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Bachelor of Science Degree

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Student ID : 110505

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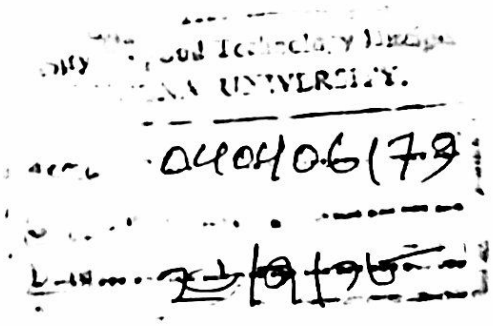

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This thesis (Course No: FWT-4114) has been prepared and submitted to the Forestry and Wood Technology Discipline, of the partial fulfillment of Bachelor of Science in forestry in Khulna University, Khulna.

Supervisor

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Tanay Biswas. 04/12/2017

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Tanay Biswas 04/12/2017

Tanay Biswas

Dedicated to

My

Beloved Parents

Abstract

Mangroves are to compete so many competing factors (salinity, tidal effect, land characteristics, etc.) to survive within their environment. This study was conducted to evaluate the effect of salinity on nutrient (Nitrogen (N), Phosphorus (P) and Potassium (K)) and Sodium (Na) storage in the different seedling parts of *Avicennia officinalis*. To analyze the saline effect on nutrients portioning Completely Randomized Design (CDR) was followed with eight treatments 0ppt-35ppt at 5 ppt. interval. There is a significance difference ($p<0.05$) for N, P, K and Na among the different plant parts (Leaves, Stem, Bark and Root) with R^2 value 0.925 (N), 0.939 (P), 0.974 (K) and 0.982 (Na) respectively for leaves, stem, bark and root. Individually in root P has no significance difference, similarly for stem P, and for bark N has not significant difference. Nitrogen concentration in leaves vary form 54.94 mg/g- 25.56 mg/g at 0 ppt -35 ppt salinity level similarly for bark 16.46 mg/g- 9.24 mg/g, for root 12.40 mg/g- 7.79 mg/g, and for stem 11.12 mg/g - 4.85 mg/g. Phosphorus concentration in leaves vary form 5.33 mg/g - 2.66 mg/g at 0 ppt - 35 ppt salinity level similarly for bark 3.2 mg/g - 1.46 mg/g, for root 0.24 mg/g - 0.18 mg/g, and for stem 0.13 mg/g - 0.16 mg/g. Potassium concentration in leaves vary form 9.24 mg/g - 6.10 mg/g at 0 ppt - 35 ppt salinity level similarly for bark 5.84 mg/g - 4.34 mg/g, for root 1.41 mg/g - 1.27 mg/g, and for stem 2.96 mg/g - 2.41 mg/g. Sodium concentration in leaves vary form 20.77 mg/g - 29.70 mg/g at 0 ppt - 35 ppt salinity level similarly for bark 15.66 mg/g - 18.76 mg/g, for root 3.61 mg/g- 4.63 mg/g, and for stem 2.81 mg/g - 3.15 mg/g. A significance impact of salinity on nutrients and Na distribution in different parts of the seedlings of the *A. officinalis* was found.

Keywords: Nitrogen, Phosphorus, Potassium, Sodium, Mangrove, Salinity, *Avicennia officinalis*.

DECLARATION

I hereby declare that the project thesis is based on my original work except for quotation and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Khulna University or other institutions.

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04/12/2017

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APPROVAL

The style and format of this project thesis submitted to the Forestry and Wood Technology Discipline, Khulna University, Khulna, Bangladesh, in partial fulfillment of the requirements for the 4-years professional B.Sc. (Hons.) degree in Forestry has been approved.

4/12/2017

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List of Abbreviation

N	Nitrogen
P	Phosphorus
K	Potassium
Na	Sodium
UV	Ultra violet
ppt	Parts per thousand
Mg/g	Milligram per gram

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Chapter I

Introduction

1.1. Introduction

Mangroves covering the boundary between land and sea in the tropics and sub tropics i.e. between 25° N and 25°S and they are rare but spectacular rare ecosystems in terms of species composition (Ewel et al, 1998, Saenger, 2002). This ecosystem consists of group of trees and shrubs, palms, ferns and epiphytes etc. (Tomlinson, 1986). They provide shelter for a large number of associated species like aquatic organisms and make the mangrove ecosystem more complex and beneficial (shelter, breeding place, home range) to the aquatic organism and others animas (Savage, 1972). The largest single tract of mangrove is the Sundarbans (Spalding et al, 2010).

The Sundarbans is the largest single tract of mangrove in the world (Spalding et al., 2010) and also largest among the four forests which is situated at the south western region of Bangladesh. The total area of The Sundarbans is 5,770 km^2 (Hussain and Karim, 1994) and it has diverse taxonomy of trees and shrubs (Iftekhar, 1999; Prain, 1903). This forest hosts a total of 334 plant species including trees, herbs and shrubs (Prain, 1903). The Sundarbans are mainly dominated by *Heritiera fomes, Excoecaria agallocha* and *Ceriops decandra* (Iftekhar and Saenger, 2008). On the basis of salinity, Sundarbans divided into three cological zones based on salinity and distribution of species composition these are i) less saline/fresh water zone named as Oligohaline zone (0.5 – 5 ppt), ii) moderately salt water/moderately saline zone designated as Mesohaline zone (5 - 18 ppt) and iii) salt water zone/active saline zone called as Polygohaline zone (18 – 30 ppt) (Siddiqi, 2001; Iftekhar, and Saenge, 2008). Plant species composition found to vary with the salinity zone of the sundarbans (Siddiqi, 2001)

Avicennia officinalis is one of the pioneer species of the sundarbans (Naskar and Bakshi, 1987) which come with *Sonneratia* and *Aegiceras* (Karim, 1994; Giri et al., 2007, Siddiqi 2001). *Avicennia officinalis* shows physical and mechanical adaptation to survive in harsh saline condition (Alongi et al., 1992). This species becomes the second most important species in costal afforestation of Bangladesh (Saenger, 1993; Islam et al., 2015; Siddiqi 2001). It alone constitutes about 5% of the total mangrove plantation and 22% in the eastern part of the shoreline (Alam, et al., 2014).

The chemical elements which are essential for plant growth and development are known as plant nutrition (Emanuel, 1972). Plants are not able to complete the life cycle in absence of required amount of nutrients (Motsara, 2008). Trees at fertile site showed greater addition of leaves, reproductive parts new branches, larger increments to existing stem (Christopher, 1977). 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 with species but also varied among the plant parts and stages of growth (Jones et al. 19991; Mahmood et al. 2006). Salinity affects the availability of nutrients to the plants (Mahmood et al. 2014). High salinity creates problems for mangroves to uptake water from the soil (Clough et al., 1982) and accumulation of salt in different parts of the plant is an important adaptation for mangrove species to cope up with salinity (Tomlinson, 1986; Lin, 1997). Increased concentration of Na^+ and Cl^- in mangrove adversely affect root and shoot growth of many mangrove species (Barrett-Lennard, 2003).

In saline waterlogged environment mangrove species exhibit some physiological and biogeochemical mechanisms to cope up with waterlogged environment (Ball, 1988, 1996). Ion retention, translocation, and immobilization in waterlogged soils; high nutrient-use efficiency, nutrient conserving mechanism (Golley, 1975). Nutrient conserving mechanism means the storage of nutrient tree biomass (Golley et al. 1975; Gandaseca, 2016). Tropical forests store comparatively low nutrients than boreal or temperate trees. Factors which have influence on nutrient storage are soil fertility, species composition, and forest age (Proctor 1989; Drechsel and Zech 1993; Grubb 1995; Aerts and Chapin, 2000). Nitrogen reserve in the leaves and structural components plays an important role in the development of new flushes of growth and flowers in the spring with environmental stress (Kato, 1986). It shows physical and mechanical adaptation to survive in harsh saline condition (Alongi et al., 1992). This species has a great importance for coastal afforestation for coastal zone protection and reduce global warming. The growth and establishment of plant depends on nutrient which is affected by salinity a common environment of mangroves. But prior to this research there is no this kind of research on this important species.

Objectives

- To determine the partitioning of nutrients (N, P and K) and Na in different plant parts *Avicennia officinalis* grown in different salinity level.

Chapter II

Literature Review

2. General Information

Avicennia officinalis, belonging to the family Avicenniaceae, is known to be a type of mangrove tree species (Ramanjaneyulu, 2015). It is an evergreen tree species. Species of this family has the highest salt tolerance ability (Rippey, 2004). Sap portion of *Avicennia* is salty because they do not exclude their salt at root level. They secrete extra salt on salt gland. They also secrete excess salt through the pore on leaves. On the leaves they form salt crystal and these crystal fall down from leaves through wind and water (Waisel, 1972).

