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EFFECT OF SALINITY ON SURVIVAL AND GROWTH OF *Xylocarpus granatum* (Koeing) SEEDLINGS

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FORESTRY AND WOOD TECHNOLOGY DISCIPLINE
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2014

Dedicated

To

My Beloved Parents

Abstract

Xylocarpus granatum (Koeing) is a mangrove species found in Sundarbans mangrove forest. In this study, survival and growth of seedlings of this species were investigated at three different salinity levels. The study was conducted in hydroponic culture with Hoagland's nutrient solution. Survivals of seedlings were found 83% upto 5 ppt in six different salinity level. Comparatively higher value was found at 0 ppt for growth. Comparatively lower value at 25 ppt.

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APPROVAL

Project thesis submitted to the Forestry and Wood Technology Discipline, Khulna University, Khulna, Bangladesh, in partial fulfillment of the requirements for one year professional MS degree in Forestry. I have approved the style and format of the project thesis.

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DECLARATION

I, Serajis Salekin here by declare that the project thesis is based on my original work except for quotations and citations, has been carried out under the direct supervision of Dr. Mahmood Hossain, Professor, Forestry and Wood Technology Discipline, Khulna University, Khulna which have been duly acknowledged and it has not been previously or concurrently submitted or accepted for any other degree at Khulna University or other institutions.

I give my consent for my thesis, if accepted, to be available for photocopying and for interlibrary loan, for the title and summary to be made available for other organizations.

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CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Mangrove forest is ecologically and ecologically important ecosystem of the tropical and subtropical coasts (Tomlinson, 1986; Siddiqi, 2001). Mangroves are almost exclusively tropical and found approximately between latitudes 32° N and 38° S. About 112 countries have mangroves within their coastline, which cover 4% of the world's coastline and 25% of the tropical coasts (Spalding, M. 1997.). There are about 12 to 20 million hectares of mangroves distributed over the world (FAO and UNEP, 2007). The distribution of world mangroves are divides into two regions Indo-pacific region and West Africa and American region and 114 mangrove species, belonging to 66 genera and 43 families is found in the world mangroves Mangroves are very important for coastal ecosystem. Mangroves trap and cycle various organic materials, chemical elements, and important nutrients in the coastal eco-system. Mangroves provide one of the basic food chain resources for marine organisms. Mangroves serve as storm buffers by reducing wind and wave action in shallow shoreline areas (Tomlinson, 1986).

The mangrove forests of Bangladesh are composed of two major components, *viz.*, the Sundarbans and the Coastal Afforestation. A large-scale coastal afforestation programme has been undertaken since 1966, that covering about 170 000 ha, which become the world's largest man made mangroves. The Sundarbans is the largest single tract of mangrove in the world occupying an area about 5,771 km^2 has supplied products and services to mankind for centuries and has been under scientific management for more than 100 years. Prain (1903) identified a total of 334 species belonging to 245 genera of angiosperms and ferns from the entire Sundarbans and adjacent areas. Of these about 123 occur in the Bangladesh part (Hussain and

Acharya 1994). Chaffey et al. (1985) recorded 65 taxa of angiosperms and ferns found in the Sundarbans. The forest is now showing signs of degradation with an annual depletion rate of about 1.7%. The real causes of depletion of the Sundarbans are not yet clear but we usually mention many factors. Of which, increase in salinity is identified as the most important one till today. Though mangrove species are capable to withstand in the saline water but only a few of them have the ability to tolerate high saline environment as Hossain *et al.* (2001) reported salt tolerance capacity of mangroves is species specific and there exists a relationship between the salinity of water and the distribution of the species (Curtis, 1933). Karim *et al.*, (1982) and Islam (1982) charecterised the soils of sunderbans as moderately saline to the east and highly saline. Soil salinity of the sunderbans is low in comparison with other mangrove areas in the world (Chansang, 1984; Johnstone and Erodin, 1982) where soil salinity usually exceeds that of sea water. So, some of the mangrove species has low salt tolerance could be eliminated from the Sundarbans mangrove ecosystem.

Growth at seedling stage are more sensitive to salinity than subsequent ones (Lal, 1985). Salt is an important regulatory factor in the costal ecosystems. There is an optimal salinity range for maximum growth of different mangrove species. *Xylocarpus granatum* a valuable timber species of the Sundarbans mangrove forest (Siddiqi, 2001) and it can be an important species for next generation coastal afforestration. But very few study is carried out about this species. It is thought that the decreasing abundance of *Xylocarpus granatum* in the Sundarbans may be due to the increased salinity, seed predation and grazing. Therefore this study has taken to investigate the effect of salinity on survival and growth of *X. granatum* seedling.

1.2 Objectives of the study

The objectives of this study include

- To study the effect of salinity on survival of *Xylocarpus granatum.*
- To study the effect of salinity on growth of *Xylocarpus granatums* seedlings.

CHAPTER TWO

REVIEW OF LITERATURE

2.1 General description of *Xylocarpus granatum*

Sunderbans is the largest single tract mangrove forest in the world. Dhundal (*Xylocarpus granatum*) is an important species and its under the red list of IUCN. This species is moderately small sized tree and its height ranged from 6 to 12 m (Sing *et al., 1998*). The peculiarity of the tree is that the flaking of bark from their stem in a patch of flake. The species cannot produce pneumataphores but it produce buttress (Tomlinson, 1994).

Around the world there are 15 species, subspecies, varieties, forms, and cultivars in this genus. *Xylocarpus mekongensis*, *Xylocarpus granatum* are available in the Sundarbans. *Xylocarpus mekongensis* differs from *Xylocarpus granatum* in the absence buttressed trunk, and in having blind root suckers, elliptic-oblong leaflets and smaller fruits by which it is easily identified in the field (Tomlinson, 1994). It hardly forms a pure zone and is found in between *Rhizophora* and *Avicennaia* zone (Das and Siddiqui, 1985).

