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LEAF PHENOTYPIC VARIATION OF *SONNERATIA APETALA* Buch. Ham. DUE TO SALINITY IN DIFFERENT SALINE ZONES IN THE SUNDARBANS MANGROVE FOREST, BANGLADESH

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DEDICATION

Dedicated to My Beloved Family

DECLARATION

I,Moumita Biswas, declare that this thesis is the result of my own works and it has not been submitted or accepted for a degree in any other university.

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Moumita Biswas

ABSTRACT

Sonneratia apetala Buch. Ham. is the most important species of Sundarbans.The study of phenotypic variation of Sonneratia apetala is very rare in Sundarbans mangrove forest. We carried out a phenotypic study of leaves of *Sonneratia apetala*, based on 15 parameters, using ImageJ software,Kaleidagraph(version 4) Analysis of variance and co-fficient of variance.The results obtained from one way analysis of variance revealed significant difference of different variable among the salinity zones. However;Keora displays a wide range of variation in its leaf size and shape. By fixing such variations, we describe the leaf phenotypic variation. Until now, only a limited number of studies have been made to describe the leaf phenotypic diversity. Here we investigated the diversity of leaf phenotypic parameter ratio shows high variation in plantation zone. The percentage of co-efficient variation indicates that petiole length shows highest variation among the saline zones and plantation area. Based on the analysis of leaf parameters, the study provides variation in leaf phenotypic parameters in keora.

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CHAPTER ONE : INTRODUCTION

1.1General Introduction

Mangroves are inter- tidal wetlands of tropical and subtropical coastal environment. They occupy a relatively small area, but are highly productive ecosystem. There is no hard and fast definition for the mangroves. A universally accepted definition of mangrove is lacking. The word mangrove may refer to plant species in a specific narrow sence. These plants are halophytes,well adapted to salt water and fluctuation of tide level.Alternately the word mangrove indicates the forest consisting of mangrove and mangrove associated plants. In a wide sence , the mangrove should mean the entire ecosystem comprising the plants, animals and non-living environment. Hamilton and Snekdaker(1984) mentioned "Mangroves are salt tolerant forest ecosystem of tropical and sub tropical inter-tidal regions of the world.

Well developed and large mangroves occur in the muddy sheltered coastline, protected from strong wind and heavy wave action. They are usually found in the mouth of big rivers. Mangroves can grow also on sandy and rocky shores,coral reefs and oceanic islands. Mangrove plants thrive in areas with plentiful supplies of fine sediments and fresh water. Level of salinity and degree of tidal inundation greatly influence the development, species composition and quality of mangrove forest.

The sundarbans, however, is quite rich in floristic composition as compared to many other mangroves of the world. The flora of Sundarbans was thoroughly explored by Heining (1892) as mentioned by Das (1980). Heining reported 70 species from 34 families.Species composition and diversity is mainly depends on the level of salinity, inundation of forest floor,rate of sedimentation,etc. Various species are located in different locations based on a study made by Siddiqi and Khan (1990). Those species *are Sonneratia apetala, Avicennia officinalis, Heritiera fomes, Excoecaria agallocha, Ceriops decandra, Nypa fruticans* and others. (Siddiqi, 1990)

Sonneratia apetala is most important species of Sundarbans and a valuable timber species. It is a pioneer species, colonizes first on newly formed land, grasses and sedges follow it. It can withstand a wide range of salinity. So the species is distributed all over the sundarbans and is successful all along the shoreline of Bangladesh. It requires higher tidal inundation for optimal growth.. *Soneratia apetala* does not grow well on relatively raised lands with low level of tidal inundation. Growth of *Sonneratia apetala* is higher along western coastline where salinity is lower and soil is finer. The growth rate declines at places with higher salinity. Rich stands of *S. apetala* are found also near the mouth of River Naf where maximum and minimum salinity is 32 and 10 ppt respectively. (Siddiqi N. , 2001)

Salinity influences survival, distribution, growth, reproduction and zonation of mangroves. Sundarbans has been divided into three ecological zones based on the criteria of the level of soil salinity, which greatly influences the distribution of species. These are less, moderate and strongly saline zones. Different species have preference for different level of salinity for survival and optimal growth. Vegetation density varies in different zones. Less saline zone is located in the eastern and northeastern part of the forests. The area receives fresh water supply from the Ganges. Different mangroves species have preference for different level of salinity for survival and optimal growth. *Sonneratia apetala* occurs on newly accreted soil in moderately to strongly saline areas and is considered as a pioneer species in ecological succession.

No other studies have been found on morphological variation of leaves in Sundarbans. Actually, very few studies have been focused on digital image-base procedure to characterize and classify taxa. Usher et al (2010) recently reported that the use of NIH Image software for measuring the quantitative parameters of scanned leaves of Banksia robur and Banksia oblongifolia species. Here, we report digital image base procedure using Imagej software for Characterization of leaves of *Sonneratia apetala* through visual comparison of leaf length, leaf width, leaf middle width, leaf upper quarter width, petiole length, leaf area, leaf peremeter, leaf index, area peremeter ratio, base angle and tip angle Ratio.

We assumed that salinity gradients may influences on morphological variation in leaf of *Sonneratia apetala*. So, we conducted a study on morphological variation of fomes. Leaf parameters are being used for identification and classification of Keora. Classification based on leaf type is subjective and may depend on individual preference. Mopreover, a single parameter does not adequately reflect the overall phenotypic experition of Keora. For these reasons phenotypic characterization based on numerical criteria has become a common tool to identify and classify leaf parameters. The purpose of these study is to describe the high leaf phenotypic diversity in *Sonneratia apetala* on scientific basis. Here we characterize Keora by leaf morphology with several parameters. The result of these study confirm an enormous diversity in leaf phenotype of Keora.

1.2Objective of the study

To study morphological variation in Keora (*Sonneratia apetala* Buch. Ham) among the salinity zones of Sundarbans mangrove forests.

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1.2Objective of the study

To study morphological variation in Keora (*Sonneratia apetala* Buch. Ham) among the salinity zones of Sundarbans mangrove forests.

CHAPTER TWO: LITERATURE REVIEW

2.1 Description of Sundarbans

Sundarbans is the largest single continuous productive mangrove forest of the world spreading over the southern part of Bangladesh and West Bengal State of India. Bangladesh is represented by both natural and planted mangrove forest. The natural mangrove forest includes the sundarbans and Chokoria Sundarbans. It is located at the southern extremity of the ganges river delta i.e.,the plain bordering the northern margin of the Bay of Bengal. The forest covers an area of about 10,000m² of which 62% falls within the territory of Bangladesh.

It occupies a land area of 401,600 ha, of which 395,500 ha are covered by forest (Chaffey et al. 1985), and comprises 44% of the total productive forest of Bangladesh (Anon, 1989). Of the total area, approximately 70% are lands and 30% are waters. (Choudhury, 1968)

History of Mangrove Forest

The Sundarbans is not much older than 7000 years and over long period of time has since been raised by 6-9 above sea level by the gradual deposition of silt carried by Ganges from Himalayas (Bandyopadhyay 1986). In the eighteenth century, before the process of land reclamation began, the total area of Sundarbans was 16,700 km² .The concept of sustainable management was implemented in Sundarbans in 1872, long before the concept become popular else where in the developing world.

2.2 Zonation of Sundarbans Mangrove Forest

The mangrove vegetation is often classified into different zones based on the depth of tidal inundation presence of dominant species. Such zonation is not distinct in the Sundarbans. Irrespective of depth or duration of tidal inundation , the Sundarbans has been divided into three ecological zones based on the criterion of the level of soil salinity, which greatly influences the distribution of species. These are less , moderate and strongly saline zones.

Less saline zones

It is located in the eastern and northeastern part of the forests. The aera receives fresh water supply from the Ganges. During the rainy season, the salinity is very low and the soil gets a good coating of fresh silt each year. The forest floor is comparatively high so the tidal water does not frequently inundate the area. Sundri (*H. fomes*) forms pure stands or stands in association with gewa (*E. agallocha*). In addition to sundri and gewa, passur (*Xylocarpus mekongensis*), kankra *(Bruguiera spp*), and baen (*Avicennia officinalis*) are also present. Keora (*Sonneratia apetala*) is also found in good proportion; it is a pioneer species and short-lived. It disappears from the areas where It first becomes established within 50 years or so making room for other species to occupy the land.

Moderately Saline Zone

It occupies the middle portion of the forest. Gewa is dominant crop. A mixture portion of gewa, sudri with varying potion of goran and other species are characteristic of this zone. Sundari decreases towards the west and south. Canopy height is usually 10m . Golpata is also abundantly found in this zone. Keora is plentiful in this zone as compared to less or strongly saline zone.

Strongly Saline Zone

This occupies the south and western part of the forest and covers a sizeable portion of forest lands. Salinity is higher in the dry season and water salinity is almost that of normal seawater salinity. Soil is hard due to lack of silt deposition. The forest is typically closed under story of goran having a height of about 4m. Keora, Baen, Kankra, passur, dhundul and garjan occur isolated. Gewa is poorly developed. Golpata is uncommon. Hantal *(Phoenix paludosa*) is well represented on relatively raised lands. (Siddiqi N. A., 2001)

2.3.Influence of salinity on mangrove growth

Salinity may affect plants in three ways: by osmotic pressure inhibition of water absorbtion by specification effects un nutrition or toxicity; or both. Different plants deal with the salt problem in different ways. Salinity not only affects the distribution of a species, it also affects productivity. Increased in salinity considerably retards the growth of the trees (Imam, 1984) The gross primary productivity of mangroves increases as fresh water becomes available. Those plant that grow in a high salinity environment tend to transpire less saline conditions. (Lugo, 1974)

2.4.General Description of *Sonneratia apetala* Buch. Ham.

Sonneratia apetala Buch. Ham. is fast growing evergreen tree with a columnar crown; it can grow up to 15 m tall with occasional specimens to 20m . The tree produces pneumetaphores (vertical roots arising above the ground from shallow, horizontal roots) up to 1.5 meters tall. Introduced as a fast-growing tree for reforestation of mangrove communities. Sonneratia a genus of plants in the family Lythraceae. Formerly the Sonneratia were placed in a family called Sonneratiaceae which included both the Sonneratia and Duabanga, but these two are now placed in their own monotypic subfamilies of the family lythraceae. The genus was also named Blatti by James Edward Smith. (Jackson, 1987)

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This species is common through most of its range, but there are increasing threats to mangrove swamps in general, mainly from human activities. consequently, the tree has been classified as least concern in the IUCN Red list of Threatened Species.

2.4.1.Systematics of Keora

Kingdom- Plantae

Phylum- Tracheophyta

Class-Magnoliopsida

Order-Myrtales

Family-Lythraceae

Genus- Sonneratia

Botanical name - *Sonneratia apetala* Buch. Ham.

(Source: Zipcodezoo, 2010)

2.5.1.Distribution

The genus, Sonneratia is represented is Asia, the pacific and east coast of Africa.There are five species of genus growing in the mangrove forests. The genus has two species in Bangladesh. *Sonneratia apetala* occurs in Sundarbans proper and in the Chokoria Sundarbans. It is the principal planting species along the shoreline of Bangladesh.

2.5.2.Habitat

Sonneratia apetala, being a pioneer species, colonizes first on newly formed land, grasses and sedges follow it. It can withstand a wide range of salinity. So the species distribution all over the Sundarbans and is successful all along the shoreline of Bangladesh. It requires high tidal inundation for optimal growth.therefore, with the rise of forest floor as a result of siltation the species finds itself in an environmentally stressed condition and may be susceptible to attack by pest and diseases.

2.5.3.Regeneration of *Sonneratia apetala* Buch. Ham.

Sonneratia apetala shows both natural and artificial regeneration. In natural regeneration a fruit of *S. apetala* contains 25 to 125 seed. (Siddiqi and Islam 1988). Ripe fruits are available in August. There is no periodicity in seed production and a plant may produce huge quantity of fruits from the age of 6 years. The seeds are buoyant and are distributed by water. Being fleshy, the fruits decay soon and the seeds germinate.

