to other parts of seedlings.

High salinity affects plant growth due to sodium toxicities, nutrient deficiencies or combination of these (Khan et al. 2000). Salinity, in general, does not show much of interaction with nitrogen and phosphorus concentration in seedling parts of *H. fomes*. Level of salinity does not affect necessarily the overall uptake of nitrogen by plants which may continue to accumulate nitrogen in the presence of excess salts despite a reduction in yield of dry mass (Silveira et al. 2001, Wahid et al. 2004). A recent study indicated that nitrogen uptake in mangrove seedlings is not inhibitory by salinity (Kao et al. 2001). The final impact of salinity on the concentration of phosphorus in plants depends heavily on plant species, phase of ontogenesis, and level of salinity (Grattan and Grieve 1999). In most cases, excess of salts in soil solution leads to a reduction in phosphorus concentration in the tissues of plants, but the results of some studies show that salinity may increase but that does not affect the uptake and accumulation of phosphorus (Sonneveld and de Kreij 1999; Kaya et al. 2001). The antagonistic relationship among sodium and potassium of this study suggested that sodium inhibited the uptake of potassium. Moreover, it is well documented that high concentrations of Na showed antagonistic relationship with uptake of N, P and K and the extent of this relationship found to vary with species and plant parts (Cramer et al. 1991, Grattan and Grieve 1999). Salinity reduces the net photosynthesis (Pezeshki et al. 1990; Sobrado 1999) and results in lower sequestration of carbon in plant parts. Similarly, the negative correlation values (Tables 2-3) indicate the antagonistic relationship for salinity and carbon; and sodium and carbon in plant parts. The findings of this study indicate that salinity is an important factor of regulating the survival and growth of *H. fomes* seedlings. It also demonstrates the impact of salinity on nutrient distributional pattern in different parts of *H. fomes* seedlings. Significant increase in sodium concentration and decrease in potassium and carbon concentration in seedling parts may inhabit the growth of seedling at higher saline condition.

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