CHAPTER 4

Summary and Conclusions

SUMMARY AND CONCLUSIONS

The species composition and structure of the 'best' mangrove forests vary as a function of the biogeographical location and environmental conditions. Various species have different ecological limits of tolerance and optimum for the various ecological parameters. Avicennia marina has wide limits of tolerance for most factors and thus has a very wide geographical distribution.

The genus Avicennia shows considerable morphological variation, especially in leaves and flowers. It is still a problem that whether the morphological forms are phenotypic variations, varieties, hybrids, ecotypes or good species. The information available on this aspect is inadequate. From this point of veiw the present work is planned.

In present investigation an attempt has been made to undertake autecology of Avicennia species which includes morphological characteristics, sediment characteristics, anatomical differences, species distribution, zonation pattern, phenology and species spatial variation in relation to environment and its taxonomic position in the ecosystem. For this the routine methods of analysis were used. Earlier observations reveal that many morphological attributes reflect eco-environmental gradients. However field studies suggest a more complex situation with corresponding genetic differences. Therefore, morphology anatomy and chemo-taxonomy of Avicennia species have been carried out to find out variations. The present study was undertaken at four different estuaries viz., Ganapatipule, Are, Sakhartar and Shirgaon along the cost Ratnagiri (Maharashtra). Selection of sites was done on the basis of Avicennia species distribution.

An Ecological Perspective :

An ecological perspective includes species distribution, zonation, association, phenology and leaf behaviour. In India, the genus Avicennia is represented by three species A. officinalis, A. Marina with two varieties A. marina var. Acutissima, A. marina var. resinifera and Avicennia alba. A. officinalis and A. marina var. acutissima are common in Maharashtra and are found distributed in all surveyed area, while A. marina var. resinifera is restricted to Sindhudurg district. Another species of Avicennia (dwarf) is restricted to Ganapatipule area. Species distribution along the west coast is not uniform and this may be due to tolerance and sensitivity of the species as well as sediment composition and natural factors. Avicennia species along with Sonneratia are the pioneers of mangrove swamp along Shirgaon estuaries, but along Ratnagiri estuaries A. marina colonies the fringe of the swamp facing the sea.

Zonation

For Avicennia physical and chemical factors, soil salinity, frequency of tidal inundation within each zone are not solely responsible for excluding species from zone but tidal sorting of propagulos play a key role in mechanism of zonation control.

Association :

Association of Avicennia species is studied to find out differences in the environmental conditions. A. officinalis is found associated with different species at different places while, association of A. marina is found only few whereas Avicennia dwarf species is found associated with

Avicennia officinalis, A. marina, Lumnitzera, Ceriops and Acanthus. Association pattern is different in different species which will reflect significant differences in species environmental condition.

Phenology :

Phenological information is vital to both taxonomic and community studies. The present data gives idea about phenophases of three different Avicennia species. Initiation, flowering and fruiting period in Avicennia differ weith species. A. officinalis and A. marina show different pattern than Avicennia dwarf species. The dwarf species initiates and flowers two months earlier than A. officinalis and A. marina. It means that the species prolong the reproductive cycle till monsoon ends. Thus variation is phenological rhythms such as flowering, fruiting. The pattern not only varies from species to species but also within the species. The present data not only gives the phenological characteristics of the species but also differentiates them.

Leaf behaviour :

The leaf behaviour is reflected in the transpiration rates. In this study relative humidity, leaf temperature, transpiration rate, diffusive resistance for water vapour, diffusive resistance and conductance for CO_2 shows the essential relationship and representative values for upper and lower leaf surface of three Avicennia species. In A. officinalis and A.dwarf species the values are similar which show high transpiration rate than A. marina for lower leaf surface while for upper leaf surface high values are seen for A. marina and Avicennia dwarf and low values for A. officinalis. It is seen that for A. dwarf species high rates are observed both for lower

and upper leaf surfaces which seems to be related to the structural modification of species and response to high temperature is probably involved.