2.5.4.Leaves

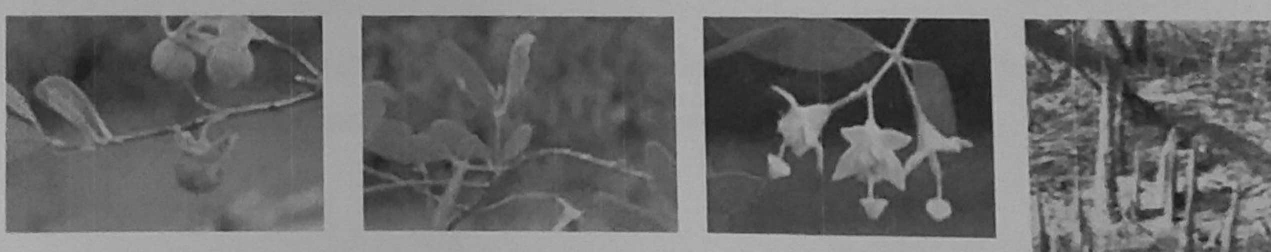
The leaves are simple opposite entire and leathery. Leaves simple, opposite, short petiolate, decussate, elliptic - oblong, obovate, apex tapering, base attenuate, 4 - 10 x 2 - 3 cm, coriaceous, glaucous on both sides. (Hassan, 2000)

2.5.5.Flowers

The flowers apetalous cream coloured, arranged in axillary 3-flowered of 7 flowered dichasial cyme. The flowers have no petals but 4 prominent green sepals. Creem colored mass of stamens give the flowers a cream colored look. The most interesting part of the flower is the style, which consist of a white 2-3 cm long, curved, stigma,falttened like umbrella or mashroom. The upper portion is reddish in color. The flowers are bisexual. (Frias, 2012)

2.5.6.Fruits

The fruit is almost round and about 2-3 mm wide. A fruit contains 25-125 seeds. Fruits globose berry seated on the flattened calyx-tube, 2 - 2.5 cm across, many seeded.



Fruits Leaves Flowers Pneumetaphore

Fig1: Morphological characteristics of Sonneratia *apetala*- fruits, leaves, flowers and pneumetaphore

2.5.7.Seed

Fruit berry with persistent leathery calyx, green with numerous seeds; seeds compactly arranged in 6-8 locules within the fleshy pulp of the placenta, yellowish, mostly U or V shaped, surface irregularly aeriolated; size 1.02 cm, weight 0.11 g, helium middle i.e. within the invaginated portion of the seed; micropyle position obscure, radicle emerges from anyone arm of the seed; exalbuminous,germination epigeal.

2.5.8.Root System

Cone roots belong to pneumatophores and are developed by Sonneratia species . Pneumatophore is Greek, 'pneuma' means something like 'air flow' and 'phoros' something like 'bearing', in English the word aerial roots are also very common for pneumatophores. Pneumatophores are roots that grow vertically up from the underground root system. Sonneratia species grow in oxygen-poor sediments. The underground root system needs and demands oxygen, the soil is not able to support the underground root system with enough oxygen, therefore the underground root system outgrows aerial roots that grow vertically up to the air above the soil. The cone roots have numerous lenticels that enable gas exchange directly above the surface. The cone roots provide the additional needed oxygen which can't be taken from the soil. (Zabala)

2.5.9.Pneumataphore

Pneumatophores 60 – 150 cm long, arising from horizontal roots, corky, forked twice or thrice, associated with anchor roots and nutrition roots.

CHAPTER THREE: Materials And Methods

3.1.Description of Study site

The study was designed to investigate the phenotypic variation of leaves of keora. The study was conducted in three different ranges of Sundarbans namely Khulna range, Satkhira range and Sarankhola range. Khulna range is located under moderate saline zone, Satkhira range is located under strong saline zone,Sarankhola range is located under less saline zone. Less saline zone falls in eastern part of Sundarbans. Moderate saline zone falls in the middle of Sundarbans adjacent to Sarankhola range and receives moderate fresh water flow through the Balershwar Meghna, and Bhoirab-passur channel.

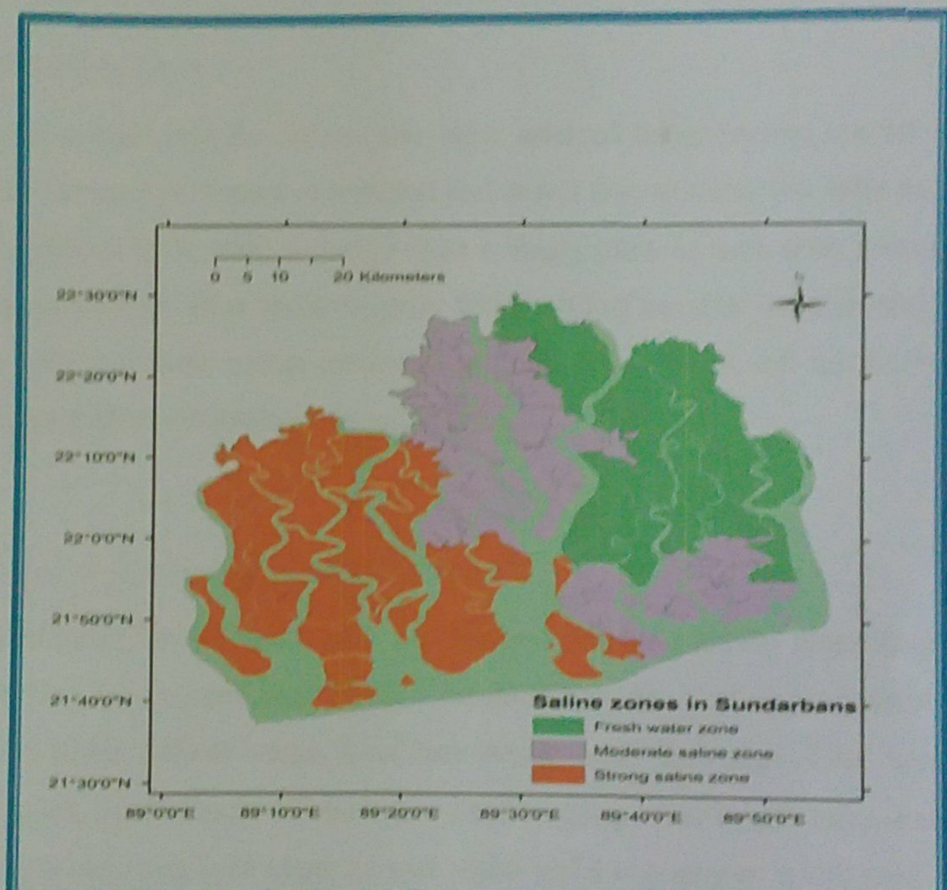


Figure 2: Description of study sites

3.2. Plant materials and Design of the experiment

For measuring the morphometric characteristics of Keora leaves the whole experiment was designated through different stages.

This experiment was designated according to the salinity range of Sundarbans through the stratified random sampling. Sample plot size was determined on the basis of species curve area. We collected fresh leaves from Sonneratia apetalaby using stratified random sampling. The leaves are simple opposite entire and leathery. Leaves short petiolate, decussate, elliptic - oblong, obovate, apex tapering, base attenuate, 4 - 10 x 2 - 3 cm, coriaceous, glaucous on both sides.

3.3. Sample collection

After selecting the sample plot the sample tree were selected for collecting leaves. All the sample trees were selected in respect of matured and defect free species. 180 fully expanded leaves from 10 different trees were collected from a single plote in each zone according to random sampling procedure. Thus approximately 540 fresh leaf samples from around 30 tree individual were collected from strong, moderate and less saline zones. All the fresh leaves were collected from different branches of sample trees.

3.4. Leaf parameter selection and measurement

We chose 15 parameters for measurement. . Sample leaves were used for measuring of the following parameters: Leaf length, Leaf width, Leaf middle width, Leaf upper quarter width, Leaf down quarter width, Petiole length, Leaf base Angle, Leaf Tip Angle, Leaf Area, Leaf perimeter, Leaf index, Leaf area perimeter ratio, Leaf length petiole length ratio, Leaf base angle Leaf Tip angle ratio and Leaf upper quarter width and down quarter width ratio.

Figure 4: Measurement of leaf

Using 15 parameters listed in Table 1, we analyzed leaf morphologica variation in keora. After collecting the fresh leaves were imaged by a digital camera. NIH ImageJ software (http://rsb.info.nih.gov/ij) was applied to obtain quantitative parameters. Ratio of leaf length to leaf width (leaf index) and leaf area to leaf perimeter were calculated from the measured parameters.Qualitative parameters were scored according to the methods repoted by Sneath and Sokal (1973) and fejerdo et al.(2008)

Table 1: List of the parameters studied for morphological Characterization of *Sonneratia apetala*

Leaf parameters	Description	Measurement unit
Leaf length	LL	cm
Leaf width	LW	cm
Leaf middle width(1/2)	LMW	cm
Leaf upper quarter width(3/4)	LUW	cm
Leaf down quarter width(1/4)	LDW	cm
Petiole length	PL	cm
Leaf base angle	LBA	Degree (°)
Leaf tip angle	LTA	Degree (°)
Leaf area	LA	cm^2
Leaf perimeter	LP	cm
Leaf index	LI	-
Leaf area perimeter ratio	A/P	-
Leaf length petiole length ratio	LL/PL	-
Leaf base angle Leaf tip angle ratio	LBA/LTA	-
Leaf upper quarter width down quarter width ratio	LUW/LDW	-

3.5. Data processing and analysis

For morpho-metric characteristics of leaves, the following statistical parameters and statistical analysis were applied: mean, standard deviation and standard error. Maximum, minimum for quantitative parameters were carried out with KaleidaGraph (version 10). CV% of different parameters was calculated to compare relative variation in each parameter among salinity gradient by using statistical software (version 10). A one-way analysis of variance (ANOVA) was performed to test the significant difference among the leaf samples for all the quantitative parameters.

CHAPTER FOUR: RESULT AND DISCUSSION

4.1.Result

The present study was conducted with a view to specified leaf morphological diversity in the leaves of *Sonneratia apetala.* It is obvious that keora showsd high diversity in leaf phenotype. We chose 15 parameters as shown in table 1 to describe the diversity. A wide range of variations were observed in the parameters of leaves.

Here we showed both column graphs and box plots for each of the parameters. Column graphs indicate the mean and Standerd deviation (SD) for 15 qualitative parameters and box plots indicate the range of variation of leaf parameters within and among the saline zone. Open box represents the inter-quartile range, upper lower vertical line indicates maximum and minimum value, horizontal line in each box is median, circle outside the box indicate extreme value.

4.1.1. Variation in leaf length

Leaf Length varied from 1.19-12.84 cm in Satkhira, 1.57-12.9 cm in Koira and 1.98-11.71 cm in Soronkhola (Table 2). The maximum Leaf Length (12.9 cm) was found in Koira and minimum Leaf Length (1.19 cm) was found in Satkhira. Mean Leaf Length in strong, moderate and less saline zones were 8.28, 8.10 and 8.17 cm respectively (Table 3). One way ANOVA showed there is no significant difference ($p>0.05$) of Leaf Length among the saline zones (Table 3).