This species can grow up to 10-15 m, trunk to 1 m in diameter. Numerous upright pneumatophores rise above soil from long shallow, horizontal cable roots. Bark is brownish-gray, thin, becoming rough and blackish, or outer bark yellowish-green and inner bark whitish. Leaves opposite obovate or broadly oblong, 4 - 12 cm long, 2 - 6 cm wide, rounded at tip, acute or rounded at base, thick, leathery, edges slightly rolled under, upper surfaces shiny green and hairless, underneath with fine gray-green hairs and resin dots. Cymes headlike in panicles, upright near ends of twigs, to 15 cm long and wide. Flowers many 2–12 together, sessile, malodorous, 7–10 mm long, 12–15 mm across. Calyx 5-lobed, hairy on edges, with resin dots; corolla bell-shaped, tubular, yellow or yellow-brown, turning orange, with 4 unequal spreading lobes, stamens 4, inserted in notches of corolla tube; ovary conical, hairy, imperfectly 4-celled with 4 ovules, style threadlike; stigma 2-forked. Capsule broadly ovoid, flattened, 2.5 cm long. Seed 1, large, flattened, without seed coat, germinating in water (Little, 1983, Mahmood, 2015). Seeds of *A. officinalis* are buoyant and it shows cryptovivipary germination (Mahmood, 2015). Roots and shoots come out when the fruit falls off and they grow well if they get good temperature and salinity. *Avicennia* spp. has power to coppice.

2.1. Species Description

This species usually colonizes after *S. apetala* in the Sundarbans of Bangladesh (Siddiqi 2001). *Avicennia officinalis* generally occurs as scattered and isolated trees in the inner part of the Sundarbans (Abdul, 2014).

This species is found in Bangladesh, India, Indonesia, Malaysia, Brunei, Myanmar, Philippines, Singapore, Sri Lanka, Thailand, Viet Nam, and southern Papua New (Figure 1) Guinea (Mahmood, 2015).

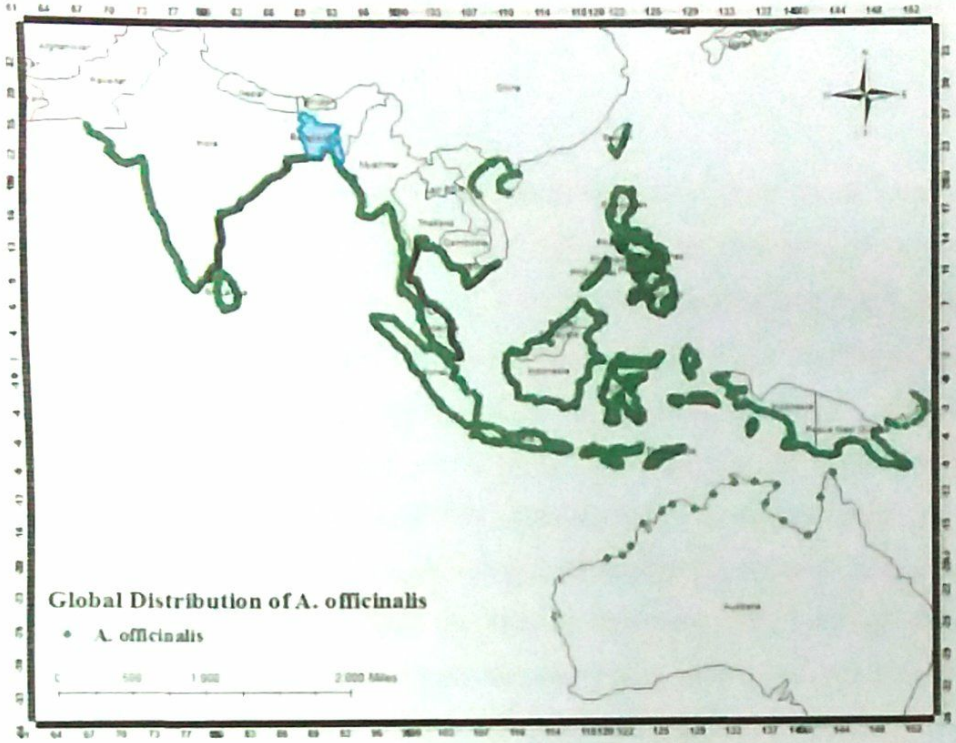

Figure 1: World distribution of *A. officinalis* (Source: Spalding, 1997)

2.2. Habitat

Avicennia species are among the first mangrove trees to colonize mud and sandbanks which are regularly flooded by seawater. Thus the trees stabilize the shores, preventing erosion and allowing other plants to grow (Colin, 1995). *Avicennia officinalis* is found in the intermediate estuarine zone in the lower intertidal region. It is shade intolerant with a maximum pore water salinity of 63 ppt (Robertson and Alongi, 1992). This species can grow 15 m but often seen 5-10 m. It generally occurs as scattered and isolated trees in the inner part of the Sundarbans (Abdul, 2014).

2.2.1. Required Climatic Condition

The preferred temperature ranges from 18 to 32°C. Absolute humidity range is from 70 to 90%. Annual precipitation is 2500 to 3000 mm, and pH ranges from 7.5 to 8.5 (Siddiqi, 2002).

2.2.2. Soil

The species prefers to grow in mangrove swamps and tidal creeks and estuaries on the low char land, higher salinity areas remain moist throughout the year by regular inundation. The tree is adopted to grow on low lying clay soils which are often flooded during high tide (Tomlinson, 1986).

2.3 Adaptation to Salinity

Avicennia officinalis has morphological and physiological adaptation to cope with saline condition (Tomlinson, 19886). This species has salt gland on its leaves to cope with saline environment (Tomlinson, 1986; Alongi et al., 1992) and has multi-cellular salt gland which is the specialized microscopic structure to remove extra salt from the inner tissue and deposit the salt on leaves surface (Flowers et al., 2010; Thomson et al., 1988). This is the main adaptation to flourish in saline condition. Leaked salt from the salt gland deposits as salt crystal on leaves (Osborne and Berjak, 1997). Salt also may accumulate in the stem and bark. *Avicennia officinalis* have sunken stomata beneath the epidermis of leave (Miller et al., 1975) also several layered hypodermal tissues are present (Saenger, 1982). In salt affected areas, plant growth is severely affected by salinity through water deficit and salt specific damages (Qureshi et al., 2007). High level salts may cause a reduction in growth of the plants, especially in plant biomass production (Iqbal et al., 2006; Sepehr and Mahlagha, 2006). The harmful effects of salinity were suggested because of water stress, ion toxicities, ion imbalance or combination of all these factors (Ashraf et al., 2005).

2.4. Morphology

2.4.1 Phenology

Flowers of *A. officinalis* are the biggest flower of this family. Color of the flowers is yellow. The penciled heads of yellow flower appears. Fruit ripe in July- October. Bud starts formation from march- late may in the Sundarbans (Mahmood, 2015). Propagule, which is usually, consists of a single embryo surrounded by a thin pericarp (Tomlinson, 1986).

2.5. Silvicultural Characteristic

2.5.1. Natural Regeneration

The fruits of *A. officinalis* are dicotyledonous and single seeded. Mature seeds shed from mother plant during the month of July to October. The seeds are buoyant and are able to spread by high tidal water. Seed germinate immediately after falling or even in the tree (Zabala, 1990).

2.5.2. Artificial Regeneration

Seedling of *A. officinalis* can be planted in vacant area but the survival of seedling could not be ensured due to its high palatability. The species was planted in Chokoria Sundarbans and coastal afforestation programme of Bangladesh (Mahmood, 2015).

Mature seeds are collected from trees and then planted. Germination starts within three days and the percentage of germination is 90% within 10 days after sowing. Plantation can be raised by seed or seedling. Seeds are sown by dibbing or broadcasting but the dibbing process is preferable. Seeds are sown by 1 x 1 m spacing (Saenger and siddiqi, 1993). Pretreated fruit can also be used to decrease establishment time (Siddiqi, 2001). Vacancy filling with seedling is preferable (Das and Siddiqi, 1985)

2.6. Use

Use as Food: Although the fruits and seeds are bitter it can be eaten after some elaborate processing. Leafy branches are chopped off as cattle fodder, and the tree rapidly grows new branches (Abdul, 2014).