2.1.1 Systematics of *Xylocarpus mekongensis*

Domain: Eukaryota

- Kingdom: Plantae
  - Subkingdom: Viridaeplantae
    - Phylum: Tracheophyta
      - Subphylum: Euphyllophytina
        - Infraphylum: Radiatopses
          - Class: Magnoliopsida
            - Subclass: Rosidae
              - Superorder: Rutanae
                - Order: Rutales
                  - Suborder: Meliineae
                    - Family: Meliaceae
                      - Genus: Xylocarpus

Specific epithet: *granatum* J.Koenig,Naturforscher (Halle). 20: 2. 1784

Botanical name: - *Xylocarpus granatum* J. Koenig

Source: Zipcodezoo, 2010

2.2 Distribution

Xylocarpus granatum is commonly described as occurring in the upper intertidal zone of mangrove forests, but the mature trees are occasionally found at the lower elevations. This species found growing well in strongly saline zone and moderately saline zone of low laying area (James et al, 2003).

2.2.1 Distribution of *Xylocarpus granatum* in the world

X. granatum occurs in East Africa including Kenya, Madagascar and the Red sea, Andaman and Nicobars Ceylon, East India, Burma, Thailand, Combodia, Malay Peninsula, Sumatra, Borneo, Java, Myanmar, Sri Lanka Lesser, Philippines, Celeare, North territory Gulf of carpesntaria, North Queensland, New Guinea, Micronesia. Southeastern Australia, Bismarck Archipelago, Pacific atolls, New Caledonia, Fiji island of west central Pacific (Tomlinson, 1994).

2.2.2 Distribution of *Xylocarpus granatum* in Bangladesh

X. granatum in occurs in the Sunderbans, Chokoria Sunderbans and other coastal areas. But sometime this species can be found in upland swamps (Das and Alam, 1994).

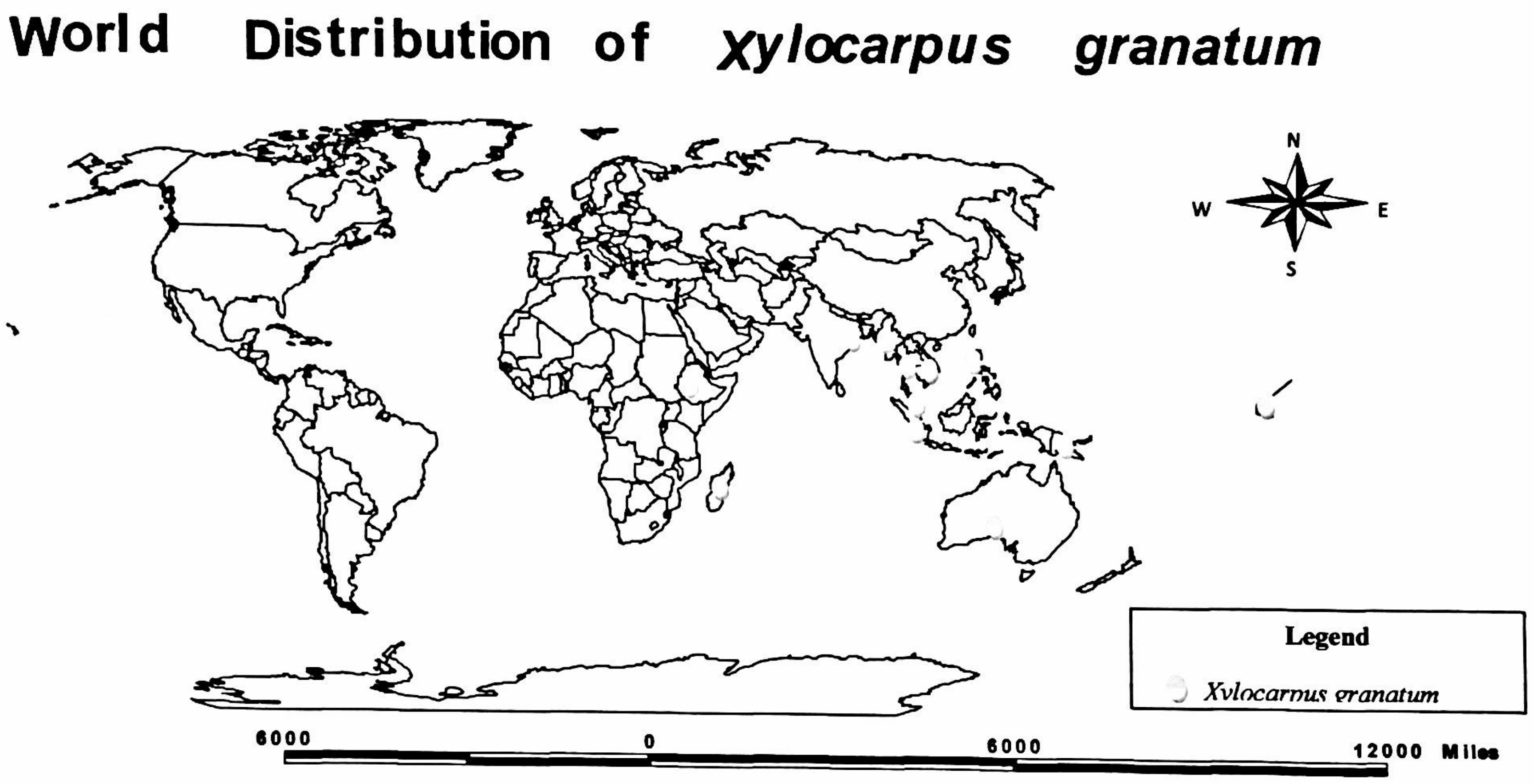


Figure 2.1: Worldwide distribution of *Xylocarpus granatum*

2.3 Morphology

2.3.1 Mature tree

Normally trees remain single trunked. The bark is very characteristic, smooth, pale greenish or yellowish brown and peeling in irregular pathes so that the trunk is blotchy. Lenticels are not conspicuous. Buttress development appears fairly late and is usually preceded by the first evidence of the plate like surface roots in trees about 5m high (Tomlinson, 1994).

Small to medium sized, glabrous, evergreen tree; leaves abruptly pinnate, occasionally simple, rachis smooth, brown or red, 7-10cm long, (leaves of young plant-lanceolate with acute tip), apex obtuse, base narrowed, very shortly petiolated. Flowers small in glabrous panicles of 4-7cm long racemes in the axils of the leaves, fruit large, 15-25 cm across. Pericarp woody; with a short pointed tip. Seeds 5-6, very large, angular and brown (Das and Alam, 2001).