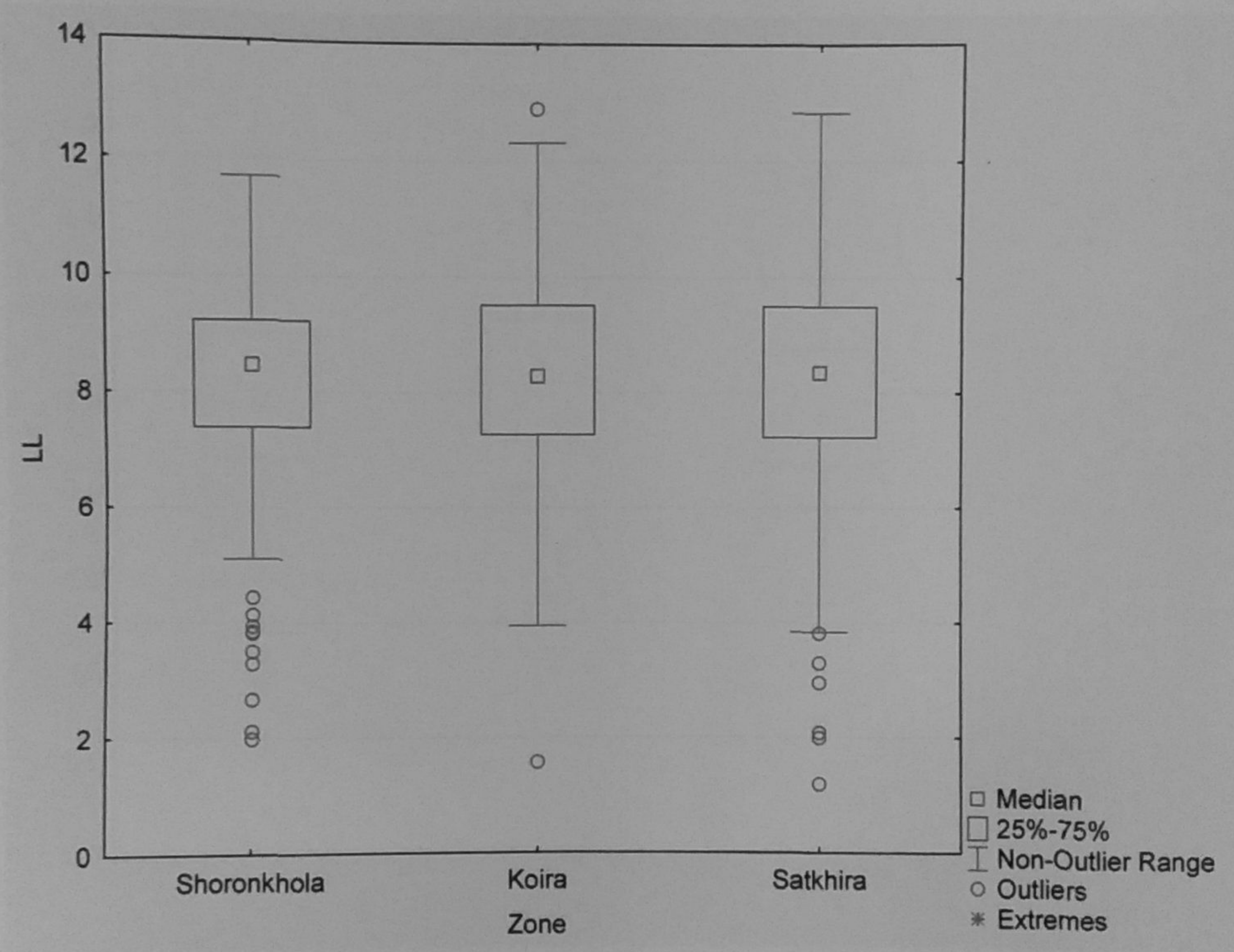


Figure 5: Variation in Leaf Length within and among the three saline zones of Sundarban mangrove forests in Bangladesh (Box and Whisker plot)

4.1.2. Variation in leaf width

Leaf width varied from 0.68-3.78 cm in Satkhira, 1.38-3.94 cm in Koira and 0.57-3.85 cm in Soronkhola (Table 2). The maximum Leaf width (3.94 cm) was found in Koira and minimum Leaf width (0.57 cm) was found in Shronkhola. Mean Leaf Length in strong, moderate and less saline zones were 2.47, 2.64 and 2.49 cm respectively (Table 3). One way ANOVA showed there is significant difference ($p<0.05$) of Leaf width between strong and moderate saline zone or moderate and less saline zone. There is no significance difference($p>0.05$) between strong and less saline zone (Table 3).

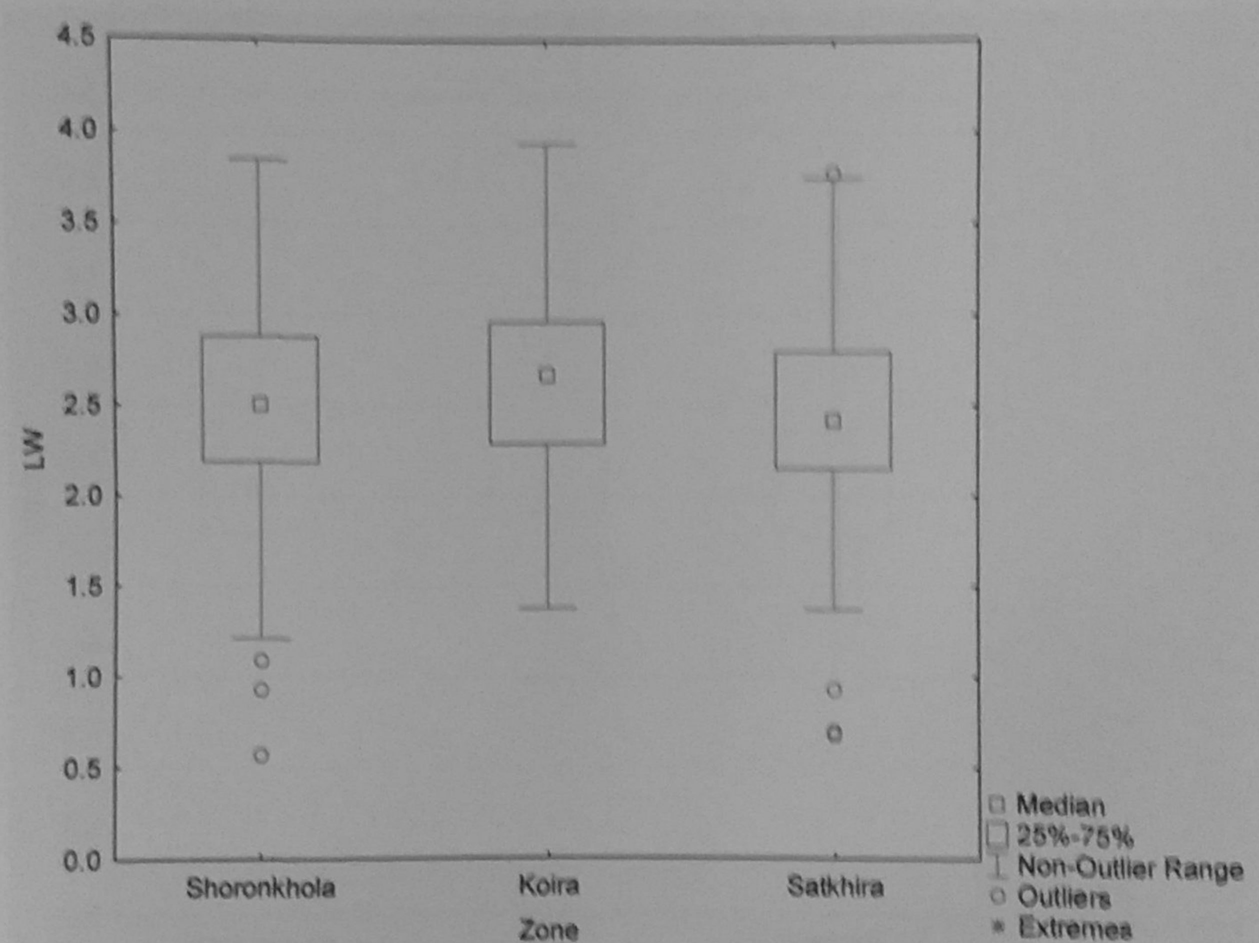


Figure 6: Variation in Leaf Width within and among the three saline zones of Sundarban mangrove forests in Bangladesh (Box and Whisker plot).

4.1.3.Variation in leaf middle width

Leaf middle width varied from 0.64-3.73 cm in Satkhira, 1.28-3.91 cm in Koira and 0.55-3.85cm in Soronkhola (Table 2). The maximum Leaf width (3.91 cm) was found in Koira and minimum Leaf width (0.55 cm) was found in Shronkhola. Mean Leaf Length in strong, moderate and less saline zones were 2.37, 2.56 and 2.42 cm respectively (Table 3). One way ANOVA showed there is significant difference ($p<0.05$) of Leafmiddle width between strong and moderate saline zone or moderate and less saline zone.There is no significance difference($p>0.05$) between strong and less saline zone (Table 3).

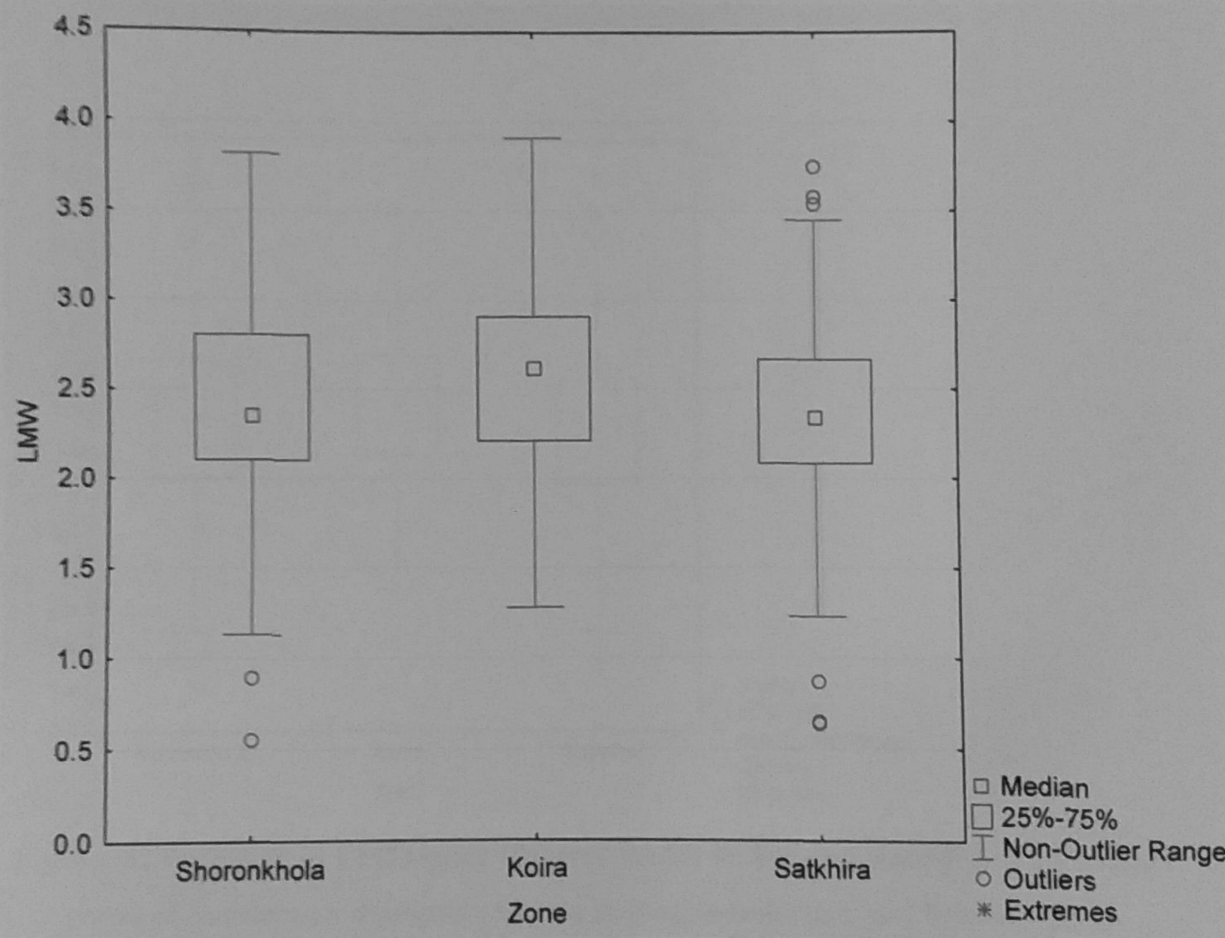


Figure7: Variation in Leaf Middle Width within and among the three saline zones of Sundarban mangrove forests in Bangladesh (Box and Whisker plot).