Other Uses: The tree produces a hard, heavy timber which is hard to saw. But it is valued for making boats, houses, and wharves; the timber has an attractive grain which is good for making furniture (Abdul, 2014). It is also made into chip wood and is being researched as a source of paper pulp. Tannin is extracted from the bark and roots. It also produces a dye, and the ashes used in making soap (Field, 1995, Bandaranayake, 1998).Fruits are plastered onto boils and tumors (India). A poultice of unripe seeds stops inflammations, and heal abscesses, ulcers, boils, and smallpox sores. Roots are considered an aphrodisiac. Fruits and leaf also used as a medicine of aphrodisiac, diuretic, hepatitis (Bandaranayake, 1998). The bark is used to treat skin problems, especially scabies (Indochina). The cut bark oozes a rubber-like, green, bitter resin that is mixed with bananas and taken by women as a contraceptive that is

successful and has no long term side-effects, and it is also used as leprosy (Bandaranayake, 1998). Seed for ulcers, the resin for snakebite (Philippines).

2.7. Nutrient in Mangrove Ecosystem

Nutrient availability varies with mangrove to mangrove plant species and sites due to salinity (Feller et al., 2003). Macro nutrient Nitrogen and Phosphorus is an important factor for plant growth (Feller et al., 2003). Regeneration and growth is affected by significant increasing of salinity in the Sundarbans (Siddique et al., 2001). In terms of germination salinity plays a vital role in the distribution of species in the Sundarbans. The site which has limited nutrient mangrove plant species have developed some adaptation like evergreens, resorption of nutrients prior to leaf fall, the immobilization of nutrients in leaf litter during decomposition, high root/shoot ratios and the repeated use of old root channels (McKee, 2001; Middleton and McKee, 2001). Availability of nutrients to mangrove trees depends on the interaction between biotic and abiotic factors. (Ruth, 2010). If abundant of denitrifying bacteria in mangrove soils denitrification rates can be high due to the anaerobic conditions (Alongi, 1994; Corredor and Morell, 1994).

Mangroves have some adaptation to cope with high salinity, including anatomical, physiological and molecular mechanisms (Hanagata et al. 1999). This leaves are a trait related to low soil nutrient availability, especially low P (Loveless 1961, Wright et al. 2001) is also linked to low water availability and, in mangroves, to high salinity habitats (Naidoo, 1987).Sclerophyllous leaves can exhibit extremely low leaf water potentials before wilting (Salleo et al., 1997). Sclerophylly has also been linked to leaf longevity and evergreen traits and to ecosystem nutrient retention through slowed decomposition (Schlesinger and Hasey, 1981) and through reductions in herbivores by primary consumers (Coley, 1983).

Root-shoot ratios in mangroves are high and above ground roots have both supportive functions and roles for aerating roots in anoxic soils (Golley et al., 1962; Snedaker, 1995). It can vary considerably as a function of environmental factors and are in part an adaptation to saline environments (Ball, 1988; Saintilan, 1997). High root biomass in mangroves, especially the abundance of fine roots (Komiyama et al., 2000), is conducive to nutrient capture and uptake from soils, low in nutrients, fine roots increase rapidly in response to high nutrient (McKee, 2001). When nutrient is high then mangrove seedling invest more in the above ground biomass than in roots (McKee, 1995; Naidoo, 2009).

Efficient metabolic process increasing the efficiency of metabolic processes is also an effective nutrient conservation strategy (Chapin, 1980). A large proportion of root respiration goes towards the uptake and assimilation of Nitrogen (Bloom et al., 1992).

To conserve nutrient, retranslocation is of the most important strategies used which consequently influences competition, nutrient uptake, and productivity (Killingbeck, 1996). Retranslocation is closely associated with leaf senescence. It helps to grow seedlings in nutrient-poor sites. Retraslocation from leaves is an important factor in the supply of nitrogen, phosphorus and potassium for new growth in tree species (Nambiar and Fife, 1991; Millard, 1994; Fife and Nambiar, 1995; Aerts, 1996; Saur et al., 2000; Heerwaarden et al., 2003). When salinity level increase then 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).

2.8. Salinity in Mangrove Ecosystem

Salinity effect and environmental stresses of plant are important to know the ecology of mangroves (John, 1988). According to John, 1988, the mechanisms of salt tolerance cannot be known, and it reflects the correlations between size or mortality and external salinity. The most salt-sensitive plants accumulate salt when it is available. Transport and in the control and integration of Na^+ acquisition and allocation in plants and those involved in readjustment of other aspects of metabolism, especially carbon. All the seedlings (100%) of *Heritiera fomes* found to survive at non saline (0 ppt) to moderate (10 ppt) saline conditions and lowest (40%) survival was observed at 35 ppt salinity (Mahmood et al., 2014). Mangroves have various strategies to cope with high salinity, including anatomical, physiological and molecular mechanisms. Most mangrove trees are evergreen with sclerophyllous leaves and high root/shoot biomass ratios (Komiyama et al., 2008)

Chapter III

Materials and Methods

3. Study Area

3.1. Location

The study was conducted at oligohaline zone of the Sundarbans mangrove forest. Study site was selected purposively on the basis of availability of *A. officinalis* seed. Samples were collected from Amurbunia forest station, Shorankhola range, Bgerhat district. The area is humid sub-tropic and mean annual rainfall is 1500 mm in summer (May to September). Mean Temperature of the area is 18-23^0 C in winter and 27-31^0 C in summer. Soil is clayey and pH is around 7.9 (MET Station, Khulna).

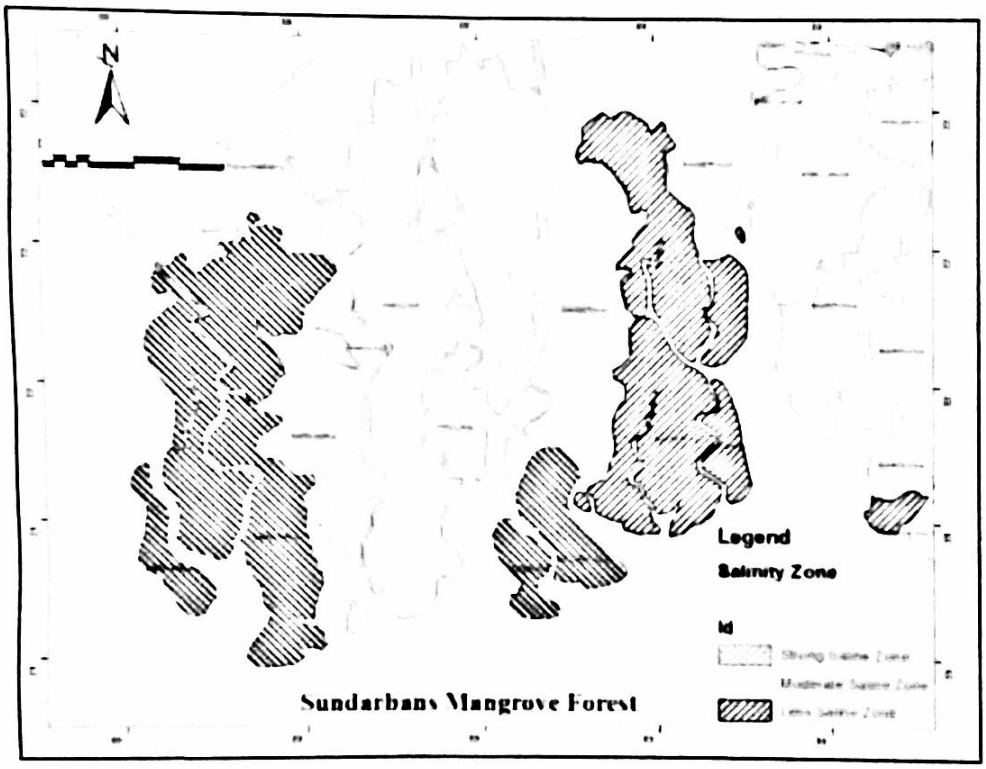

Figure 2: Location of study area. The dot points indicate the study sites. (ODA, 1985)

3.2. Soil Characteristics

Soil characteristics of those sites are presented in Table 1. Organic matter (OM), electric conductivity (EC) was high in less saline zone. pH was 7.68±0.05 in strong saline zone and 7.10±0.07in less saline zone. Nitrogen (N), Phosphorous (P) concentration in soil was high in less saline zone that was 31.47±4.84 and 39.95±11.09 respectively where in high saline zone

these were 23.44±1.28 and 29.08±10.14 respectively. Potassium (P) and Sodium (Na) was higher in strong saline zone than less and medium saline zone.