2.3.2 Leaves

Light green in color, with a rounded apex, and on average 10cm long and 4cm wide. Petiole of the leaf is short and corky (Tomlinson, 1986). Leaves are oval-shaped and thickened at the base where they meet the stem. This thickening allows the leaves to either face or avoid the sun (S. Shaikh, 2004).

Plate 2.2: leaves of *Xylocarpus granatum*

2.3.3 Flowers

The flowers of *X. granatum* are very small (about 0.5cm) and are white to pink in color (S. Shaikh, 2004). Flowers fragrant, with white petals, about 8mm across (S. Shaikh, 2004).

Plate 2.3: Flowers of *Xylocarpus granatum*

2.3.4 Fruit

Fruits up to 25cm in diameter, to the size of the melon (Tomlinson, 1994). The fruits are light yellowish red to brownish. Vertically stripped with dark brownish color. Split 10days after collection into 3-4 parts. Each contains 2-3 dark brown seeds (Hossain, 1997).

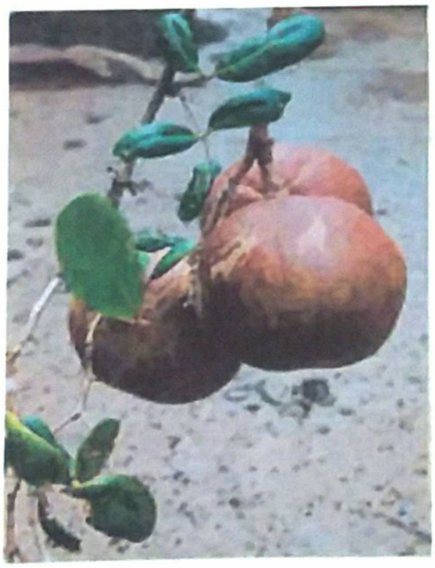


Plate 2.4: Fruits of *Xylocarpus granatum*

2.3.5 Seed

The seeds are dark brown; the average weight of epicarp is 350±280 gm with a range of 180 to 630 gm. The weights of big, medium and small seeds are 140.98±10.73, 106±12.03 and 61.92±4.43 gm, respectively (Hossain, 1997).

The seeds are angular and fitted completely into the fruit cavity, the outer convex surface is pressed against the inner fruits wall and the angular, often pyramidal facets are fitted together in a completely closed – packed arrangement. Seeds have a thick corky testa; the embryo has an un-differentized cotyledonary mass with the plumule and radical some time on one internally facing facet but more usually on the outer convex face. The site of the radical is evident as a small boss. Seeds may start to germinate by extrusion of the radical while still floating (Tomlinson, 1994).

Plate 2.5: Seeds of *Xylocarpus granatum*

2.3.6 Bark

The bark is smooth, pale greenish to yellowish brown and peeling in irregular patches so that the trunk is blotchy. The bark is unfissured and thin patches. (S. Shaikh, 2004).

2.3.7 Root system

The above ground root system of *X. granatum* is often absent in young individuals. Older individuals often display buttresses, which cause enlargement of the trunk base diameter and which extend into partially above-ground ribbon like roots (Tomlinson, 1986).

2.4 Silviculture and Management

2.4.1 Flowering of *Xylocarpus granatum*

Inflorescences consist of a central axis supporting spirally arranged inconspicuous and ephemeral bracts. Each bract usually subtends a 3- flowered cyme with even smaller braceoes. The irregular inflrencence structure in this species, emphasized by Noamesi, is the result of zigzag development of the axis and the frequent abortion of flowers in the cymes. In a regular cyme the terminal flower seems most often to be female, the lateral to be male. Flowers expand rather irregularly (usually the terminal flower of a cyme opens first) and are quite strongly but pleasantly scented (Tomlinson, 1994).

2.4.2 Development of fruits

A fruit develops rapidly and normally only 1 fruit appears from a single inflorescence. As the fruit enlarges, a short massive axis is produced, becoming pendulous with increasing weight. The mature fruit is the size of a good melon and weight 2 or 3 kg. the 4 sutures of the future woody valves are evident as 4 shallow equidistant furrows. The fruit mainly shatters on impact after its fall from the tree, with the valves breaking away from the fruit stalk releasing the several seeds. Fruits are always well filled, as if there is no abortion of ovules, and Noamesi records up to 20 seeds, but 8 to 10 is a more usual number (Tomlinson, 1994).

2.4.3 Seeds development

Seeds are angular and fitted completely into the fruit cavity; the outer convex surface is pressed against the inner fruit wall, and the angular, often pyramidal internal facets are fitted together in a completely close-packed arrangement. Seeds have a thick corcky testa; the embryo has an undifferentized cotyledonary mass with the plumule and radical sometimes on one internally facing facet but more usually on the outer convex face. The site of the radical is evident as a small boss. Seeds may start to germinalte by extrusion of the radical while still floating. No information is available about the longevity of seeds. Seedlings are quite common in *Xylocarpus* communities so that maintaenance of populations as well as dispersal seems effective (Tomlinson, 1994).

2.4.4 Seed germination of *Xylocarpus granatum*

Germination is initiated by extension of the hypocotyls so that the radical is extruded from the seed. The cotyledons stay within the seeds, which may remain attached to the seedling for a long time. The plumule grows upward through the cleft between the paired cotyledons, which are fused within the seed. The plumule extends rapidly and it reaches a height of 50 cm in a few weeks. It bears a series of spirally arranged scale leaves, which are progressively more distant. At the same time the radical extends and branches to form, at least initially, a distinct taproot (Tomlinson, 1994).

2.5 Regeneration

2.5.1 Natural regeneration

The large woody capsule of *Xylocarpus granatum* may split on the parent tree to release the angular seeds or may shatter when they fall. The testa is woody or corky. seeds of *X. granatum* may start to germinate by extrusion of the radicle while still floating (Tomlinson, 1994).

2.5.2 Artificial regeneration

2.5.2.1 Seed collection

This species have two flowering and fruiting times, ripen fruits are found during March and also in the month of June- July. Color changes from light brown to dark brown indicates the maturation of fruits. Fruits are collected manually and a fruits usually contain 5-15 seeds (Siddiqi, 1993; Hossain, 1997).

2.5.2.2 Nursery technique

The seeds were usually sown in 30 cm × 20 cm poly bags with loamy soils and watered regularly. Initially polybag soil has been moistened with 0.2% sodium chloride solution. Germination usually started after 7 days. Initial fast growth of observed 50 days (Hossain, 1997).