4.1.4. Variation in leaf upper quarter width

Leaf upper quater width varied from 0.5-3.02 cm in Satkhira, 0.9-2.86 cm in Koira and 0.43-3.08 cm in Soronkhola (Table 2). The maximum Leafupper quater width (3.08 cm) was found in Shoronkhola and minimum Leaf width (0.43 cm) was found in Shronkhola. Mean Leaf Length in strong, moderate and less saline zones were 1.75, 1.87 and 1.78 cm respectively (Table 3). One way ANOVA showed there is significant difference ($p<0.05$) of Leaf upper quarter width between strong and moderate saline zoneThere is no significance difference($p>0.05$) between strong and less saline zone or moderate and less saline zone (Table 3).

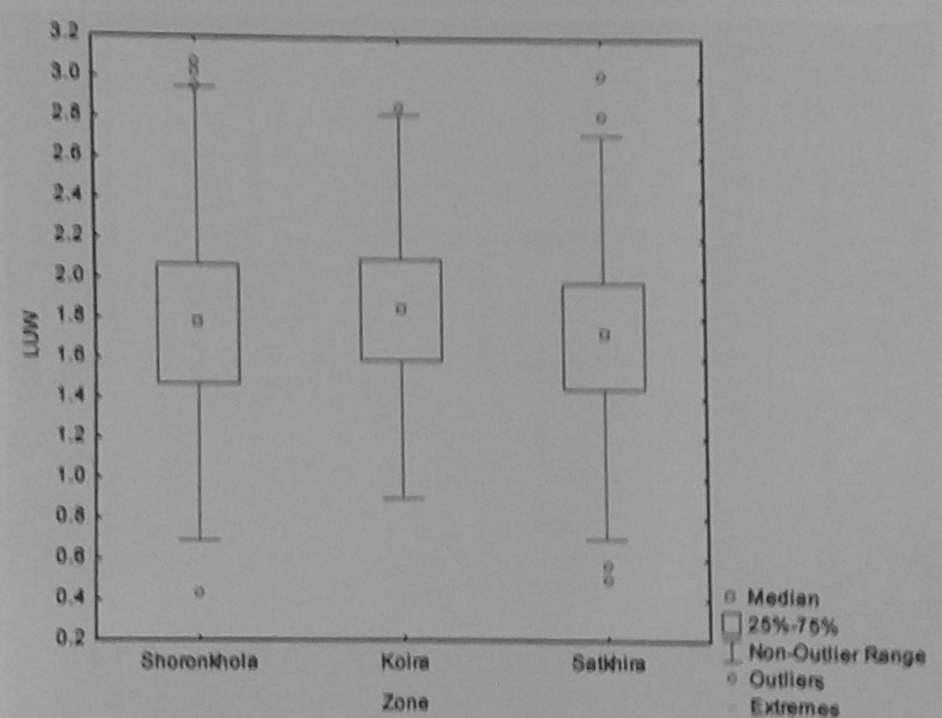


Figure 8: Variation in Leaf Upper Quarter Width within and among the three saline zones of Sundarban mangrove forests in Bangladesh (Box and Whisker plot).

4.1.5.Variation in leaf down quarter width

Leaf down quater width varied from 0.51-3.43cm in Satkhira, 1.19-3.69 cm in Koira and 0.31-3.58 cm in Soronkhola (Table 2). The maximum Lea fupper quater width (3.69 cm) was found in Koira and minimum Leaf width (0.31 cm) was found in Shronkhola. Mean Leaf Length in strong, moderate and less saline zones were 2.18, 2.38 and 2.26 cm respectively (Table 3). One way ANOVA showed there is significant difference ($p<0.05$) of Leaf upper quarter width between strong and moderate saline zone.There is no significance difference($p>0.05$) between strong and less saline zone or moderate and less saline zone (Table 3).

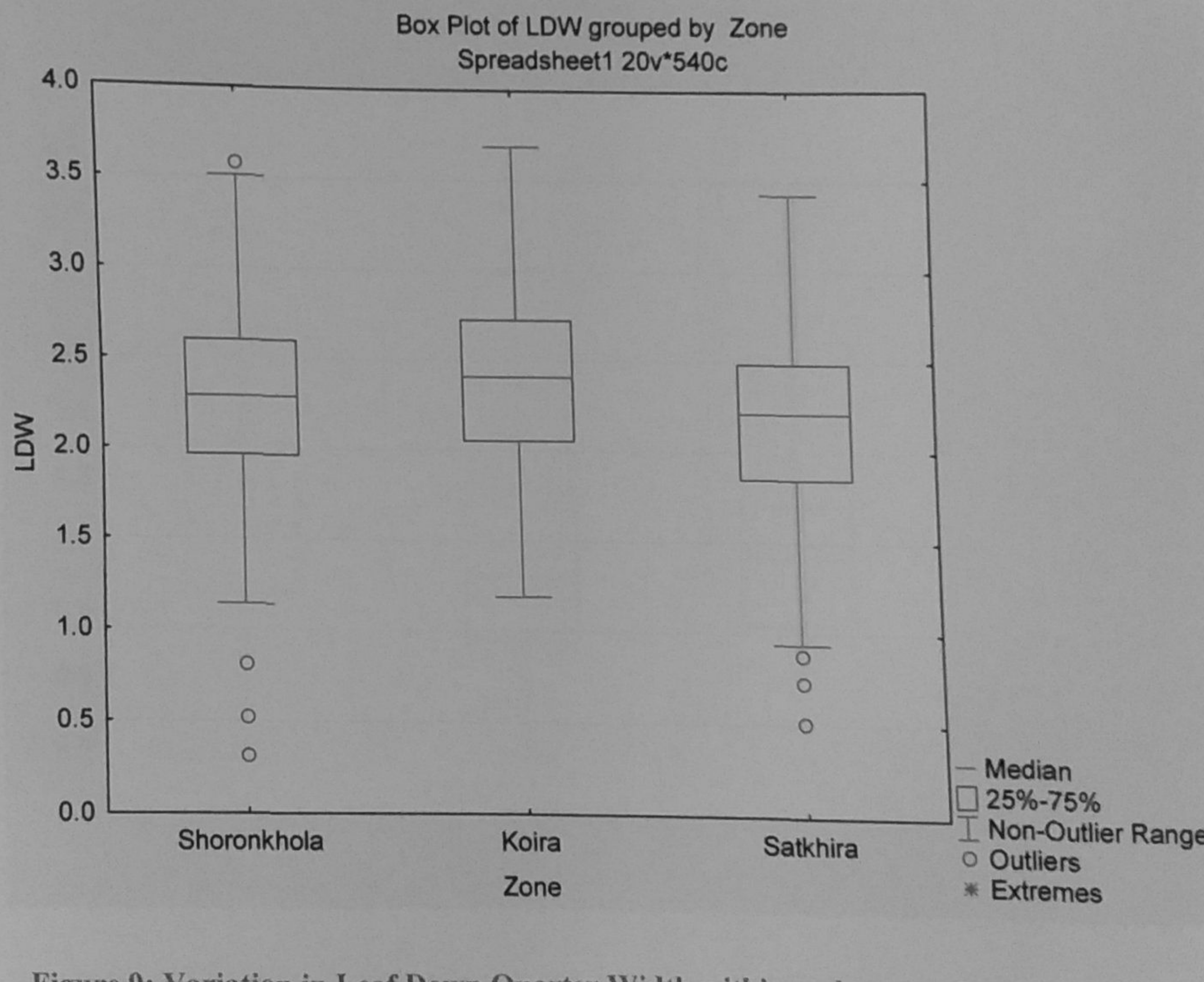


Figure 9: Variation in Leaf Down Quarter Width within and among the three saline zones of Sundarban mangrove forests in Bangladesh (Box and Whisker plot)

4.1.7. Variation in leaf base angle

Leaf base angle varied from 34.22-121.9 degree in Satkhira, 24.59-104.44 degree in Koira and 48.41-103.17 in Soronkhola (Table 2). The maximum leaf base angle (121.9) was found in Satkhira and minimum leaf base angle (24.59) was found in Koira. Mean leaf base angle in strong, moderate and less saline zones were 65.50,76.37 and 67.95 degree respectively (Table 3). One way ANOVA showed there is no significant difference ($p>0.05$) of leaf base angle between strong and less saline zone.There is significance difference($p<0.05$) between strong and moderate saline zone or moderate and less saline zone (Table 3).

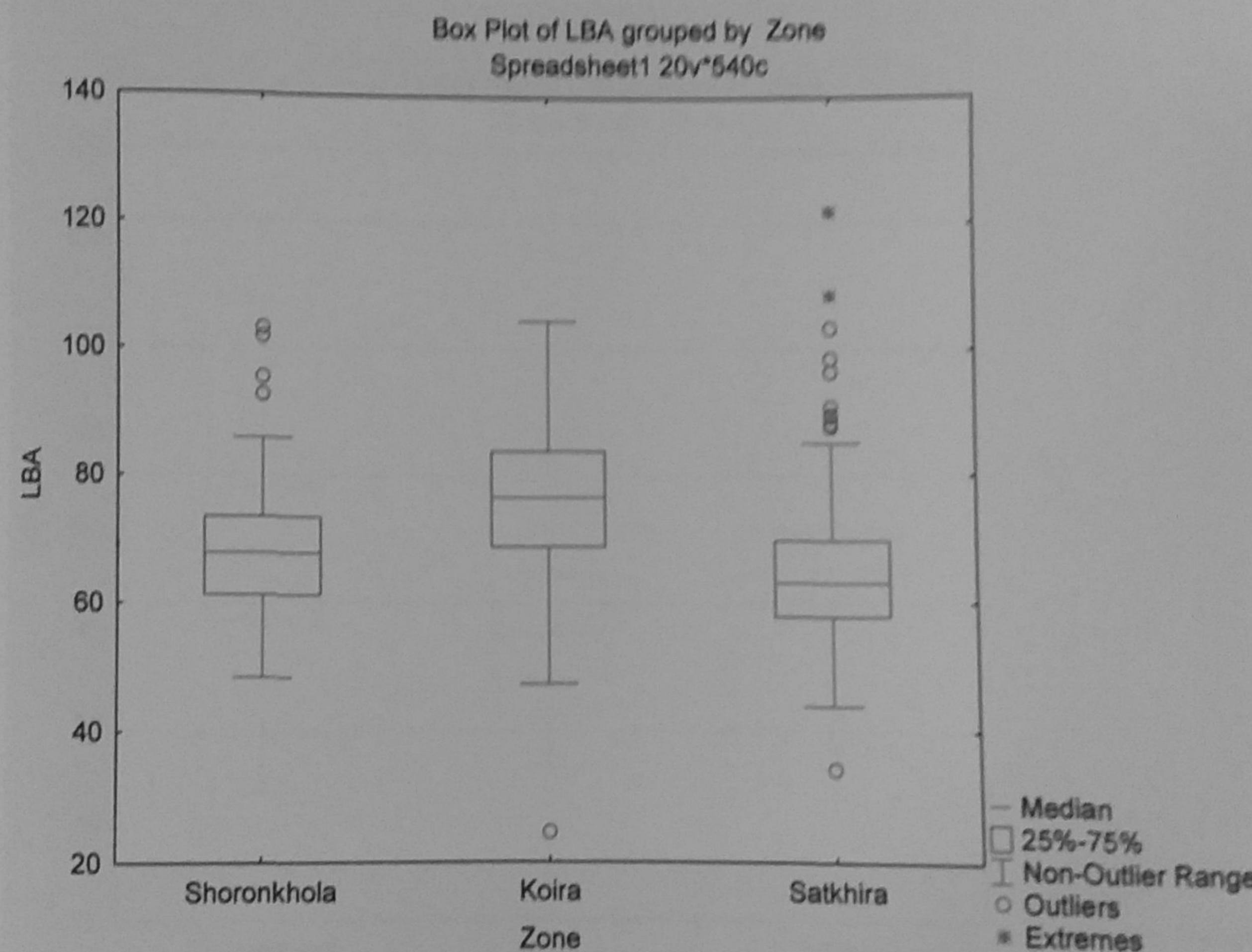


Figure11: Variation in Leaf Base Angle within and among the three saline zones of Sundarban mangrove forests in Bangladesh (Box and Whisker plot)

4.1.8. Variation in leaf tip angle

Leaf Tip angle varied from 52.66-135.9 degree in Satkhira, 27.28-117.63 degree in Koira and 45.97-165.25degree in Soronkhola (Table 2). The maximum leaf Tip angle (165.25) was found in Shoronkhola and minimum leaf Tip angle (27.28) was found in Koira. Mean leaf base angle in strong, moderate and less saline zones were 93.08,79.75 and 95.66 degree respectively (Table 3). One way ANOVA showed there is no significant difference ($p>0.05$) of leaf Tip angle between strong and less saline zone. There is significance difference($p<0.05$) between strong and moderate saline zone or moderate and less saline zone (Table 3).