Sediment Characteristics :

Texture :

The changing important component is soil therefore, to understand the status of species soil analysis is carried out. Soil texture gives idea about grain size distribution. Silt and clay percentage is found to be higher along Ganapatipule estuaries for the soil near *Avicennia* dwarf root zone. Sediment distribution and species development is controlled to a considerable extent by wave and current energy. For the distribution of *Avicennia* dwarf species substratum may possibly play key role. The dwarf species community is limited to the flat fringe of Ganapatipule site which has its own characteristic of environmental variables.

Electrical Conductivity :

Electrical conductivity is usually caused due to water soluble solutes. It is recorded seasonaly. Electrical conductivity of soil at Ganapatipule ranges from 1.45-2.90 mS/cm, 2.41-3.51 mS/cm for Are and 4.50-7.13 ms/cm for Shirgaon estuary. Low electrical conductivity is recorded in monsoon. Variations at different stations are due to different levels of total dissolved solids for different estuaries.

pH :

pH of soil ranges from 4.2 - 6.6. Low pH is recorded from Sakhartar and Shirgaon sites. The pH of soil changes in relation to tides, rainfall, rate of evaporation and also due to human activities.

Organic matter :

Variation in organic matter is occuring as a function of seasonal change. The lowest value recorded is 1.3% and the maximum recorded is 10.5%. The differences in organic matter content may due to seasonal periodicity associated with the quantity of detritus available to consumers but however this is to be confirmed. The mangrove soil inspite of its water logged condition, poor deriation does not accumulate much humus. This is possibly due to washing away of the decaying organic matter by the tides. This may be reason for lower levels of organic matter content.

Chlorides :

The determination of chloride content of soil under different species are characteristic and confirm different stages of succession. Chlorides of Shirgaon sites are higher than other sites. This area receives direct estuarine water. The chloride content of Avicennia soil fluctuates with season.

Salinity :

The range of soil salinity for Ganapatipule is 0.48 - 0.91% and for Shirgaon is 0.97 - 2.16%. Salinity variation at different sites during most of the period shows a gradient variation. On the basis of salinity Avicennia species may be listed in sequential order of salinity tolerance.

Elements :

Elements like Na, K, Ca vary with change in the surrounding condition. Sodium content from Ganapatipule and Are sites do not show much differences but significant difference is seen from other sites.

Sodium, potassium and calcium show a wide range, minimum in monsoon and maximum in summer.

Leaf Characteristics :

The leaf characteristics studied in the present investigation are leaf thickness and area. The values show sufficient variation giving dignostic feature to each species. Leaf thickness varies according to degree of salinity and also leaf age. The anatomical basis for this is the differential expansion of mesophyll cells. Leaf succulence in different species of Avicennia has explanation in terms of salt balance. It is correlated with soil salinity, since the leaves are found thicker along the sites of constant high salinity. The area, weight and thickness are well correlated and are dignostic for different species of Avicennia.

Seedling Morphology :

In the present investigation seedling morphology is covered. Shoot length, root length and number of leaves show species diversity and it is found that seedling character of each species have definite pattern. In A. officinalis shoot length in young seedling varies from 13-20 cm. and root length from 3 - 6.3 cm. While in Avicennia dwarf shoot length varies from 6.4 - 12.5 cm and root length from 3.6 - 8.3 cm. Seedling morphology and establishment form one of the means for species identification.

Salt glands :

Salt galnds in Avicennia species are scattered in individual shallow pits in the upper leaf surface. The structure of salt glands of three Avicennia species varies greatly with leaf age. In A. officinalis and A. marina the gland is 5.8 celled but it is 4-7 celled in Avicennia dwarf species. The structure of the gland is similar in all the three species, but size and number of cells differ. Avicennia dwarf species has numerous salt glands and comparatively less number of cells than A. officinalis and A. marina.

Trichomes :

The use of trichome in taxonomy is well known. To find out variations in species of Avicennia trichomes are studied from all the three species. They show wide variation. The trichomes are simple, multicellular, T shaped glandular hairs consisting of stalk and unicellular head. The size varies in three species. The height of the trichome of A. officinalis is less than that of A. marina and Avicennia dwarf species but the length of the head cell is greater in A. officinalis that A. dwarf species. The height of trichome of Avicennia species is intermediate between A. officinalis and A. mairna which suggest significant relationship among species.