2.5.2.3 Vegetative propagation

Vegetative propagation through air layering has been successful for *Xylocarpus granatum*. The mature *Xylocarpus granatum* having a length of about 35mm, treated with IAA, IBA AND 2,4-D (2,5 and 10mg/liter), and IAA-L-alanin, IAA-L-aspartic acid and IAA-L-glycine (all at 2 mg/liter), or not treated (control) before covering the wrapping. rooting was observed only during monsoon and post-monsoon months in the shoot branches treated with hormones. the twig were cut off after root formation, planted and establishd successfully in the soil (Kathiresan and Ravikumar, 1995).

2.6 Uses of *Xylocarpu. granatum*

Xylocarps. granatum is used for various purposes, for example, fuel wood, boat building, house post and making furniture etc. (Sastri, 1993; Das and Siddiqi, 1985).

Its fine textured whitish wood is used in statue carving (FAO, 1982; Hellal, 1998).

In Tanzania *Xylocarpus granatum* is used for chows and furniture (Temu, 1975).

The calorific value of *Xylocarpus granatum* is 3899 cal/g and can be used as fuel and other energy producing materials (FAO, 1994).

Bark and Seeds of *Xylocarpusgranatum* are contains high amount of tannin and fruits also contains resin (Das and Alam, 2001).

The bark and leaf ethanolic extracts showed potential anti-diarrhoea activity against castor oil-induced diarrhea in rats in a dose-dependent manner. The bark extract showed antibacterial activity (Gram positive) and anti-yeast activity (Rao *et al., 2003*).

The seeds are used to treat stomach problems and the fruit pulp to treat stomach problems and the fruit pulp to cure rashes (Diop, 1993).

2.7 Salinity and mangrove

Salt is an essential requirement for mangrove but it is a critical factor for the development of mangrove ecosystems. At lower intensities, it influences survival, distribution, growth, reproduction and zonation of mangroves by eliminating more vigorous terrestrial plants. Even germination of some seeds of some halophytes is dependent on a certain level of salinity. On the contrary, at increased level it might cause overall degradation of mangroves. For example, *Heritiera fomes* has strong performance for low salinity and its growth rate significantly decreases with increasing salinity. Some species can adjust to a wide range of salinity levels, whereas many others can withstand a narrow range of it (Siddiqi, 2001).

The optimal range of salinity of physiological function and growth of seedlings is approximately from 3 to 27 ppt (Field, 1984; Hutchings and Saenger, 1987; Ball and Pidsley, 1995; Aziz and Khan, 2001) although salinity optima have been shown to vary with seedling age (Hutchings and

Saenger, 1987). Above or below the optimal salinity, gas exchange and growth are reduced (Ball and Farquhar, 1984; Ball, 1988; Ball *et al.,* 1995; Allen and Krauss, 2003).

Increased saline conditions affect plant growth by limiting the availability of water against the osmotic gradient, reducing nutrient availability and causing toxic accumulation of sodium and chloride ions (Waisel, 1972). Toxic accumulation of Na^+ and Cl^- causing water stress conditions which enhance closure of stomata, reduced photosynthesis (Waisel, 1972). When salinity increases and water potentials around plant roots decrease, turgidity of plant cells declines and cells cease to divide and elongate. Under water-stress conditions stomata are closed, photosynthesis is reduced, protein breakdown is accelerated and plants lose weight (Kozlowski, 1972; Kramer, 1951). Thus increased salinity affects negatively mangrove plants.

Salinity is also a controlling factor for seedling recruitment and the relation is negatively proportional.10, 000 to 53,350 seedlings/ha occur naturally in different parts of the Sunderbans (Chaffey *et al.,* 1985; Siddiqi, 1994; Faizuddin *et al.,* 1996) but failed to regenerate. Whereas Stoddard (1978) reported that 2,500 – 4,000 seedlings/ha may be enough to produce a well stocked stand. Siddiqi (2001) noted that recruitment of sundri and gewa seedling in the Sunderbans reduced with increased of salinity. There also exist adverse impact of increased salinity on canopy development, leaf initiation and leaf area expansion in *S. alba* and *S. lanceolata* (Ball and Pidsley, 1995). Salinity, therefore, greatly influences the overall growth and productivity of the mangroves (Das and Siddiqi, 1985).

The impact of increased salinity in the Sunderbans is great since it controls the distribution of species and productivity of the forest considerably (Das and Siddiqi, 1985). In the Sunderbans, the western part is more saline, which do not bear tall, and dense vegetation coverage. Rather it has been occupied by less economic dwarf trees like *Exoecaria agallocha* etc. Besides the production of sundri and *Nypa fruiticans* (golpatta) all over the Sunderbans have been declined due to increased salinity (Siddiqi, 2001).

2.7.1 Factors affecting salinity

Salinity in the mangroves is regulated by tidal inundation, salinity of tidal waters, fresh water discharge, temperature, rainfall, humidity, wind action, evaporation etc. Clarke, (1970) observed that soil salinity is the consequence of the interaction among the frequency of tidal inundation, evaporation and supply of fresh water. Other factors contributing towards the development of salinity include soil type and topography, depth of impervious subsoil, amount and seasonality of rainfall, freshwater discharge in rivers, run on from adjacent terrestrial areas, and run off (Hutchings and Saenger, 1987).

Increased temperature enhances evaporation and thereby causes increase of salinity. Rainfall lessens salinity through adding freshwater in the ecosystem and makes the environment suitable for mangrove. Humidity influences the evapotranspiration in the mangrove which regulates salt movement in the soil. High salinity accompanied with high temperature and wind causes accumulation of salt at the surface of the soil that makes the site unsuitable for mangroves. The extent of plant cover also has a significant influence on evaporative losses from the mangrove community (Hutchings and Saenger, 1987).

2.8 Salinity status of the Sunderbans

Sunderbans is the single largest natural mangrove tract in the world, located in the southern part of Bangladesh. Being on the land sea interface, this forest is always associated with and subjected to saline water which is the causes of frequent fluctuation of salinity levels. This tidal mangrove swamp is inundated twice daily. Tidal inundation mainly regulates the salinity level of Sunderbans. Depth and duration of tidal inundation depend on many factors like distance from the main rivers and sea including local relief and sediment load in the inundating water (Rahman, 1995).