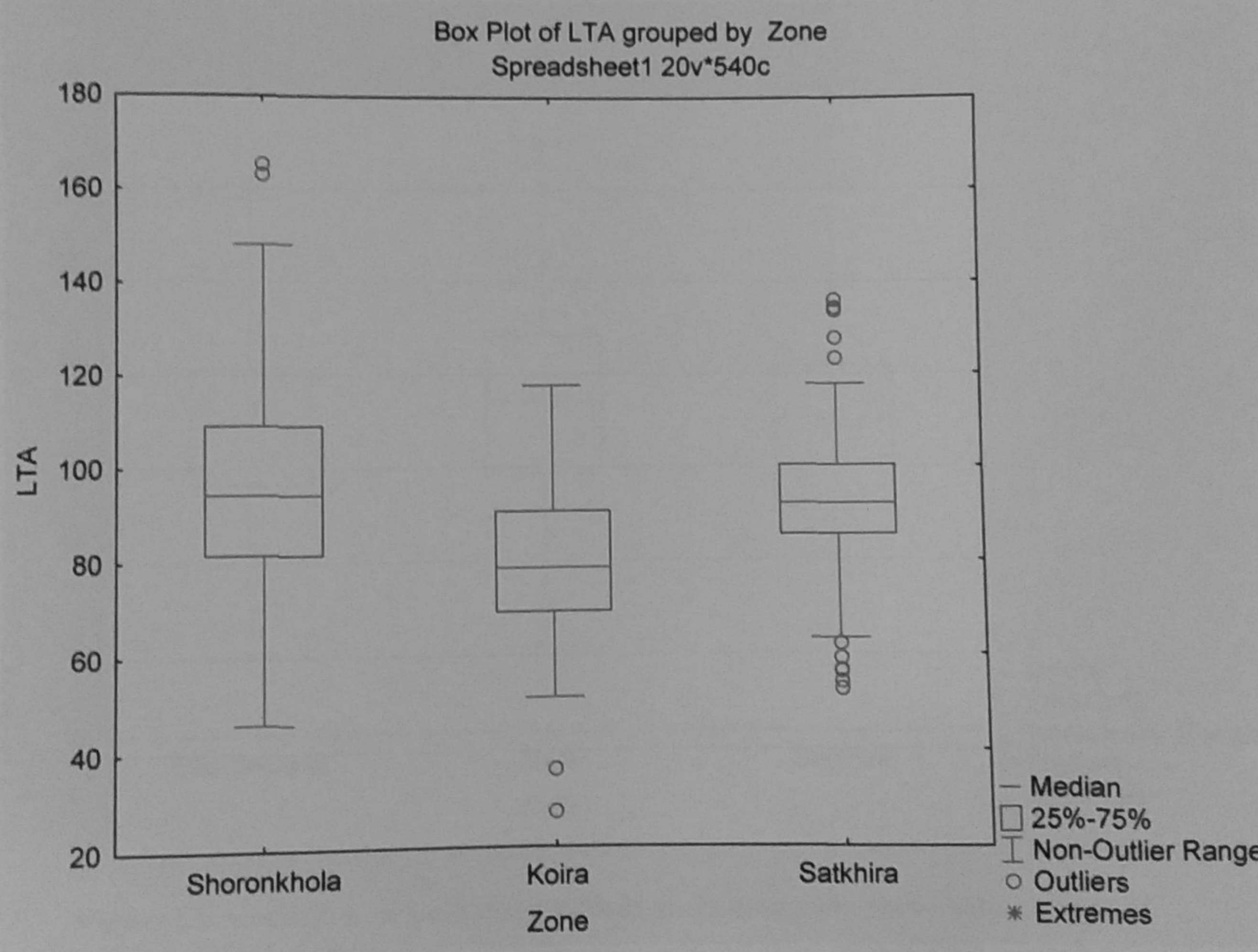


Figure12: Variation in Leaf Tip Angle within and among the three saline zones of Sundarban mangrove forests in Bangladesh (Box and Whisker plot)

4.1.9.Variation in leaf area

Leaf area varied from 3.325-34.151 cm^2 in Satkhira, 4.484-36.515 cm^2 in Koira and 3.817-29.125 cm^2 in Soronkhola (Table 2). The maximum Leaf area (36.515 cm^2) was found in Koira and minimum Leaf area (3.325 cm^2) was found in Satkhira. Mean Leaf area in strong, moderate and less saline zones were 16.04, 17.41and 16.25 cm^2 respectively (Table 3). One way ANOVA showed there is no significant difference ($p>0.05$) of Leaf area among the saline zones (Table 3).

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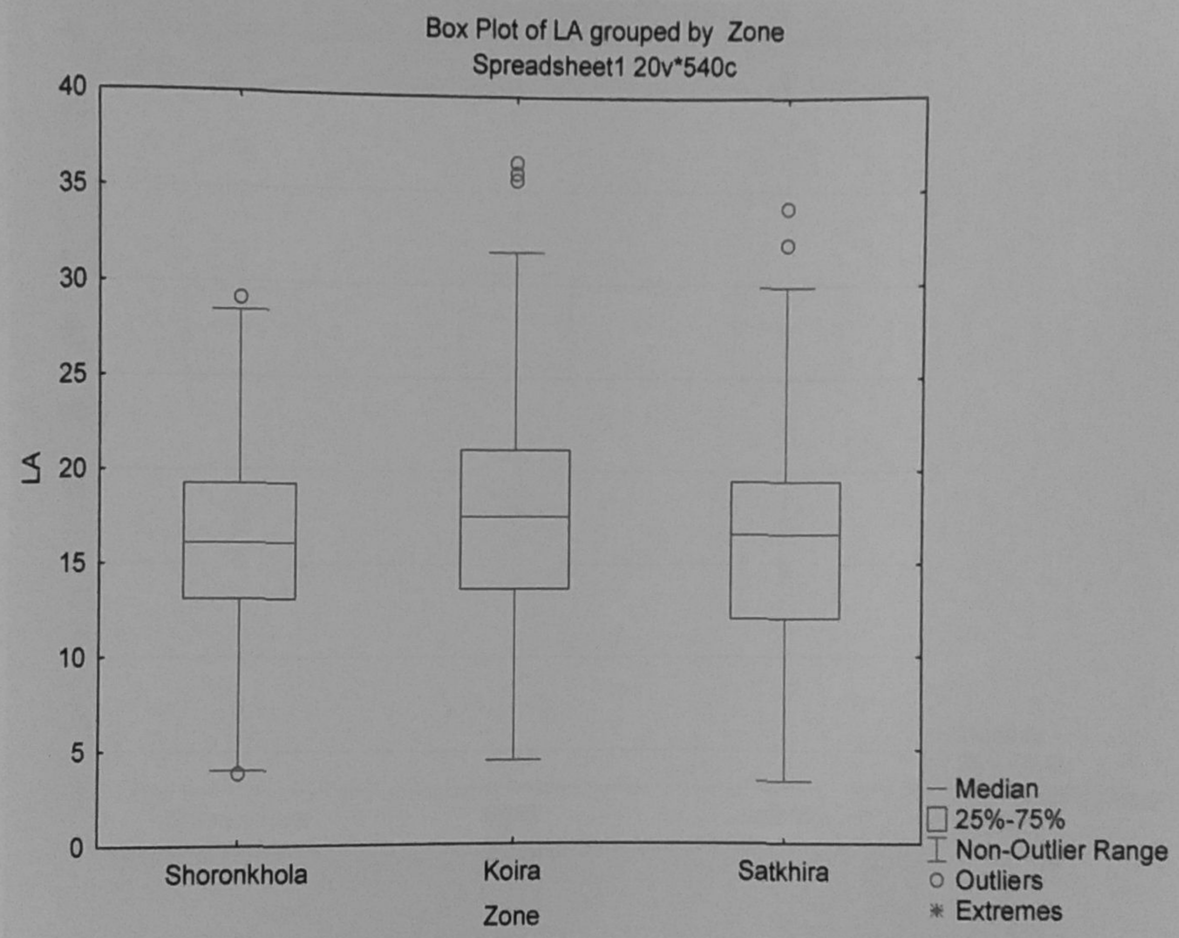

Figure13: Variation in Leaf Area within and among the three saline zones of Sundarban mangrove forests in Bangladesh (Box and Whisker plot)

4.1.10.Variation in leaf perimeter

Leaf perimeter varied from 6.89-43.196 cm in Satkhira, 8.77-41.41 cm in Koira and 0.156-37.71 cm in Soronkhola (Table 2). The maximum Leaf perimeter (43.196 cm) was found in Satkhira and minimum Leaf perimeter (.156 cm) was found in Shoronkhola. Mean Leaf perimeter in strong, moderate and less saline zones were 25.58, 26.06 and 25.10 cm respectively (Table 3). One way ANOVA showed there is no significant difference ($p>0.05$) of Leaf perimeter among the saline zones (Table 3). .

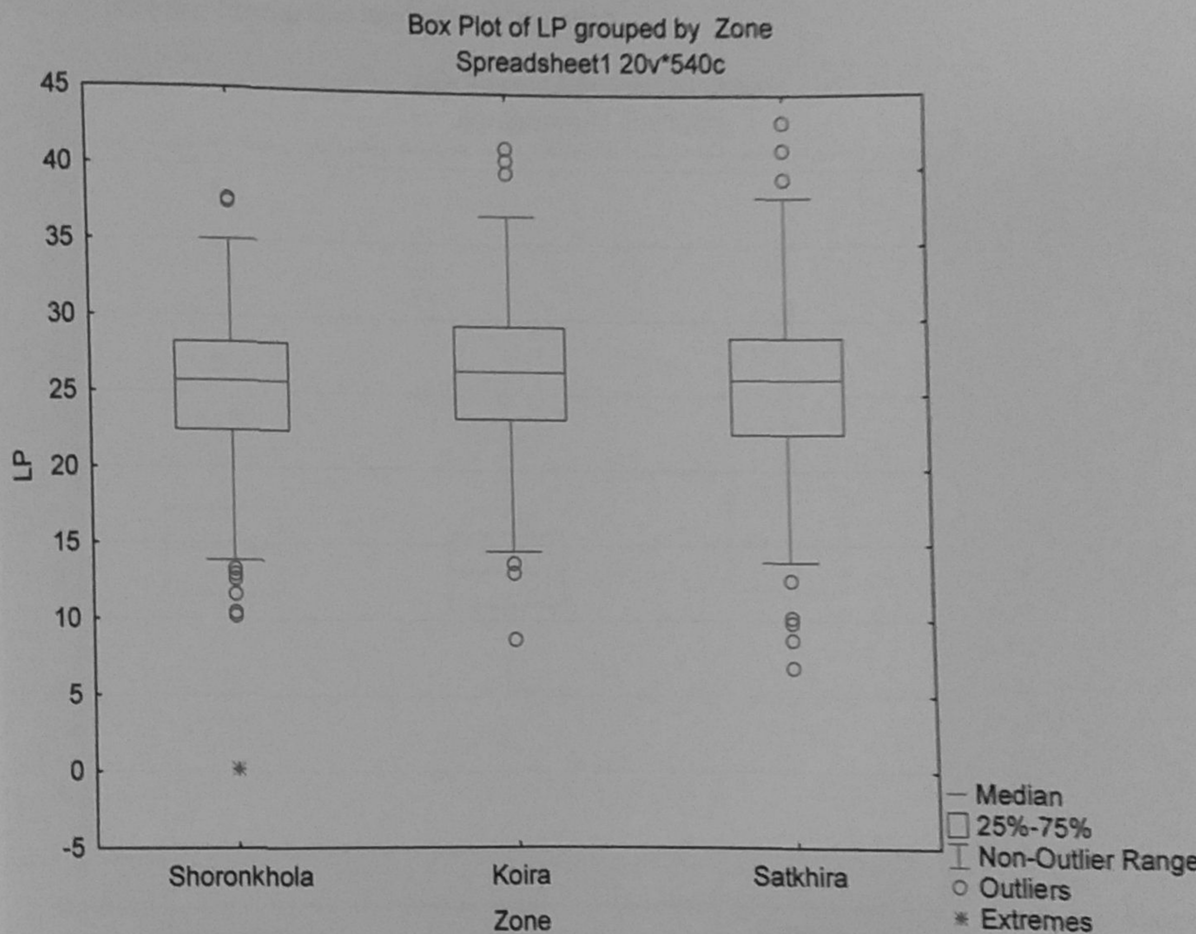

Figure14: Variation in Leaf Perimeter within and among the three saline zones of Sundarban mangrove forests in Bangladesh (Box and Whisker plot)