Table 1: Soil chemical properties of study area. The value after the '±' sign is the standard error. (Source: Rima, MS thesis, 2016)

Parameter	Mean value
OM (%)	6.06±0.83
EC (dS/m)	5.90±0.52
pH	7.10±0.07
N (µg/g)	31.47±4.84
P (µg/g)	39.95±11.09
K (mg/g)	0.20±0.01
Na (mg/g)	2.94±0.18

3.3. Stand Characteristics

Stand density and regeneration density of Strong saline zone was higher than other two zones (Table 2). But basal area, average DBH, average Height was higher in less saline zone. Crown density was 79%. for strong saline zone where in less saline zone the crown density was 73%. *Heritiera fomes, Excoecaria agallocha, Avicennia officinalis, Amoora cucullata Xylocarpus mekongensis, Ceriops decandra* were found in the study area. Importance value of *A. officinalis* was higher in less and moderate saline zone but in strong saline zone *E. Agallocha* had the highest importance value.

Table 2: Stand characteristic of study area. The value after the '±' sign is the standard error. (Source: Rima, MS thesis, 2016)

Parameters	Value
Stand density (Stem ha^{-1})	700±145
Basal area (m^2 ha^{-1})	50.44±7.51
Average DBH (Cm)	28.57±5.80
Average Height (m)	9.76±1.30
Crown Density (%)	73.17±2.85
Regeneration density (No. ha^{-1})	8271±990

3.4. Experiment Setup

Seedlings of *A. officinalis* were raised in Forest Nursery of Forestry and Wood Technology Discipline, Khulna University. The raised seedlings were originated from the seeds of oligohaline zone of the Sundarbans. Seedlings of one year old were raised in in hydroponic culture with different salinity levels. Eight levels of crude sea salt solutions (0 to 35 ppt at 5 ppt interval) were applied. At the end of this experiment, the seedlings were harvested and separated into parts (leaf, Stem, bark and root). The parts of seedlings were oven-dried at 80 ° C. For nutrient analysis root, steam, bark and leaf were taken from each individual plant.

3.5. Nutrient Analysis

3.5.1. Sample Preparation

All of the collected leaves were dried at 80°C for 24 hrs. The oven dried sample was crashed and sieved through 2mm mesh sieve and preserved at dry place in air tight plastic container for further analysis.

3.6. Determination of Nutrients (N P, K) and Sodium (Na)

To determine nitrogen (N) concentration 0.1 gm. plant sample was digested with 1.1 gm catalyst mixture and 3ml sulphuric acid (H_2SO_4) according to Baethgen and Alley (1989). Catalyst mixture was prepared with Potassium sulphate (K_2SO_4), Cupper sulphate (CuSO4) and Selenium powder (Se) in the proportion of 100:10: 1. Digested sample were filtered with whiteman filter paper 1 and diluted to 100 ml. Filtered sample solution was mixed with working buffer solution known as solution 1-$Na_2HPO_4.12H_2O$ (35.8 gm), N-K tartrate (50 gm) and NaOH (54 gm) dilute to 1 litter with distilled water, for solution 2- Na salicylate (150 gm)-Na Nitroprussidesolution (0.30 gm) dilute to 1 litter with distilled water and (solution 3- was 5.25% Na Hypochlorite Solution (30 ml dilute to 500 ml distilled water) to develop color and let it stand for 45 minutes at 25 °C or 15 minutes at 37 °C. Diluent is prepared with K_2SO_4, $CuSO_4$ and Selenium powder to make the standard curve. Stock solution (100 ppm) was prepared with dry NH_4Cl. Afer preparing standard curve measurements were taken with UV-Spectrophotometer at 650 nm wavelength. Plant sample was digested with concentrated nitric acid at 100 °C for 50 to 60 minutes. After that 6.4 ml mixed acid (Nitric acid, Perchloric acid 60% and Sulphuric acid mixed at the proportion of 10:2:1) to the predigested samples and digest at 200°C for 20 minutes Allen (1974). This digestion was used to determine phosphorus (P), potassium (K) and sodium (Na) in plant

samples. Filter the digested samples through Whiteman filter paper No 42 and diluted to 100 ml. Phosphorus was measured according to Murphy and Riley, 1962. A mixed solution was prepared to mix with digested, Solution 1- Ammonium molybdate solution $(NH_4)_6Mo_7O_{24}.4H_2O$- 4 gm dilute to 100 ml distilled water at 50 °C), Solution 2- Ascorbic Acid Solution (2.64 gm dilute to 50 ml and kept it in freez), Solution 3- Antimony potassium tartrate Solution (0.1454 gm dilute to 50 ml), and solution 4- Sulfuric acid (35 ml dilute to 250 ml). Stock solution preparation (50 ppm) was prepared with Dry KH_2PO_4. To prepare 50 ppm o.1098 gm was diluted to 500 ml before doing final volume 3 ml H_2SO_4 was added. To prepare 5 ppm solution 10 ml of 50 ppm solution was diluted to 100 ml with distilled water. Measure the absorbance of the standards and samples with UV-Spectrophotometer at 880 nm wavelength. Potassium (K) and Sodium (Na) was measured by Flame Photometer (PFP7, Jenway LTD, England). To determine potassium and sodium dilute the digest sample as required (Adding 1ml sample and 9 ml distilled water makes the sample 10 times diluted). For preparation of standard curve, solution of 0, 5, 10 ppm was prepared from the stock solution of Flame Photometry Standard 1000 ppm Potassium an Flame Photometry Standard 1000 ppm Sodium. Then K and Na-concentration was calculated of each sample by using the standard equation.

3.7 Data Analysis

Statistical analyses were done by using SAS (6.12.0.1) and IBM SPSS statistics 20 statistical software. Nutrients (N, P, K) and Na concentration in different parts of *A. officinalis* seedlings in response to salinity were analyzed by two-way Analysis of variance (ANOVA) followed by Least Significant Difference (LSD) with Bonferroni adjustment (sig^b) at .05 level of significance.

Chapter IV

Results

Results

4.1. Nitrogen Concentration in Parts of *Avicennia officinalis* Seedlings

Nitrogen concentration found to vary significantly ($p<0.05$) among the parts of seedling and leaf contains comparatively higher concentration of nitrogen followed by bark, root and stem (Table: 20 (a)),On the other hand nitrogen concentration in plant parts found to decrease with the increase of salinity (Fig: 3). However, Post ANOVA result with Bonferroni adjustment (sig^b at .05 level) showed that there was no significant difference in N concentration from 0 to 15 ppt salinity level (Table: 3). Initial concentration was 54.94 mg/g in leaf at 0 ppt salinity was significantly ($p<0.05$) decrease to 25.56 mg/g at 35 ppt salinity (Fig: 3).

Table 3: Pairwise comparisons of nitrogen concentration among different salinity levels. Means are significantly different (sig^b) at .05 level.

Salinity	0	5	10	15	20	25	30	35
0	-	-	-	-	*(.001)	*(.000)	*(.000)	*(.000)
5	-	-	-	-	*(.007)	*(.000)	*(.000)	*(.000)
10	-	-	-	-	*(.028)	*(.000)	*(.000)	*(.000)
15	-	-	-	-	-	*(.003)	*(.000)	*(.000)
20	*(.001)	*(.007)	*(.028)	-	-	-	*(.011)	*(.001)
25	*(.000)	*(.000)	*(.000)	*(.003)	-	-	-	-
30	*(.000)	*(.000)	*(.000)	*(.000)	*(.011)	-	-	-
35	*(.000)	*(.000)	*(.000)	*(.000)	*(.001)	-	-	-

* The mean difference is significant at the 0.05 level

On the other hand nitrogen concentration in bark found to decrease with the increase of salinity (Fig: 3). However, Post ANOVA result with Bonferroni adjustment (sigb at .05 level) showed that there was no significant difference in N concentration from 0 to 10 ppt salinity level (Table: 4). Initial concentration was 16.41 mg/g in bark at 0 ppt salinity was significantly ($p<0.05$) decrease to 9.24 mg/g at 35 ppt salinity.

Table 4: Pairwise comparisons of nitrogen concentration in bark among different salinity levels. Means are significantly different (sig[b]) at .05 level.