The salinity of Sunderbans increases from east to west and north to south, but remains less than 6 dS m^{-1} even in the driest month (Hassan and Razzaque, 1981). Soil salinity in April-May remains between 2 and 4.5 dS m^{-1} in most part of the Sunderbans. Based on the degree of salinity, the Bangladesh Sunderbans has been divided in to three salinity zones—less saline zone (salinity < 2 ds m^{-1}), moderately saline zone (2-4 dS m^{-1}) and strong saline zone (>4 dS m^{-1}). Water salinity along the northern part of the Sunderbans ranges from 1-9 ppt (parts per thousand) in the late monsoon (September). This range in water salinity during the dry season (May) varies from 4 - 28 ppt (Siddiqi, 2001, 1992).

However, salinity of Sunderbans has considerably increased in recent years due to reduce fresh water flow in the Ganges. This problem followed by the construction of the Farakka barrage in the Indian territory to withdraw water from the Ganges (Shafi, 1982).

2.8.1. Salinity Influence on seedling development

The optimal range of physiological function and growth of seedlings is approximately from 3 to 27 ppt (Field, 1984; Hutchings and Saenger, 1987; Ball and Pidsley, 1995; Aziz and Khan, 2001) although salinity optima have been shown to vary with seedling age (Hutchings and Saenger, 1987). Above or below the optimal salinity, gas exchange and growth are reduced (Ball and Farquhar, 1984; Ball, 1988a; Ball *et al.,* 1997; Tuffers *et al.,* 2001; Munns, 2002; Krauss and Allen, 2003a; Biber, 2006).

Photosynthesis of mangroves, like that of many vascular woody plants, on average ranges between 5 and 20 mmol CO_2 m_2 s_1 (Von Caemmerer and Farquhar, 1981; Andrews et al., 1984; Clough and Sim, 1989; Naidoo et al., 2002). Under favorable conditions of low salinity, the rate of photosynthesis can exceed 25 mmol CO_2 m_2 s_1 (Clough and Sim, 1989). At higher salinities, gas exchange becomes restricted by both stomatal and non-stomatal (i.e., biochemical) limitations in many halophytes (Flowers and Yeo, 1986; Kozlowski, 1997; Munns, 2002). When freshwater is limiting (i.e., physiological drought) mangroves have to be more restrictive with water loss. Stomatal restrictions reduce photosynthesis and transpiration rates and increase PWUE (Ball and Farquhar, 1984; Clough and Sim, 1989; Lin and Sternberg, 1992; Sobrado and Ball, 1999; Sobrado, 2005).

Mangroves exhibit conservative water use patterns relative to other woody vascular plants as increased water use efficiency is an effective mechanism at maintaining metabolic function in highly saline environments (Clough, 1992; Sobrado, 2000, 2001). Transpiration is decoupled from salt exclusion at the roots, since salt flux to the leaves does not increase with higher transpiration (Ball, 1988). Instead, stomatal constraints restrict water loss under conditions of limited water availability. In what is known as the dessication– starvation dilemma (Luttge, 1997), plant CO^2 uptake for growth occurs simultaneously with transpirational water loss via the stomates. Consequently, to grow, mangroves have to allow for some degree of water loss. The observed patterns of growth in mangroves may have developed as strategies to avoid vascular embolisms and excess salt accumulation around the roots (Ball and Passioura, 1994).

At high salinities, the non-stomatal limitations to gas exchange are purportedly the result of biochemical damage to a leaf's Photosystem II: chronic exposure to salinity can lead to the collapse of plant biochemical function, cell damage, and ultimately plant death (Flowers and Yeo, 1986). However, studies of *Avicennia marina* and *A. germinans* have not demonstrated these biochemical impairments. Instead, reduced net carbon assimilation at 60 ppt was a function of higher PWUE coupled with greater photorespiration (Sobrado and Ball, 1999); similar observation was also found *in R. mangle* by Lo´pez-Hoffman *et al*. (2006).

Growth responses of congeneric (Ball and Pidsley, 1995) and sympatric (Cardona-Olarte et al., 2006) mangrove seedlings have been shown to differ across a range of salinities and with salinity fluxes. Increasing salt tolerance, however, is at the expense of higher nutritional demands and lower maximal growth rates at low salinities (Ball, 1988, 1996). Exposure to a constant salinity level might even be less physiologically demanding on a seedling than fluctuating salinity levels. For example, Lin and Sternberg (1992) showed that growth and leaf gas exchange rates of *R. mangle* were lower under fluctuating salinities compared to constant salinities.

Prolonged high salinity exposure may result in restricted growth due to water uptake limitations: leaves become small and thick (Camilleri and Ribi, 1983; Medina and Francisco, 1997; Sobrado, 2001) and plants have less leaf area than those growing at lower salinity (Naidoo, 2006)

2.8.2.Increased salinity and the Sunderbans mangrove ecosystem

Salt is an essential requirement for mangrove but it is a critical factor for the development of mangrove ecosystems. At lower intensities, it influences survival, distribution, growth, reproduction and zonation of mangroves by eliminating more vigorous terrestrial plants. Even germination of some seeds of some halophytes is dependent on a certain level of salinity. On the contrary, at increased level it might cause overall degradation of mangroves. For example, *Heritiera fomes* has strong performance for low salinity and its growth rate significantly decreases with increasing salinity. Some species can adjust to a wide range of salinity levels, whereas many others can withstand a narrow range of it.

Increased saline conditions affect plant growth by limiting the availability of water against the osmotic gradient, reducing nutrient availability and causing toxic accumulation of sodium and chloride ions (Waisel, 1972). Toxic accumulation of Na^+ and Cl^- causing water stress conditions which enhance closure of stomata, reduced photosynthesis (Waisel, 1972). When salinity increases and water potentials around plant roots decrease, turgidity of plant cells declines and cells cease to divide and elongate. Under water-stress conditions stomata are closed, photosynthesis is reduced, protein breakdown is accelerated and plants lose weight (Kozlowski, 1972; Kramer, 1951). Thus increased salinity affects negatively mangrove plants.