4.1.11: Variation in Leaf Index

Leaf Index varied from 0.506-5.956 in Satkhira, 0.562-4.69 in Koira and 1.54-6.6 in Sarankhola (Table 2). The maximum Leaf Index (15.912) was found in Shoronkhola and minimum Leaf Index (0.506) was also found in Satkhira. Mean Leaf Index in Satkhira, Koira and Sharankhola were 3.41, 3.09 and 3.34 respectively (Table 3). One way ANOVA showed There are significant difference ($p<0.05$) between strong and moderate zone or moderate and less saline zone of Leaf Index. And there are no significance difference ($P>0.05$) between Strong and moderate saline zone.

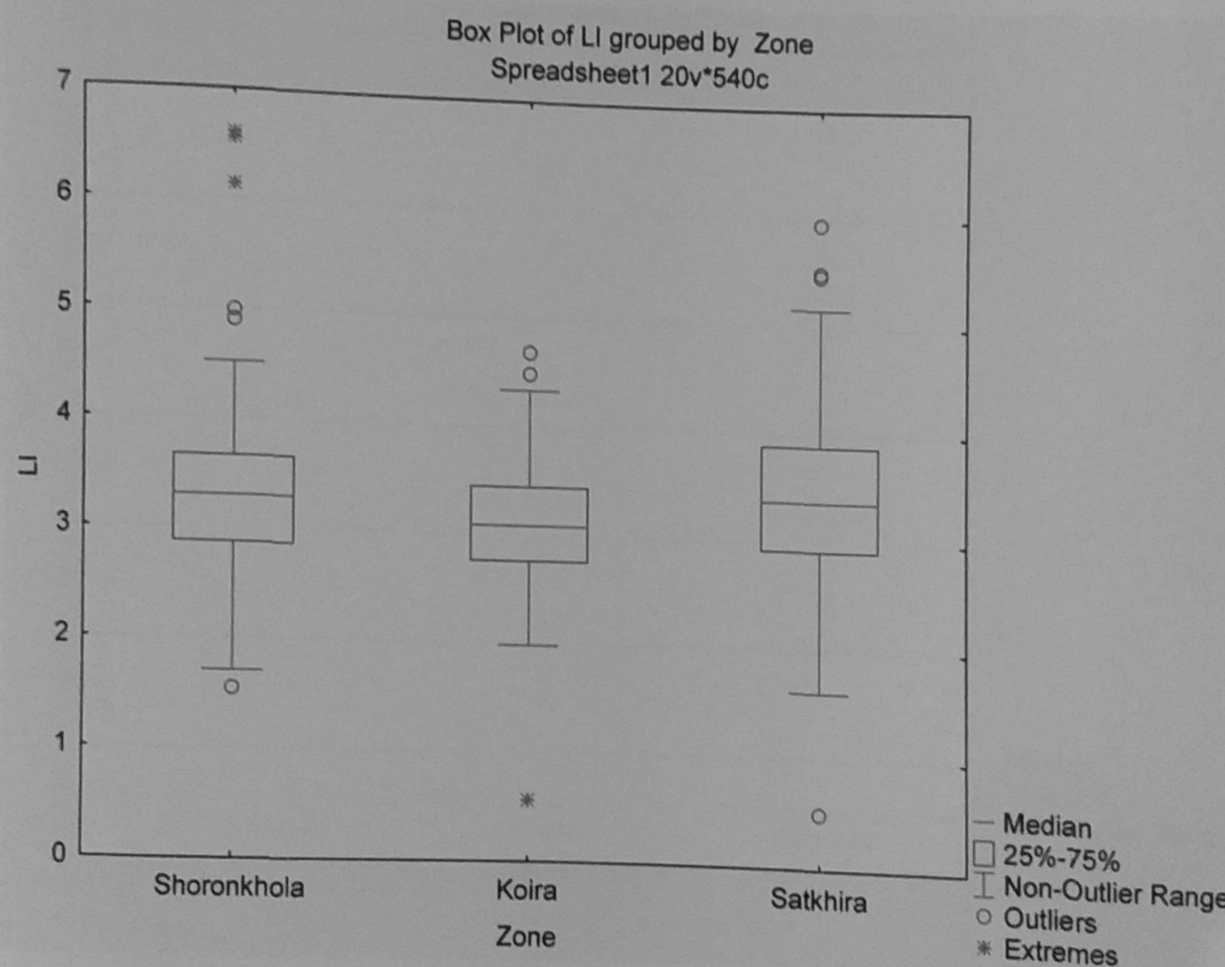

Figure15: Variation in Leaf Index within and among the three saline zones of Sundarban mangrove forests in Bangladesh (Box and Whisker plot)

4.1.12: Variation in Leaf Area-Perimeter Ratio

Leaf Area-Perimeter Ratio varied from 0.308-1.258 in Satkhira, 0.203-2.399 in Koira and 0.286-1.154 in Sarankhola (Table 2). The maximum Leaf Area-Perimeter Ratio (2.399) was found in Koira and minimum Leaf Area (0.203) was found in Koira. Mean Leaf Area-Perimeter Ratio in Satkhira, Koira and Sharankhola were .63, 0.65 ando .63 respectively (Table 3). One way ANOVA showed no significant difference ($p>0.05$) of Leaf Area-Perimeter Ratio among the saline zones (Table 3).

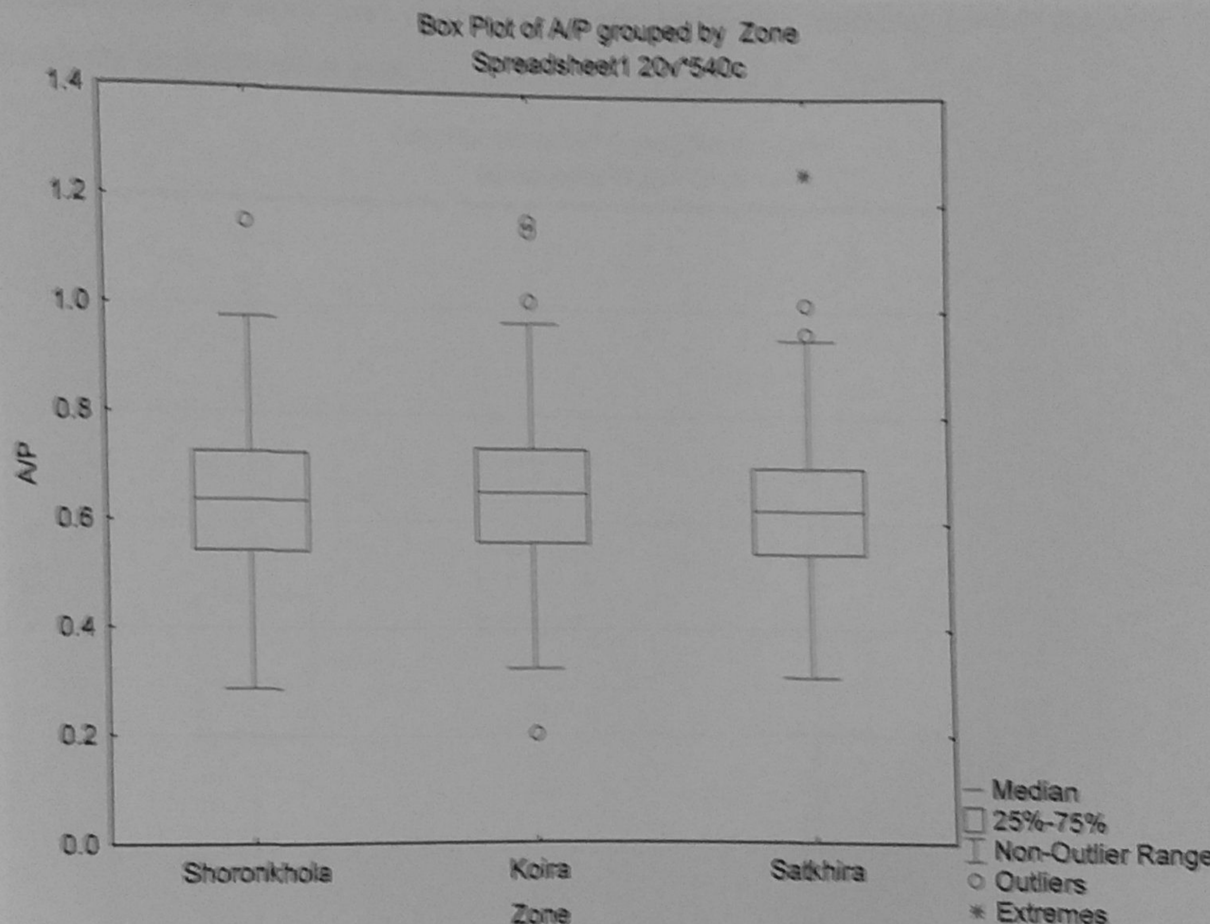

Figure 16: Variation in Leaf Area-Perimeter ratio within and among the three saline zones of Sundarban mangrove forests in Bangladesh (Box and Whisker plot)

4.1.13: Leaf Base Angle Leaf Tip Angle Ratio

Leaf Base Angle Leaf Tip Angle Ratio varied from 0.396-2.247 in Satkhira, 0.311-2.814 in Koira and 0.346-1.523 in Sarankhola (Table 2). The maximum Leaf Base Angle Leaf Tip Angle Ratio (2.814) was found in Koira and minimum Leaf Base Angle Leaf Tip Angle Ratio (0.311) was found in Koira. Mean Leaf Base Angle Leaf Tip Angle Ratio in Strong , moderate and less saline zone were 0.71, 0.98 and 0.75 respectively. One way ANOVA showed There are significant difference ($p<0.05$) between strong and moderate zone or moderate and less saline zone. And there are no significance difference ($P>0.05$)between Strong and moderate saline zone.