Salinity	0	5	10	15	20	25	30	35
0	-	-	-	*(.023)	*(.000)	*(.000)	*(.000)	*(.000)
5	-	-	-	-	*(.010)	*(.000)	*(.000)	*(.000)
10	-	-	-	-	-	*(.000)	*(.002)	*(.001)
15	*(.023)	-	-	-	-	*(.027)	*(.013)	*(.004)
20	*(.000)	*(.010)	-	-	-	-	-	-
25	*(.000)	*(.000)	*(.005)	*(.027)	-	-	-	-
30	*(.000)	*(.000)	*(.002)	*(.013)	-	-	-	-
35	*(.000)	*(.000)	*(.001)	*(.004)	-	-	-	-

Nitrogen concentration in root found to decrease with the increase of salinity (Fig: 3). Initial concentration was 12.40 mg/g in leaf at 0 ppt salinity was significantly ($p<0.05$) decrease to 7.79 mg/g at 35 ppt salinity. Post ANOVA result with Bonferroni adjustment (sig[b] at .05 level) showed that there was no significant difference in N concentration from 0 to 15 ppt salinity level (Table: 5).

Table 5: Pairwise comparisons of nitrogen concentration in root among different salinity levels. Means are significantly different (sig[b]) at .05 level.

Salinity	0	5	10	15	20	25	30	35
0	-	-	-	-	*(.000)	*(.000)	*(.000)	*(.000)
5	-	-	-	-	*(.003)	*(.000)	*(.000)	*(.000)
10	-	-	-	-	*(.005)	*(.000)	*(.000)	*(.000)
15	-	-	-	-	-	*(.005)	*(.001)	*(.000)
20	*(.000)	*(.003)	*(.005)	-	-	-	-	-
25	*(.000)	*(.000)	*(.000)	*(.005)	-	-	-	-
30	*(.000)	*(.000)	*(.000)	*(.001)	-	-	-	-
35	*(.000)	*(.000)	*(.000)	*(.000)	-	-	-	-

Stem contains the lowest amount of nitrogen. Initial concentration was 11.12 mg/g in leaf at 0 ppt salinity was significantly ($p<0.05$) decrease to 4.85 mg/g at 35 ppt salinity (Fig: 3). However, Post ANOVA result with Bonferroni adjustment (sig[b] at .05 level) showed that there was significant difference in N concentration from 0 to 35 ppt salinity level (Table: 6).

Table 6: Pairwise comparisons of nitrogen concentration in stem among different salinity levels. Means are significantly different (sig[b]) at .05 level.

Salinity	0	5	10	15	20	25	30	35
0	-	*(.002)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)
5	*(.000)	-	*(.000)	*(.007)	*(.001)	*(.000)	*(.000)	*(.000)
10	*(.000)	-	-	-	-	*(.000)	*(.000)	*(.000)
15	*(.000)	*(.007)	-	-	-	*(.000)	*(.000)	*(.000)
20	*(.000)	*(.001)	-	-	-	*(.001)	*(.000)	*(.000)
25	*(.000)	*(.000)	*(.000)	*(.000)	*(.001)	-	*(.000)	*(.009)
30	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	-	-	-
35	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.009)	-	-

* The mean difference is significant at the 0.05 level

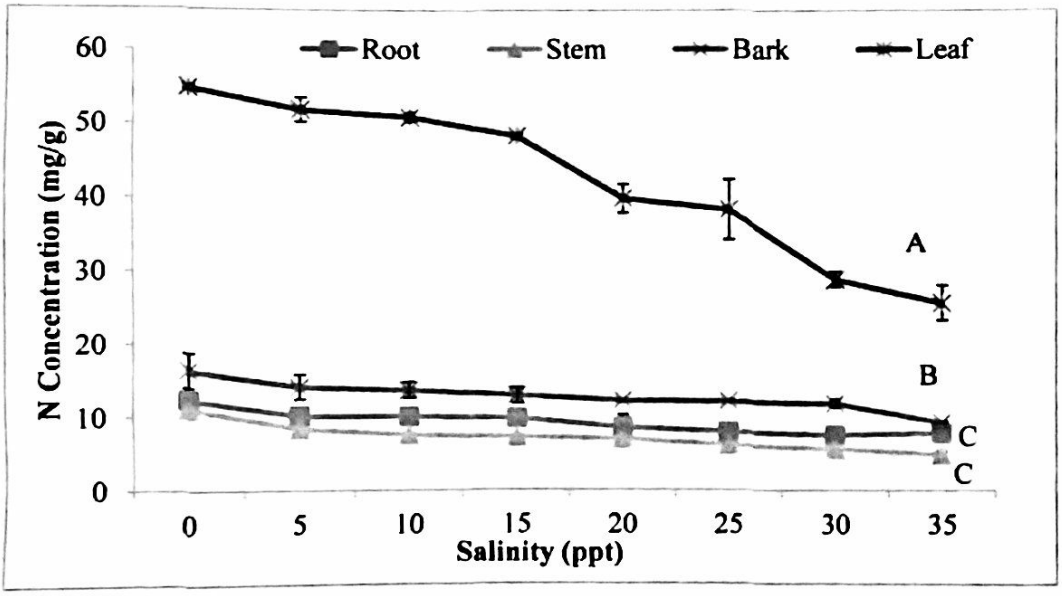

Fig 3: Nitrogen concentration in different parts of seedlings

However significant difference ($P<0.05$) in N concentration was found among root, stem, bark and leaf (Fig: 3) of seedling.

4.2. Phosphorus Concentration in Parts of *Avicennia officinalis* Seedlings

Phosphorus concentration found to vary significantly ($p<0.05$) among the parts of seedling and leaf contains comparatively higher concentration of phosphorus followed by bark, root and stem (Table: 20 (b)). Phosphorus concentration in plant parts found to decrease with the increase of salinity (Fig: 4). Initial concentration was 5.33 mg/g in leaf at 0 ppt salinity was

significantly ($p<0.05$) decrease to 2.66 mg/g at 35 ppt. salinity. Post ANOVA result with Bonferroni adjustment (sig^b at .05 level) showed that there was no significant difference in N concentration from 0 to 15 ppt salinity level (Table: 7).

Table 7: Pairwise comparisons of phosphorus concentration in leaf among different salinity levels. Means are significantly different (sig^b) at .05 level.

Salinity	0	5	10	15	20	25	30	35
0	-	-	-	-	*(.000)	*(.000)	*(.000)	*(.000)
5	-	-	-	-	*(.000)	*(.000)	*(.000)	*(.000)
10	-	-	-	-	*(.000)	*(.000)	*(.000)	*(.000)
15	-	-	-	-	*(.001)	*(.000)	*(.000)	*(.000)
20	*(.000)	*(.000)	*(.000)	*(.001)	-	-	*(.000)	*(.000)
25	*(.000)	*(.000)	*(.000)	*(.000)	-		*(.002)	*(.000)
30	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.002)	-	-
35	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	-	-

* The mean difference is significant at the 0.05 level

On the other hand phosphorus concentration in bark found to decrease with the increase of salinity (Fig: 4). Initial concentration was 3.2 mg/g in bark at 0 ppt. salinity was significantly ($p<0.05$) decrease to 1.46 mg/g at 35 ppt. salinity. However, Post ANOVA result with Bonferroni adjustment (sig^b at .05 level) showed that there was no significant difference in P concentration from 0 to 5 ppt salinity level (Table: 8).

Table 8: Pairwise comparisons of phosphorus concentration in bark among different salinity levels. Means are significantly different (sig^b) at .05 level.

Salinity	0	5	10	15	20	25	30	35
0	-	-	*(.001)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)
5	-	-	*(.008)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)
10	*(.001)	*(.008)	-	-	-	*(.022)	*(.000)	*(.001)
15	*(.000)	*(.000)	-	-	-	-	*(.003)	*(.004)
20	*(.000)	*(.000)	-	-	-	-	*(.022)	*(.001)
25	*(.000)	*(.000)	*(.022)	-	-	-	-	*(.003)
30	*(.000)	*(.000)	*(.000)	*(.003)	*(.022)	-	-	-
35	*(.000)	*(.000)	*(.000)	*(.000)	*(.001)	*(.003)	-	-

* The mean difference is significant at the 0.05 level

Phosphorus concentration in root found to decrease with the increase of salinity (Fig: 4). Initial concentration was 0.24 mg/g in root at 0 ppt. salinity was not significantly ($p>0.05$) decrease to 0.18 mg/g at 35 ppt. salinity. Post ANOVA result with Bonferroni adjustment (sig^b at .05 level) showed that there was no significant difference in P concentration from 0 to 5 ppt salinity level (Table: 9).