Salinity is also a controlling factor for seedling recruitment and the relation is negatively proportional.10, 000 to 53,350 seedlings/ha occur naturally in different parts of the Sunderbans (Chaffey *et al.*, 1985; Siddiqi, 1994; Faizuddin *et al.*, 1996) but failed to regenerate. Whereas Stoddard (1978) reported that 2,500 – 4,000 seedlings/ha may be enough to produce a well stocked stand. Siddiqi (2001) noted that recruitment of sundri and gewa seedling in the Sunderbans reduced with increased of salinity. There also exist adverse impact of increased salinity on canopy development, leaf initiation and leaf area expansion in *S. alba* and *S. lanceolata* (Ball and Pidsley, 1995). Salinity, therefore, greatly influences the overall growth and productivity of the mangroves (Das and Siddiqi, 1985).

The impact of increased salinity in the Sunderbans is great since it controls the distribution of species and productivity of the forest considerably (Das and Siddiqi, 1985). In the Sunderbans, the western part is more saline, which do not bear tall, and dense vegetation coverage. Rather it has been occupied by less economic dwarf trees like *Exoecaria agallocha* etc. Besides the production of sundri and *Nypa fruiticans* (golpatta) all over the Sunderbans have been declined due to increased salinity.

CHAPTER THREE

MATERIALS AND METHODS

Effect of salinity on the growth of *Xylocarpus granatum* (Koeing.) seedlings was studied under different salinity levels. In sea water and thus in mangrove environment, NaCl represent the highest proportion of salts and others are present only in trace amount. Thus in this study salt means NaCl. This growth study was carried out in hydrophonic condition.

3.1 Materials

The experiment was carried out in hydroponic culture in glass house at Khulna University nursery as it permits efficient control on level of salinity and nutrient supply to plants and ease of management.

The following materials were used to perform the experiment.

- 2 liter PET bottle
- Plastic tub
- Knife and Scissors
- Cork sheet Box
- Tap water
- Modified Hoagland's nutrient solution
- Coarse sand
- Salinity meter

3.2 Collection of seeds

Mature seeds of *Xylocarpus mekongensis* were collected from the Sundarbans Reserved Forest (SRF) during March 2012.

3.4 Preparation solution

3.4.1 Preparation of salt solution

A stock of salt solution of 100 ppt was prepared by adding normal salt (NaCl) in water, which was checked with a hand held salinity Refractometer ATAGO, S/MILL-9502, Japan. Using the stock saline, solutions of various salinity levels were prepared using the following formula:

$$V_1S_1=V_2S_2$$

Here, V_1 = volume of solution in cubic centimeter.

S_1 = final concentration of solution in ppt

S_2 = known concentration of stock solution in ppt (100 ppt).

V_2 = determining volume of stack solution in ppt

The prepared solution concentration was justified by the Refractometer again.

3.4.2 Preparation of modified Hoagland's nutrient solution

Modified Hogland solution was used as nutrient solution for the growth study (Table-1). To avoid further contamination of Na^+ and Cl^- from the Hogland nutrients some of the chemicals containing Na^+ and Cl^- were replaced.

Table-1. Chemical constitutions of modified Hoagland's nutrient solution

Salt	For Stock Solution (gm/L)	To Use (ml/L)
KH_2PO_4	136.09	1.00
KNO_3	101.11	5.00
$Ca(NO_3)_2.4H_2O$	236.20	5.00
$MgSO_4.7H_2O$	246.50	2.00
H_3BO_3	2.86	1.00
$MnSO_4.H_2O$	1.81	1.00
$ZnSO_4.5H_2O$	0.22	1.00
$CuSO_4.5H_2O$	0.08	1.00
$(NH_4)_6Mo_7.4H_2O$	0.02	1.00
Ferric Citrate	0.05	1.00

3.5 Experiment Setup

Individual seedlings were placed in a pet bottle of 2 litters and thus a total of 72 seedlings were prepared. Twelve seedlings were put in one cork sheet box (dimension) and in this way a total of six box were prepared. Different treatments of salinity were given to those boxes. Eight litter of modified Hoagland's nutrient solution was added to each box to get the upto the mark with desired salinity levels.

3.6 Growth study

Growth performance for gradual increase of salinity level was studied by taking fresh watered germinated seedlings with gradually increasing the salinity level. Initially the salinity of the growth study media was zero and in second week the salinity of the first treatment was remain zero and all other treatment were increased into 1 ppt in the 3rd week the salinity of the first treatment was remain zero and other treatment were increase 2 ppt following the same procedure salinity increased gradually from 0 to 25 ppt.

3.7 Survival Study

A total of 12 seedlings were used for each treatment having three replications. Three samples were used in each replication. A total of six treatment of salinity (from 0 to 25 ppt) were prepared at an interval of 5 ppt. Modified Hoagland solution was used to fulfill the nutrient requirement. The experiment was continued for six months and the numbers of survived seedlings were counted at the end of the experiment

3.8 Data collection and analysis

Before seedlings replacement for growth study biomass of each seedling was recorded and these data were used as initial biomass. After completion of growth study for 6 months final biomass was taken. These data were analyzed with SPSS-12 and SAS software.

CHAPTER FOUR

RESULTS

4.1. Survival of seedling

Highest number of seedlings survived at non saline (0 ppt) to moderate saline (5 ppt) condition which are 83% and the survival of seedling showed significant ($p<0.05$) strong correlation ($r=-0.94$) with salinity while the lowest survival (40%) was found at salinity of 25 ppt. Beside this a moderate number of seedlings survived (50%) in 10 ppt to 20ppt salinity range (Fig-).