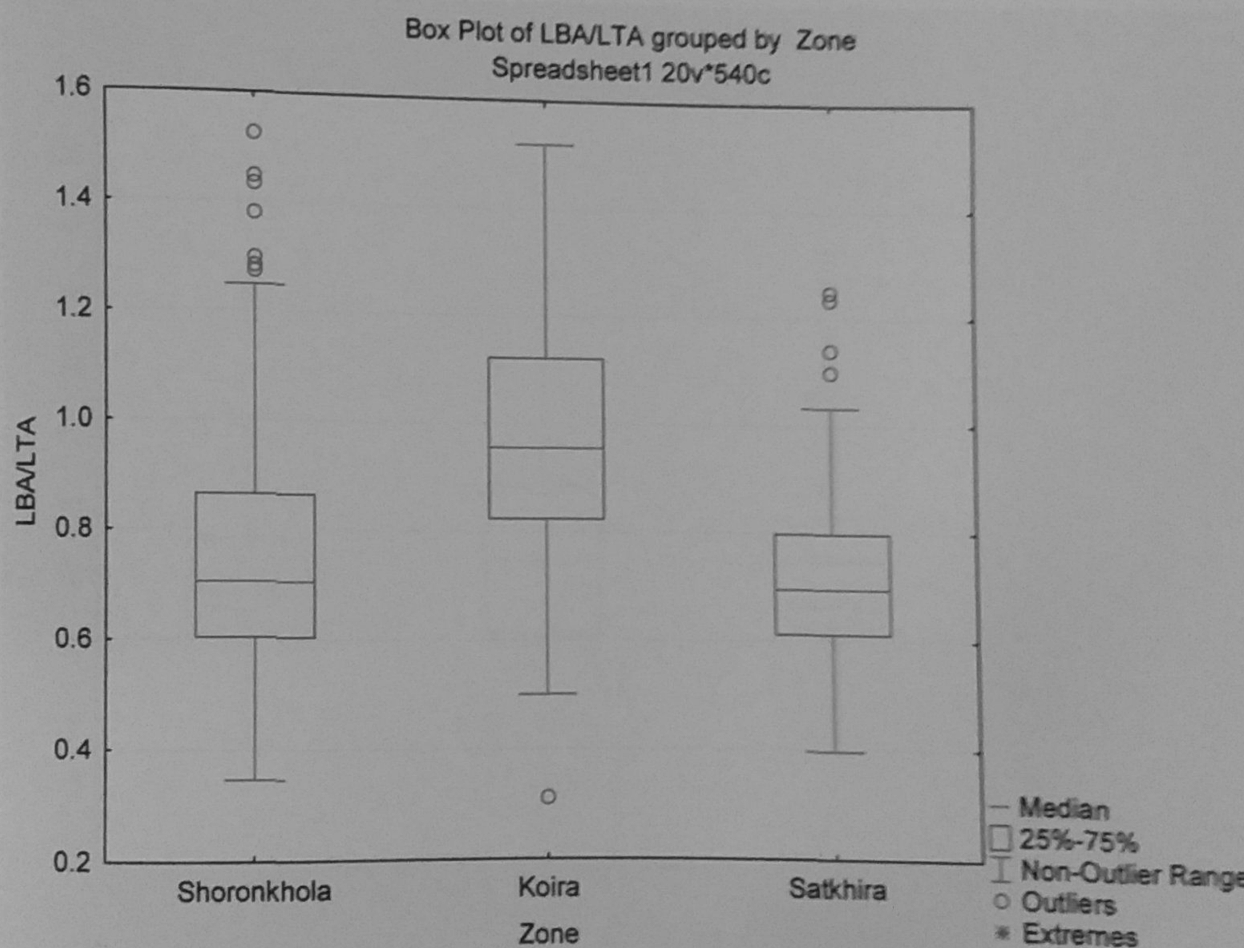

Figure 17: Variation in Leaf Base Angle Tip Angle ratio within and among the three saline zones of Sundarban mangrove forests in Bangladesh (Box and Whisker plot)

4.1.14. Variation in Leaf Length Petiole Length Ratio

Leaf Length Petiole Length Ratio varied from 1.09-17.63 in Satkhira, 1.45-19.43 in Koira and 3.35-16.39 in Sarankhola (Table 2). The maximum Leaf Length Petiole Length Ratio (19.43) was found in Koira and minimum Leaf length petiole length ratio (1.09) was found in Satkhira zone. Mean Leaf Length Petiole Length Ratio in Satkhira, Koira and Sharankhola were 8.83 ,8.88 and 7.85 respectively (Table 3). One way ANOVA showed significant difference ($p<0.05$) of Leaf Length Petiole Length Ratio between strong and less or moderate saline zone and there was no significant difference($P>0.05$) between strong and moderate saline zone. (Table 3).

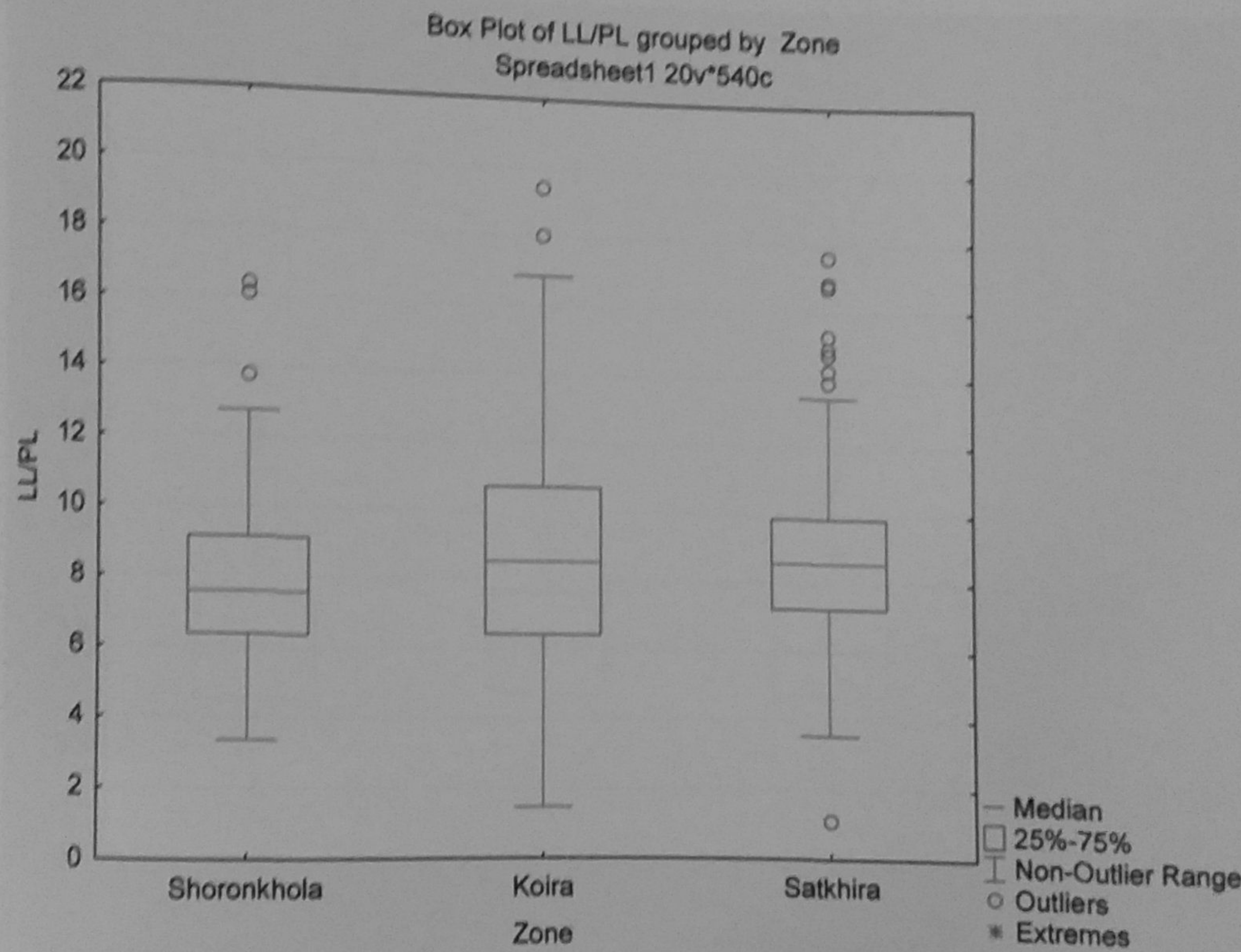

Figure18: Variation in Leaf Length Petiole Length ratio within and among the three saline zones of Sundarban mangrove forests in Bangladesh (Box and Whisker plot)

4.1.15: Leaf Upper Quarter Width Down Quarter Width Ratio

Leaf Upper Quarter Width Down Quarter Width Ratio varied 0.453-1.56 in Satkhira, 0.54-1.54 in Koira and 0.47-4.84 in Sarankhola (Table 2). The maximum Leaf upper quarter and down quarter width Ratio (4.43) was found in Shoronkhola and minimum ratio (0.45) was found in Sarkhira. Mean Leaf Area-Perimeter Ratio in Satkhira, Koira and Sharankhola were 0.83, 0.8 and 0.79 respectively (Table 3). One way ANOVA showed no significant difference ($p>0.05$) of Leaf upper quarter and down quarter ratio among the saline zones (Table 3).

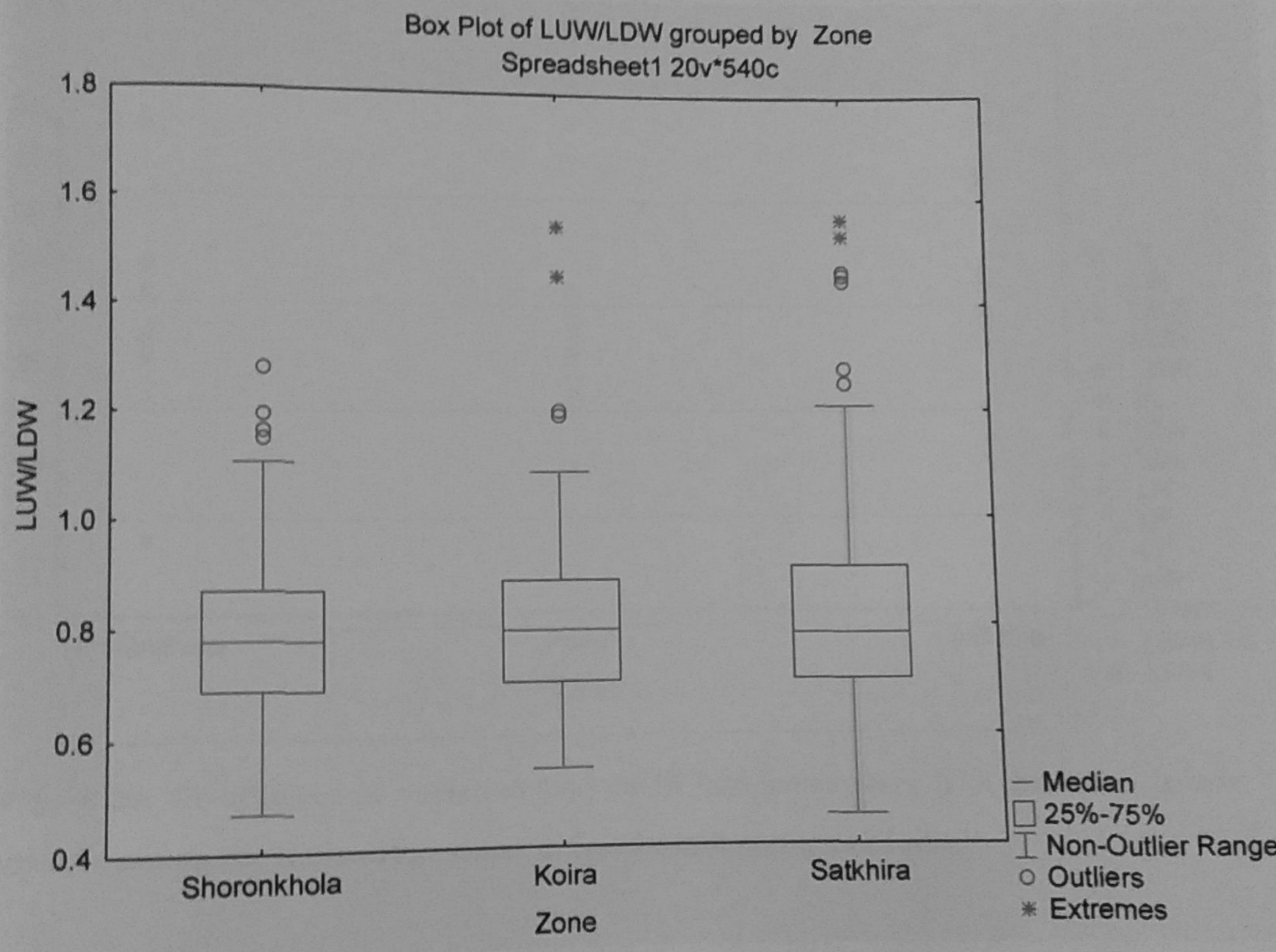

Figure19: Variation in Leaf Upper Quarter Width Down Quarter Width ratio within and among the three saline zones of Sundarban mangrove forests in Bangladesh (Box and Whisker plot)

4.1.16.Co-efficient of variation(%)of 15 leaf parameters

Co-efficient of variation (CV%) for all the Quantitative parameters were shown in Fig 20. The average CV of all quantitative parameters was <35%. The highest CV was observed in petiole length and the lowest CV was observed in leaf base angle.