Table 9: Pairwise comparisons of phosphorus concentration in leaf among different salinity levels. Means are significantly different (sig^b) at .05 level. Root

Salinity	0	5	10	15	20	25	30	35
0	-	-	*(.027)	*(.011)	*(.000)	*(.000)	*(.000)	*(.000)
5	-	-	-	-	*(.027)	*(.011)	*(.000)	*(.000)
10	*(.027)	-	-	-	-	-	*(.000)	*(.000)
15	*(.011)	-	-	-	-	-	*(.001)	*(.000)
20	*(.000)	*(.027)	-	-	-	-	-	*(.004)
25	*(.000)	*(.011)	-	-	-	-	-	-
30	*(.000)	*(.000)	*(.000)	*(.001)	-	-	-	-
35	*(.000)	*(.000)	*(.000)	*(.000)	*(.004)	-	-	-

* The mean difference is significant at the 0.05 level

Stem contains the lowest amount of phosphorus. Initial concentration was 0.13 mg/g in leaf at 0 ppt salinity an increase to 0.16 mg/g at 35 ppt. salinity and was not significantly difference ($P>0.05$) (Fig: 4). Post ANOVA result with Bonferroni adjustment (sig^b at .05 level) showed that there was no significant difference in P concentration from 0 to 15 ppt salinity level (Table: 10).

Table 10: Pairwise comparisons of phosphorus concentration in stem among different salinity levels. Means are significantly different (sig[b]) at .05 level.

Salinity	0	5	10	15	20	25	30	35
0	-	-	-	-	*(.001)	*(.000)	*(.000)	*(.000)
5	-	-	-	-	*(.008)	*(.000)	*(.000)	*(.000)
10	-	-	-	-	*(.049)	*(.001)	*(.000)	*(.000)
15	-	-	-	-	-	*(.014)	*(.001)	*(.000)
20	*(.001)	*(.008)	*(.049)	-	-	-	-	*(.026)
25	*(.000)	*(.000)	*(.001)	*(.014)	-	-	-	-
30	*(.000)	*(.000)	*(.000)	*(.001)	-	-	-	-
35	*(.000)	*(.000)	*(.000)	*(.000)	*(.026)	-	-	-

* The mean difference is significant at the 0.05 level

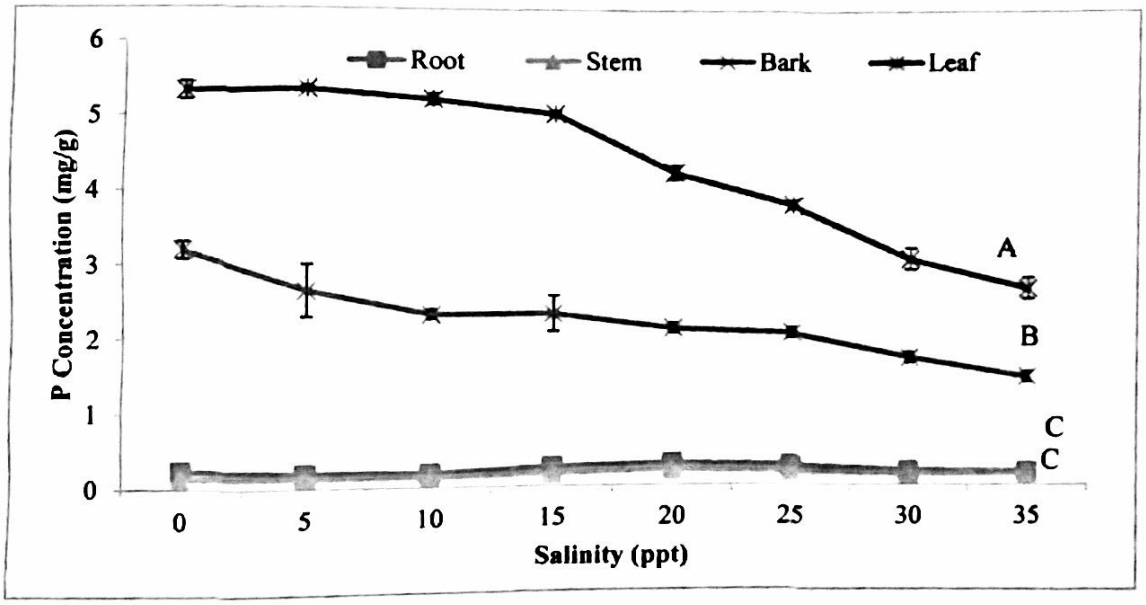

Figure 4: P concentration in different parts of seedlings

However significant difference ($P<0.05$) in P concentration was found among root, stem, bark and leaf (Fig.4) of seedling.

4.3. Potassium Concentration in Plant Parts of *Avicennia officinalis* Seedlings

Potassium concentration found to vary significantly ($p<0.05$) among the parts of seedling and leaf contains comparatively higher concentration of potassium followed by bark, stem and root (Table: 20 (c)). Potassium concentration in plant parts found to decrease with the increase of salinity (Fig: 5). Initial concentration was 9.25 mg/g in leaf at 0 ppt salinity was

significantly ($p<0.05$) decrease to 6.06 mg/g at 35 ppt salinity. Post ANOVA result with Bonferroni adjustment (sig^b at .05 level) showed that there was no significant difference in K concentration from 0 to 15 ppt salinity level (Table: 11).

Table 11: Pairwise comparisons of Potassium concentration in leaf among different salinity levels. Means are significantly different (sig^b) at .05 level.

Salinity	0	5	10	15	20	25	30	35
0	-	-	-	-	*(.001)	*(.000)	*(.000)	*(.000)
5	-	-	-	-	*(.007)	*(.000)	*(.000)	*(.000)
10	-	-	-	-	*(.028)	*(.000)	*(.000)	*(.000)
15	-	-	-	-	-	*(.003)	*(.000)	*(.000)
20	*(.001)	*(.007)	*(.028)	-	-	-	*(.011)	*(.001)
25	*(.000)	*(.000)	*(.000)	*(.003)	-	-	-	-
30	*(.000)	*(.000)	*(.000)	*(.000)	*(.011)	-	-	-
35	*(.000)	*(.000)	*(.000)	*(.000)	*(.001)	-	-	-

* The mean difference is significant at the 0.05 level

Potassium concentration in bark found to decrease with the increase of salinity (Fig: 5). Initial concentration was 5.84 mg/g in bark at 0 ppt. salinity was significantly ($p<0.05$) decrease to 4.34 mg/g at 35 ppt salinity. Post ANOVA result with Bonferroni adjustment (sig^b at .05 level) showed that there was no significant difference in K concentration from 0 to 5 ppt salinity level (Table: 12).

Table 12: Pairwise comparisons of Potassium concentration in leaf among different salinity levels. Means are significantly different (sig^b) at .05 level Bark

Salinity	0	5	10	15	20	25	30	35
0	-	-	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)
5	-	-	*(.008)	*(.001)	*(.000)	*(.000)	*(.000)	*(.000)
10	*(.000)	*(.008)	-	-	*(.001)	*(.000)	*(.000)	*(.000)
15	*(.000)	*(.001)	-	-	*(.008)	*(.000)	*(.000)	*(.000)
20	*(.000)	*(.000)	*(.001)	*(.008)	-	-	*(.002)	*(.000)
25	*(.000)	*(.000)	*(.000)	*(.000)	-	-	*(.040)	*(.000)
30	*(.000)	*(.000)	*(.000)	*(.000)	*(.002)	*(.040)	-	*(.000)
35	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	-

* The mean difference is significant at the 0.05 level

Potassium concentration in root found to decrease with the increase of salinity (Fig: 5). Initial concentration was 1.41 mg/g in root at 0 ppt salinity was significantly ($p<0.05$) decrease to 1.27 mg/g at 35 ppt salinity. Post ANOVA result with Bonferroni adjustment (sig^b at .05 level) showed that there was no significant difference in K concentration from 0 to 30 ppt salinity level (Table: 13)

Table 13: Pairwise comparisons of Potassium concentration in root among different salinity levels. Means are significantly different (sig^b) at .05 level.

Salinity	0	5	10	15	20	25	30	35
0	-	-	-	-	-	-	-	*(.009)
5	-	-	-	-	-	-	-	*(.015)
10	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-
20	-	-	-	-	-	-	-	*(.017)
25	-	-	-	-	-	-	-	-
30	-	-	-	-	-	-	-	-
35	*(.009)	*(.015)	-	-	*(.017)	-	-	-

* The mean difference is significant at the 0.05 level

In Stem initial concentration was 2.96 mg/g in stem at 0 ppt salinity was significantly ($p<0.05$) decrease to 2.41 mg/g at 35 ppt salinity (Fig: 5). Post ANOVA result with Bonferroni adjustment (sig^b at .05 level) showed that the1re was no significant difference in K concentration from 0 to 30 ppt salinity level (Table: 14)

Table 14: Pairwise comparisons of Potassium concentration in stem among different salinity levels. Means are significantly different (sig^b) at .05 level.