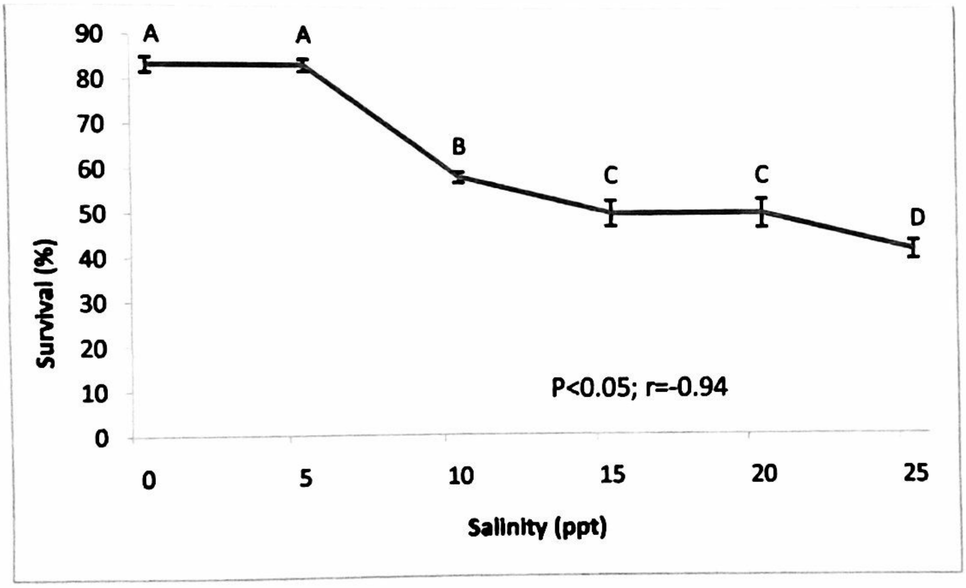
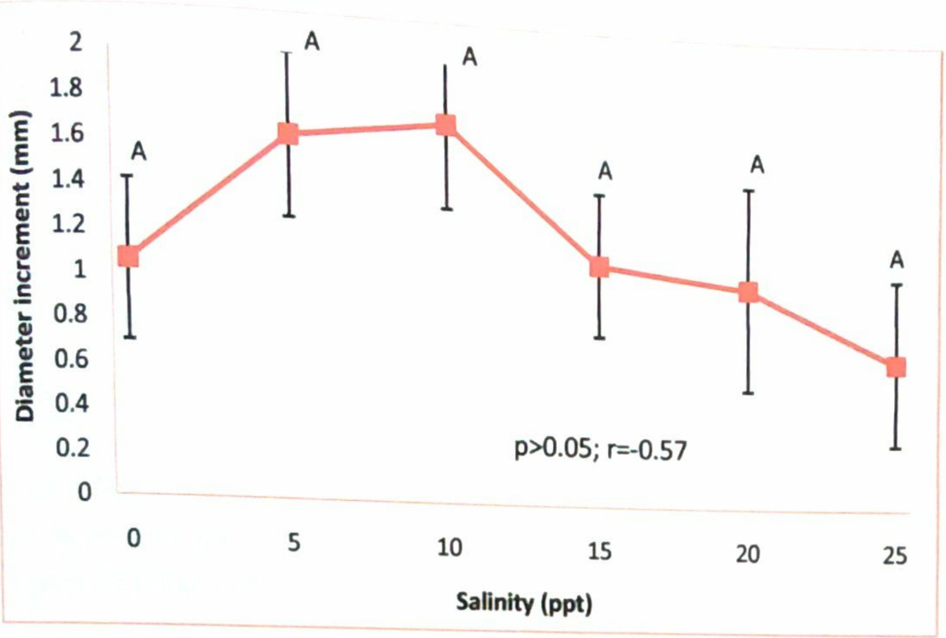


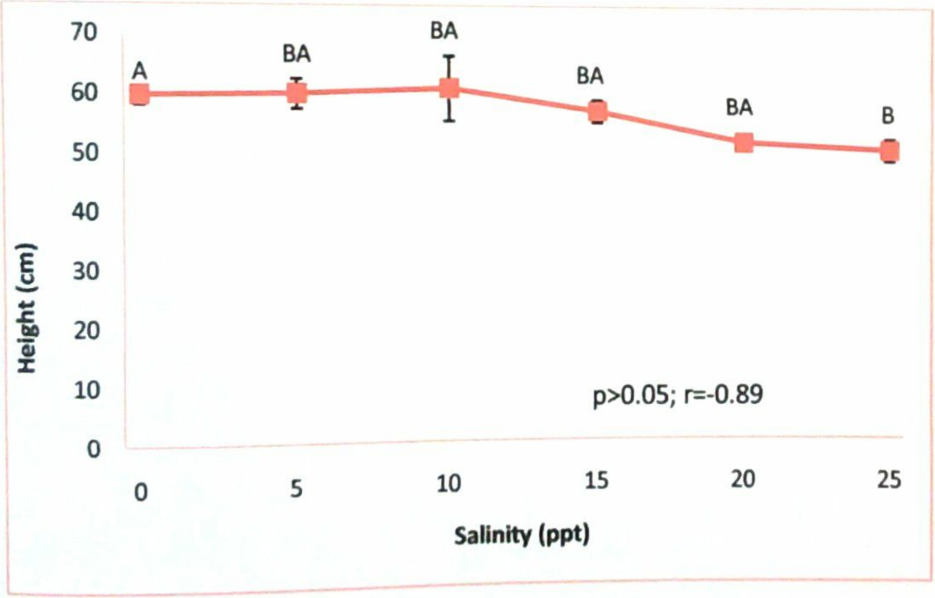
Fig-4.1: Effect of salinity level on survival of seedlings

4.2 Growth of *Xylocarpus granatum* seedling

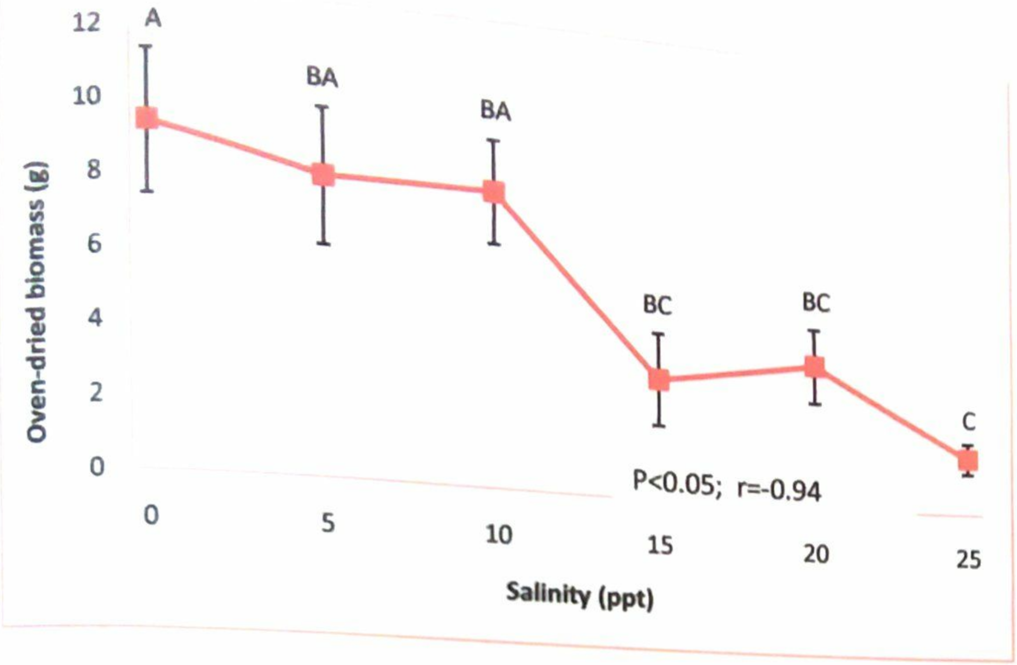
To inspect the growth of X. granatum we considered collar diameter, height and toatal oven dry biomass of the seedlings. Higher growth of seedlings was observed at non-saline condition (0ppt) to moderate (10 ppt) as seedlings survival. Where total biomass increment is highly significant ($p<0.05$) but the other two parameters (collar diameter and height of the seedlings) didn't show any statistical significance with increasing salinity level ($p>0.05$). Furthermore, from the graphical representation it is found that in low salinity level the increment of collar diameter and height of the seedlings are better than that of the high salinity level. Moreover, all of them showed strong negative correlation with increasing salinity level (Fig-).