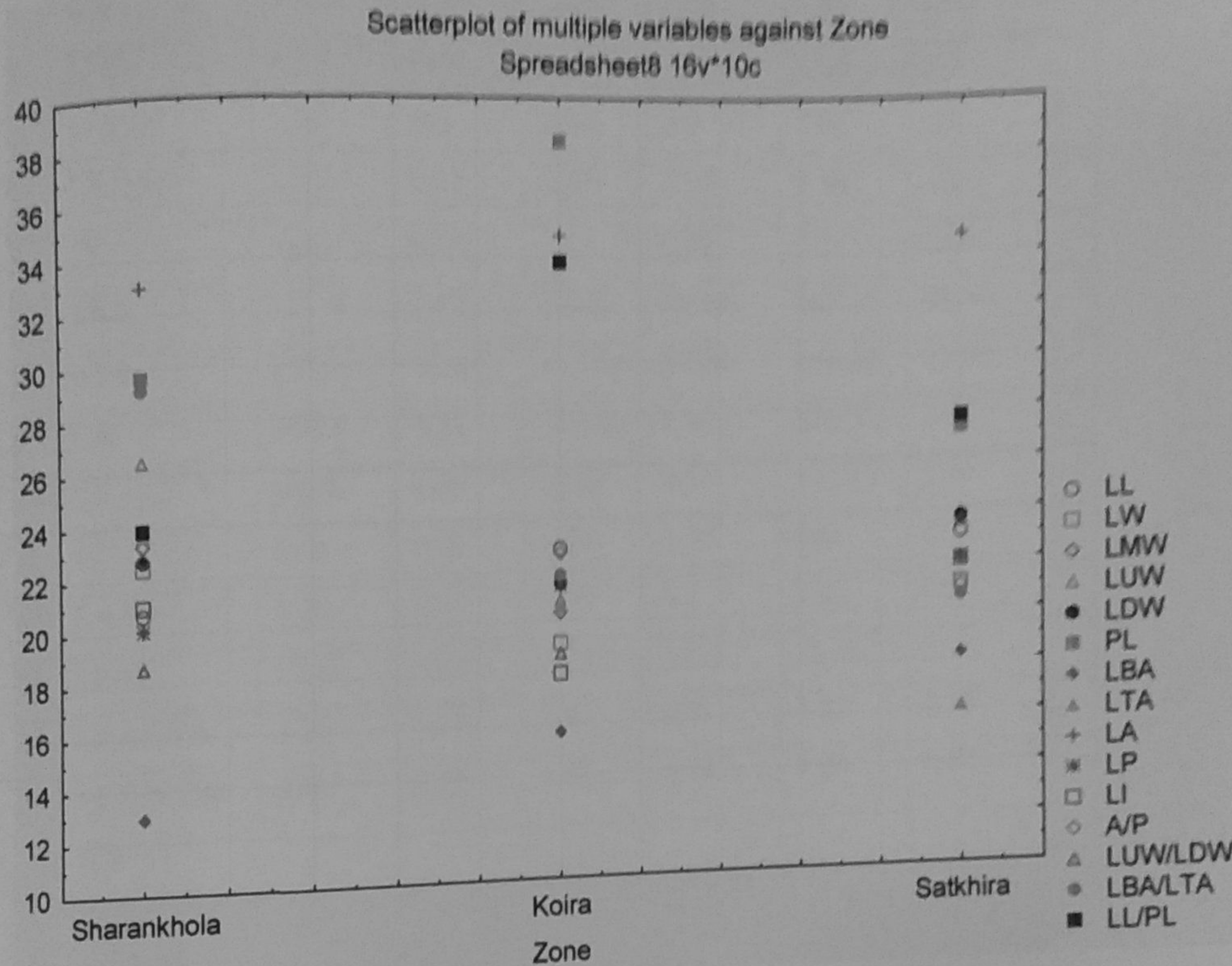

Figure 20: Co-efficient of variation (%) of 15 leaf parameters in Keora (*Sonneratia apetala*)among the three saline zones of Sundarban mangrove forests.

Table 2: Variation among the Leaf Parameters among three saline zones of the Sundarban mangrove forests.

SL	Parameters	Satkhira		Koira		Shoronkhola	
		Max.	Min.	Max.	Min.	Max.	Min.
1	LL	12.84	1.19	12.9	1.57	11.71	1.98
2	LW	3.78	0.68	3.94	1.38	3.85	0.57
3	LMW	3.75	0.64	3.91	1.28	3.82	.55
4	LUQW	3.02	0.5	2.86	0.9	3.08	.43
5	LDQW	3.43	0.51	3.69	1.19	3.58	.31
6	PL	1.89	0.39	2.15	0.37	2.21	0.36
7	LBA	121.9	34.22	104.4	24.59	103.17	48.41
8	LTA	135.9	52.66	117.63	27.28	165.25	45.97
9	LA	34.15	3.33	36.515	4.484	29.152	3.82
10	LP	43.19	6.89	41.41	8.77	37.713	0.16
11	LI	5.96	0.51	4.69	0.56	6.6	1.54
12	LA/LP	1.26	0.31	2.39	0.2	1.15	0.29
13	LL/PL	17.63	1.09	19.43	1.45	16.387	3.35
14	LBA/LTA	2.25	0.39	2.81	0.31	1.52	0.35
15	LUQW/LDQW	1.56	0.45	1.54	0.54	4.84	0.47

Table 3: ANOVA test and Tukey post-hoc test result for different leaf parameters of *Sonneratia apetala*: (Same alphabets showed no significant difference; Different alphabets showed significant difference of row to row)

Parameters	KOIRA	SATKHIRA	SHORONKHOLA
LL	8.10±0.14 a	8.28±0.14a	8.17±0.13 a
LW	2.64±0.04 b	2.47±0.04a	2.49±0.04a
LMW	2.56±0.04b	2.37±0.04 a	2.42±0.04 a
LUW	1.87±0.03 a	1.75±0.03 b	1.78±0.04ab
LDW	2.38±0.04a	2.18±0.04b	2.26±0.04ab
PL	1.00±0.03b	0.98±0.02b	1.09±0.02a
LBA	76.37±0.89b	65.50±0.89a	67.95±.65a
LTA	79.75±1.22b	93.08±1.12a	95.66±1.69a
LA	17.41±0.45a	16.40±0.42a	16.25±0.39a
LP	26.06±0.42a	25.58±0.42a	25.10±0.38a
LI	3.09±0.04 b	3.41±0.06 a	3.34±0.05 a
A/P	0.65±0.01a	0.63±0.01a	0.63±0.01a
LUW/LDW	0.80±0.01a	0.83±0.01a	0.79±0.01a
LBA/LTA	0.98±0.02 b	0.71±0.01a	0.75±0.01a
LL/PL	8.88±0.22 b	8.83±0.18 b	7.85±0.16 a

4.2.DISCUSSION

Sonneratia apetala Buch. Ham. shows a wide range of phenotypic variation leaf morphology. Salinity gradients plays a vital role for morphological variation. In general,leaf morphological characteristics can be varied between different species, different population of the same species or within an individual at different development stages (Dickinson et al,1987). Previous studied discussed possible relationship between changes in chromosome numbers and morphological variation on a basis of leaf morphological variation in croton cultivars. (SHARMA, 1958) (F., 1963) (Ogunwenmo, 2007) From box plot the present study has demonstrated that the quantitative leaf parameter of Sonneratia apetala characterize a wide range of phenotypic variations. Among the numerical parameter tested, leaf area perimeter ratio showed highest significant differences in plantation than strong, moderate and less saline zones. One way ANOVA also confirmed that there were significant phenotypic variation among all quantitative parameters. Co-efficient of variance indicated that leaf area showed highest significant variation among the saline zones. So, we can say that , salinity is a driving force of leaf morphological variation.

CHAPTER FIVE: CONCLUSION

In this experiment it is observed that salinity is mainly responsible for leaf morphological variation in Keora. This is a comprehensive evaluation of leaf phenotypic characteristic of the the *Sonneratia apetala*. The study has demonstrated that digital image-based procedure is an effective method to describe leaf phenotypic differences among the leaf parameters.

In this study we made effort to see the effect of salinity on Keora leaves in different saline zones of sundarbans. Thus, for scientific interest it is recommended that in future such studies should be under taken for other scientific research of Keora.

CHAPTER SIX: REFERENCES

Acharya, G. and Kamal, D. 1994. Fisheries. pp. 101-114. Mangrove of Sundarbans Volume two:Bangladesh. IUCN, Bangkok.

Alam, M. K. 1990 Tour report on Sundarbans trip during May. Forest Bottany Division, Bangladesh Forest Research Institute, Chittagong 2 pp.

Anon. 1989. Integrated resource Development of Sundarbans Reserved Forest, Project documents.pp - 55

Brown, B F. 1995. A Codiaeum Encyclopedia:Crotons of the world.Valkaria Tropical Garden, Valkaria, Florid.

Brown, B. F. 1995. A Codiaeum Encyclopedia:Crotons of the world.Valkaria Tropical Garden, Valkaria, Florid.

Choudhury, A. M. (1968) Working plan of Sundarbans Forest Division for the period from 1960-61 to 1979-80. East Pakistan Government Press, Dhaka. Pp - 82

Chowdhuri, A. B. and Naithani, H.B. 1985. A Comprehensive Survey of Tropical Mangrove.

Das, S. 1980 Mangrove forest of Banglades (management, exploitation and economics.)

Das, S. 1980 Mangrove forest of Bangladesh (Management,exploitation and economics.)

Das,S and Ghose M. 2003. Seed structure and Germination Pattern of Some Indian Mangroves with taxonomic Relevance. Taiwana,48(4):287-298

Forestal,1960.Forest inventory of Sundarbans forest.Oregon:LForestal

Hassan, D. Z. (2000). Some plants of Sundarbans. Chittagong: Tectona Computing. International Incorporated,Canada.

Jackson, D. A. (1987). A systamitic of mangrove genus Sonneratia in Australia. 277-302.

PAUL, A. A. (2015). Bangladesh Sundarbans: Present Status of the Environment and Biota. Diversity, 242-269.

Rahman, N. M. (1979, December 9-15). Preparation of an up to date map of Sundarban forests and estimation of forest areas of the same by using Landsat imageries. Second Bangladesh National Seminar on Remote Sensing.

Reveal, G. S. (1999). Validation of subfamily names Lythraceae. 435-436.

Sanyal, P. (1983). Mangrove tiger land: the Sundarbans of India. Tigerpaper10(3), 1-4.

Sanyal, P., Banerjee, L. K., & Choudhury, M. (1984). Dancing Mangals of India Sundarbans. J. Indian Soc. Coast. Agric. Res.2, 10-16.

SHARMA, A. (1958). A cytological study on the different varieties of Codiaum variegatum BL. 223-266.

Siddiqi, N. (2001). Mangrove Forestry inBangladesh. Chittagong: University of Chittagong.

Siddiqi, N. A. (1990). Gorowth performance of mangrove trees along the coastal belt of Bangladesh. Delhi: Thomson Press.

Siddiqi, N. A. (2001). Mangrove Forestry in Bangladesh. chittagong.

Tomlinson P., The botany of mangrove. Cambridge University Press, Cambridge, London. pp 413.

Wessler,S.R., 1988. Phenotypic diversity medited by the maize transposable elements Ac and Spm. Science 242, 399-405.

Zabala, N. Q. 1991. Silviculture of species.Development of Professional Education in the Forestry sector of Bangladesh .