Salinity	0	5	10	15	20	25	30	35
0	-	-	-	-	-	-	-	*(.047)
5	-	-	-	-	-	-	-	-
10	-	-	-	-	-	-	-	-
15	-	-	-	-	-	-	-	-
20	-	-	-	-	-	-	-	-
25	-	-	-	-	-	-	-	-
30	-	-	-	-	-	-	-	-
35	*(.047)	-	-	-	-	-	-	-

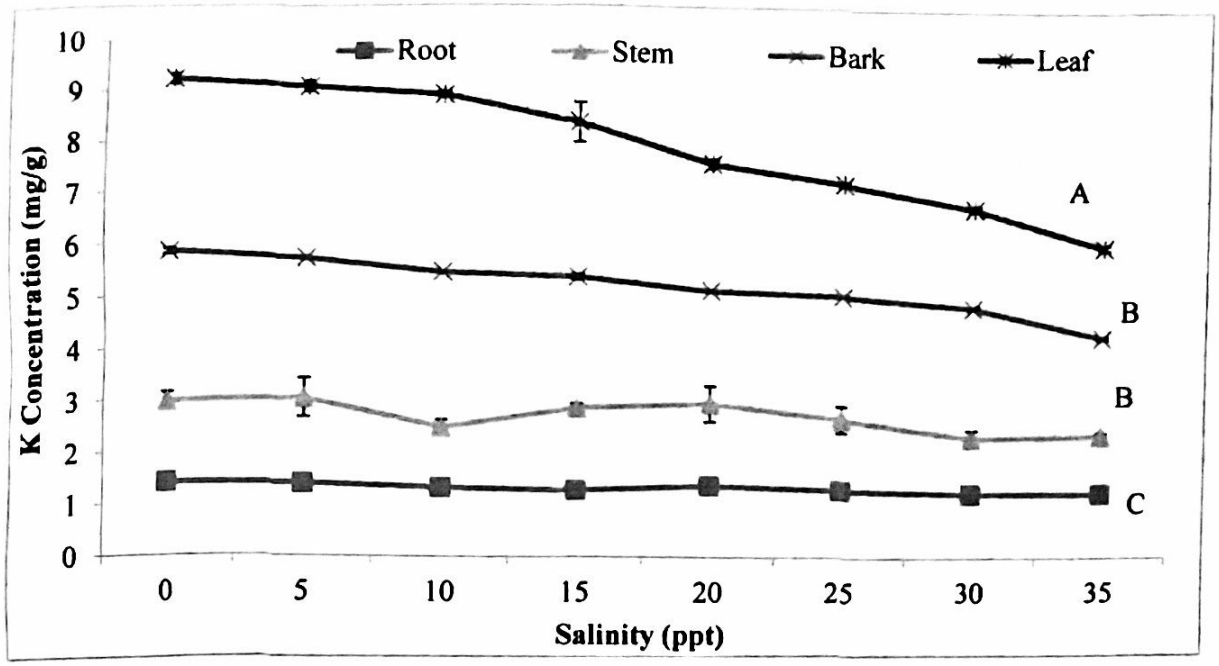

Figure 5: K concentration in different parts of seedlings

However significant difference ($P<0.05$) in K concentration was found among root, stem, bark and leaf (Fig.5) of seedling.

4.4. Sodium Concentration in Plant parts of *Avicennia officinalis* Seedlings

Sodium concentration found to vary significantly ($p<0.05$) among the parts of seedling and leaf contains comparatively higher concentration of sodium followed by bark, root and stem (Table: 20 (d)). On the other hand nitrogen concentration in plant parts found to decrease with the increase of salinity (Fig: 6). Initial concentration was 20.77 mg/g in leaf at 0 ppt salinity was significantly ($p<0.05$) increase to 29.70 mg/g at 35 ppt. salinity. However, Post ANOVA result with Bonferroni adjustment (sig^b at .05 level) showed that there was no significant difference in Na concentration from 0 to 10 ppt salinity level (Table: 15).

Table 15: Pairwise comparisons of Sodium concentration in leaf among different salinity levels. Means are significantly different (sig[b]) at .05 level. Leaf

Salinity	0	5	10	15	20	25	30	35
0	-	-	-	*(.007)	*(.000)	*(.000)	*(.000)	*(.000)
5	-	-	-	-	*(.001)	*(.000)	*(.000)	*(.000)
10	-	-	-	-	*(.017)	*(.001)	*(.000)	*(.000)
15	*(.007)	-	-	-	-	*(.017)	*(.000)	*(.000)
20	*(.000)	*(.001)	*(.017)	-	-	-	*(.017)	*(.003)
25	*(.000)	*(.000)	*(.001)	*(.017)	-	-	-	*(.041)
30	*(.000)	*(.000)	*(.000)	*(.000)	*(.017)	-	-	-
35	*(.000)	*(.000)	*(.000)	*(.000)	*(.003)	*(.041)	-	-

* The mean difference is significant at the 0.05 level

On the other hand sodium concentration in bark found to increase with the increase of salinity (Fig: 6). Initial concentration was 15.55 mg/g in bark at 0 ppt. salinity was significantly ($p<0.05$) increase 18.76 mg/g at 35 ppt. salinity. Post ANOVA result with Bonferroni adjustment (sig[b] at .05 level) showed that there was no significant difference in Na concentration from 0 to 25 ppt salinity level (Table: 16).

Table 16: Pairwise comparisons of Sodium concentration in leaf among different salinity levels. Means are significantly different (sig[b]) at .05 level Bark

Salinity	0	5	10	15	20	25	30	35
0	-	-	-	-	-	-	*(.000)	*(.000)
5	-	-	-	-	-	-	*(.004)	*(.000)
10	-	-	-	-	-	-	*(.000)	*(.000)
15	-	-	-	-	-	-	*(.004)	*(.000)
20	-	-	-	-	-	-	*(.004)	*(.000)
25	-	-	-	-	-	-	-	*(.037)
30	*(.000)	*(.004)	*(.000)	*(.004)	*(.004)	-	-	-
35	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.037)	-	-

* The mean difference is significant at the 0.05 level

Sodium concentration in root found to increase with the increase of salinity (Fig: 16). Initial concentration was 3.61 mg/g in root at 0 ppt. salinity was significantly ($p<0.05$) increase to

4.63 mg/g at 35 ppt salinity. Post ANOVA result with Bonferroni adjustment (sig[b] at .05 level) showed that there was no significant difference in Na concentration from 0 to 20 ppt salinity level (Table: 17).

Table 17: Pairwise comparisons of Sodium concentration in root among different salinity levels. Means are significantly different (sig[b]) at .05 level.

Salinity	0	5	10	15	20	25	30	35
0	-	-	-	-	-	*(.000)	*(.000)	*(.000)
5	-	-	-	-	-	*(.000)	*(.000)	*(.000)
10	-	-	-	-	-	*(.000)	*(.000)	*(.000)
15	-	-	-	-	-	*(.000)	*(.000)	*(.000)
20	-	-	-	-	-	*(.000)	*(.000)	*(.000)
25	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	-	-	-
30	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	-	-	-
35	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	-	-	-

* The mean difference is significant at the 0.05 level

Stem contains the lowest amount of nitrogen. Initial concentration was 2.81 mg/g in leaf at 0 ppt. salinity was significantly ($p<0.05$) decrease increase 3.15mg/g at 35 ppt salinity (Fig: 6). Post ANOVA result with Bonferroni adjustment (sig[b] at .05 level) showed that there was no significant difference in Na concentration from 0 to 25 ppt. salinity level (Table: 18).

Table 18: Pairwise comparisons of nitrogen concentration in stem among different salinity levels. Means are significantly different (sig[b]) at .05 level.