(a)



(b)



(c)

Fig-: Effect of salinity levels on seedlings of *X. granatum* (a) collar diameter increment (b) height increment and (c) Oven-dried biomass increment. Similar alphabet along the line are not significantly (p>0.05) different.

CHAPTER FIVE

DISCUSSION

5.1. Effect of salinity on survival and growth of *Xylocarpus granatum* seedlings

Salt is an essential and critical factor for the development of mangrove ecosystems Mangroves are not salt lovers, rather they tolerate salt. Irrespectively, higher salinities adversely affect the survival, germination, distribution, growth, reproduction, physiology and zonation of mangrove species (Davis, 1940; Unger 1982; Siddiqi, 2001; Walker *et al.*, 1979; Cornelius, 1980; Ball and Farquhar, 1984; Kozlowski, 1997). Lower intensities favor the development of mangroves by eliminating more vigorous mesophytes.

Seedling survival and growth of mangroves depends on salinity level and the range of salt tolerance which is species specific (Gilles et al. 2001; Nandy Datta et al. 2007). Mangorve seedling involves most of the energy for their growth at the lower saline condition. Conversely, the major part of the energy found to engage for survival at the higher salinity (Lopez-Hoffman 2006). Moreover, Munns, R and Tester, M. (2008) reported unknown mechanism that indicates different changes in plant physiological properties at different part while plant induced to tolerate salinity. These could be the reason to observe comparatively higher survival and growth of *X. granatum* 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., *Rizophora* spp.) found to increase at moderate salinity (Yan et al. 2007; Patel et al. 2010a; Hoppe-Speer 2011). X. granatum being a non-exclusive mangrove species may have the charecteristics of affecting growth even at low saline condition. Higher salinity (>15) 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 (Prezeshki et al. 1990; Sobrado 1999).

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

From the experiment it can be concluded that salinity has significantly negative impact on the growth of *Xylocarpus granatum* seedling. Optimum salinity range for the species appears to be 0-10 ppt though the species can survive a wider range of salinity. Higher salinities do not have any lethal effect on *X. granatum* seedling; rather they are better preserved in higher salinities In field condition the species may tolerate wide range of salinity because this experiment was carried out in laboratory condition and hydroponics culture. But in nature where the environmental factors are interactive, clay in the substrate reduces the effect of salt on plant.

This study has some limitations which draws attention for further research. The limitations are as follows:

- The survival and growth study is carried out in hydroponically culture condition which is not consistent with the natural environment.

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Anova for Survival

Source	DF	Sum of Squares	F Value	Pr > F
Model	5	4752.96955345	65.86	0.0001
Error	12	173.21490438		

Duncan's Multiple Range test for Survival

Duncan Grouping	Mean	N	SALINE
A	83.429	3	0
A	83.076	3	5
B	58.374	3	10
C	50.333	3	20
C	50.000	3	15
D	42.222	3	25

Correlations for Survival

	SALINE	SUR
SALINE	1.00000	-0.94026
0.0	0.0052	
SUR	-0.94026	1.00000
	0.0052	0.0

Anova for Diameter

Source	DF	Sum of Squares	F Value	Pr > F
Model	5	5.05451082	0.87	0.5100
Error	38	44.13276190		

Duncan's Multiple Range test for Diameter

```
Duncan Grouping          Mean    N  SALINE

        A            1.7286    7  10
        A            1.6400    10  5
        A            1.1333    6  15
        A            1.0600    10  0
        A            1.0429    7  20
        A            0.7000    4  25
```

Correlations for Diameter

```
SALINE         1.00000        -0.57099
  0.0          0.2366

 SUR          -0.57099         1.00000
               0.2366          0.0
```

Anova for Height

```
Source          DF   Sum of Squares   F Value    Pr > F

Model            5   644.00033264      2.06      0.0916

Error           38   2372.15292190
```

Duncan's Multiple Range test for Height

```
Duncan Grouping          Mean    N  SALINE

        A            60.843     7  10
     B     A            59.960   10  5
     B     A            59.682   10  0
     B     A            56.967    6  15
     B     A            51.571    7  20
     B                  50.250    4  25
```

Correlations for Height

```
               SALINE            HT

SALINE         1.00000        -0.89174
  0.0          0.0169
```

```
HT          -0.89174        1.00000
             0.0169          0.0
```

Anova for Oven-dry biomass

```
Source          DF   Sum of Squares   F Value   Pr > F

Model            5   343.88291526      3.30    0.0143

  Error         38    791.97435574
```

Duncan's Multiple Range test for Oven-dry biomass

```
Duncan Grouping            Mean    N  SALINE

        A           9.389    10  0
    B       A          8.158    10  5
    B       A          8.157     7  10
    B       C          3.532     7  20
    B       C          3.398     6  15
        C           1.643     4  25
```

Correlations for Oven-dry biomass

```
           SALINE             WT
SALINE           1.00000          -0.94111
         0.0            0.0051

WT           -0.94111          1.00000
         0.0051          0.0
```

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