Salinity	0	5	10	15	20	25	30	35
0	-	-	-	-	-	-	*(.005)	*(.002)
5	-	-	-	-	-	-	*(.035)	*(.012)
10	-	-	-	-	-	-	*(.028)	*(.010)
15	-	-	-	-	-	-	-	-
20	-	-	-	-	-	-	-	-
25	-	-	-	-	-	-	-	-
30	*(.005)	*(.035)	*(.028)	-	-	-	-	-
35	*(.002)	*(.012)	*(.010)	-	-	-	-	-

* The mean difference is significant at the 0.05 level

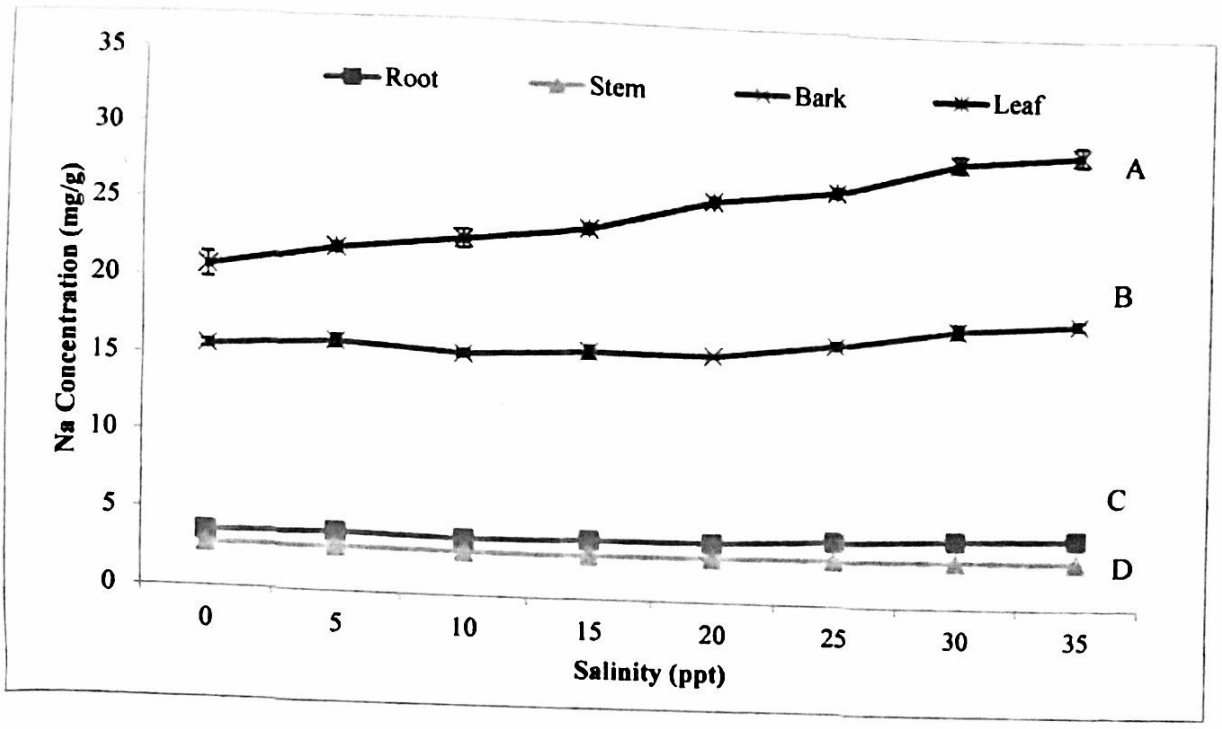

Fig 6: Na concentration in different parts of seedlings

However significant difference ($P<0.05$) in Na concentration was found among root, stem, bark and leaves of seedling.

Strong negative correlation was observed in leaf, stem, bark, and root for nitrogen, phosphorus, and potassium (Table: 19). But positive correlation was found for sodium.

Table 19: Correlation among the nutrient concentration and seedling parts.

S. Parts \ Nutrient	N	P	K	Na
Root	-0.956	-0.18	-0.803	0.9389
Stem	-0.941	0.4622	-0.676	0.9286
bark	-0.945	-0.967	-0.96	0.8956
Leaf	-0.974	-0.959	-0.983	0.9942

Table 20: Pairwise comparisons of N concentration among different Seedling parts.

S. Parts \ Salinity		Nitrogen (N)							
		0	5	10	15	20	25	30	35
Leaf	Bark	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.001)
	Stem	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)
	Root	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)
Bark	Leaf	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.001)
	Stem	*(.000)	*(.008)	(.001)	-	-	-	*(.001)	-
	Root	*(.000)	*(.050)	(0.24)	-	-	-	*(.003)	-
Stem	Bark	*(.000)	*(.008)	(.001)	-	-	-	*(.001)	-
	Leaf	*(.000)	*(.000)	(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)
	Root	*(.049)	-	-	-	-	-	-	-
	Stem	*(.049)	-	-	-	-	-	-	-
Root	Bark	*(.000)	*(.050)	*(.001)	-	-	-	*(.003)	-
	Leaf	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)

(S. Parts- Seedling parts)

Table 21: Pairwise comparisons of P concentration among different Seedling parts.

S. Parts \ Salinity		Phosphorus (P)							
		0	5	10	15	20	25	30	35
Leaf	Bark	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)
	Stem	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)
	Root	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)
Bark	Leaf	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)
	Stem	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)
	Root	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)
Stem	Bark	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)
	Leaf	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)
	Root	-	-	-	-	-	-	-	-
	Stem	-	-	-	-	-	-	-	-
Root	Bark	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)
	Leaf	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)

(S. Parts- Seedling parts)

Table 22: Pairwise comparisons of K concentration among different Seedling parts.

S. Parts	Salinity	Potassium (K) 0	5	10	15	20	25	30	35
Leaf	Bark	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)
	Stem	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)
	Root	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)
Bark	Leaf	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)
	Stem	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)
	Root	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)
Stem	Bark	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)
	Leaf	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)
	Root	*(.000)	*(.000)	*(.000)	*(.004)	*(.001)	*(.001)	*(.000)	*(.000)
Root	Stem	*(.000)	*(.000)	*(.000)	*(.004)	*(.001)	*(.001)	*(.000)	*(.000)
	Bark	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)
	Leaf	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)

(S. Parts- Seedling parts)

Table 23: Pairwise comparisons of Na concentration among different Seedling parts.

S. Parts	Salinity	Sodium (Na) 0	5	10	15	20	25	30	35
Leaf	Bark	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)
	Stem	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)
	Root	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)
Bark	Leaf	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)
	Stem	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)
	Root	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)
Stem	Bark	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)
	Leaf	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)
	Root	-	-	-	-	*(.020)	*(.002)	*(.035)	*(.019)
Root	Stem	-	-	-	-	*(.020)	*(.002)	*(.035)	*(.019)
	Bark	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)
	Leaf	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)	*(.000)

Chapter V

Discussion

5. Discussion

Comparatively higher concentrations of nutrients (N, P, K) were observed in leaves and lower concentration were found in bark, stems, and root. The trend of N, P and K concentrations in different parts of *A. officinalis* similar to that of *R. apiculata* (Ong et al. 1984), *Bruguiera* spp. and *Ceriops* spp (Aksornkoae and Khemnark 1984) and *H. fomes*(Mahmood et al. 2014) and *M. pinnata* (Nasrin et al., 2017). N, P, K are more aboundant in physiologically active and photosynthetic tissue like leaves (Marschner, 1995) This could be the reason to get comparatively higher concentration of nutrients in a living green parts of plants than the woody parts (Binkley, 1986; Khan et al., 2000; Mahmood et al., 2006).

Present study also demonstrated the impact of salinity on nutrient distributional pattern in different parts of *A. officinalis* seedlings. Where we get significant increase in sodium concentration lead to decrease the concentration of nitrogen, phosphorus, potassium in seedling parts, that ultimately showed negative relationship among nutrient concentration and salinity. However, this phenomenon has been well describing by the Cramer et al. (1991), Grattan and Grieve (1999), Mahmood et al. (2014) and Nasrin et al. (2017). Their studies describe that high concentrations of Na showed antagonistic relation with uptake of N, P, and K by plants. This phenomenon has been well demonstrated by the photo-synthetically active plant parts like leaves.

Moreover, the inherent mechanism describes that chlorine ion (Cl^-) as well as salinity has a negative impact on NO_3^- uptake (Kafkafi et al., 1982; Feigin et al., 1987; Bar et al., 1997; Kao et al. 2001). Similarly, salinity decreases the uptake of P in plant tissue and leads to reduce the accumulation phosphorus in tissues of plants. Sharpley et al., 1992, Sonneveld and de Kreij 1999; Kaya et al. 2001). Under saline-sodic or sodic conditions, high levels of external Na interfere with K acquisition by the roots (Grattan, 1999). Excess sodium in soil limits the uptake of water due to decreased water potential, which may result in wilting (Munns, 2002; Zhu, 2010). This could be the reason to get negative correlation between nitrogen in plant parts and salinity. Bar et al., 1997; Feigin et al., 1987; Kafkafi et al., 1982; Lea-Cox and Syvertsen, 1993 for different plant species.

Conclusion

There is a significance difference ($p<0.05$) for N, P, K and Na among the different plant parts (Leaves, Stem, Bark and Root). Individually in root P has no significant difference, similarly for stem P, and for bark N was not significant difference. For every case it was found that leaf contains more nutrients and sodium as it is more active part in plants. And as a woody part stem contains less minerals. So leaves store more minerals than other parts (bark, stem, and root) of seedlings.

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