Pneumatophores :

The pneumatophores of the three species are studied with respect to length, girth and number of pores/cm to know the differences if any. The analysis reveals the variation in length as per the species and site. The length ranges from 7.5 - 18.8 cm, 16-20 cm and 19-30 cm for

A. officinalis, A. marina and Avicennia dwarf species respectively. The variation is to accomodate fluctuations and extremes of water, soil salinity and shifting anaerobic substrate. This characteristic of species is important to know the requirement of each species as a function of ecological factor. The soil type is also important in determining the nature of pneumatophore of the species.

Flowers :

Genus Avicennia shows considerable variation in flowers also. Classifications based on these attributes, therefore depend on the extent to which an observer considers the variation to be genetic. The variation observed in populations of A. officinalis, A. marina and Avicennia dwarf species reflect environmental influences in different geographic estuarine and intertidal locations. The flowers are 2-14, 2-12, 10-20 per head in A. officinalis, A. marina and Avicennia dwarf species respectively. The flowers show wide variation with respect to colour, size and number.

Pollens :

Variation in mangrove pollens is of systematic significance. The morphological characterization of pollen grains are studied with respect to shape, size, aperature and exine pattern. The main object of the present investigation on pollen characterization is to understand differences in the species. This aspect is helpful in identifying the taxonomic status of the species. The range of pollen size difers with the species in question. Thus the present information is helpful in clarifying the doubts among the genus.

Fruits :

Keeping in mind the ecological view and differentiation of species fruit morphology is carried out. The average length of fruit is 2.2-2.8 cm

1.5 - 2.4 cm., 1.3 - 1.7 cm. For A. officinalis, A. marina and Avicennia dwarf species respectively. Significant differences are observed. Thus the physical properties of fruits are important to find out suitable mature propagule. Fruit morphology of these species clearly indicates species and varietal differences.

Anatomy :

Leaf :

It is observed that both upper epidermis and lower epidermis are present in leaves of three Avicennia species. Lower epidermis is not clearly visible due to presence of trichomes. Upper epidermis has a thick cuticle which bear salt glands. The epidermal cells are polygonal in shape but size differs with species. The size and shape of epidermal cells vary according to conditions where the plant grow. Below the upper epidermis there are layers of hypodermal cells. In Avicennia hypodermal water storage tissue are present on adaxial side only. In A. officinalis water storage tissue forms 1/4th of the leaf thickness whereas in Avicennia dwarf species it is upto 50%. Specific differences are seen in Avicennia species with respect to water storage tissue. Palisade mesophyll is well developed in all the three species. In the present study no specific pattern is observed. Below palisade cells there is spongy tissue in all species. Trichomes are present on the lower leaf epidermis. Frequency and size of trichome varies with species. This characteristic gives white to whitish dull appearance to leaf surface.

Stem :

The present attempt is made to find out differences in anatomical characteristics in Avicennia species if any. There is no specific difference found in T.S. of stem. A conspicuous feature of the stem of Avicennia

is uniform. Anomolous growth rings consists of bands of xylem, including radial multiple large vessels, alternating with bands of conjuctive tissue, with strands of phloem. Seperating each band is a narrow strand of sclerenchyma, 2-3 cells wide. The bands are regular. The rings are non annual therefore, the number of rings cannot be used to determine age in Avicennia species. Further investigations are needed on this line.

Pneumatophore :

Pneumatophores of Avicennia have limited secondary growth. In young pneumatophore the cortex is lacunose, cells of the middle cortex become lobed, creating enlarged intercellular space. Few differences are found between the pneumatophores of Avicennia species which can be correlated with their relative positions in soil of each species.

Starch distribution pattern :

The starch distribution pattern differs in Avicennia species which show very intense reaction in mesophyll cells of Avicennia dwarf species while it gives faint blue colour to A. marina. In A. officinalis reaction is slight on the mesophyll cells. The pattern varies with species.

Chlorophylls and Polyphenols :

To find out photosynthetic efficiency chlorophylls are estimated as one of the phytochemical parameter. The chlorophyll content varies from species to species and site to site. The values of chlorophyll a and chlorophyll b are maximum in leaves of Avicennia dwarf species from Ganapatipule. The ratio of chlorophyll a to chlorophyll b does not vary significantly. The polyphenol contents for the leaves of mature plants and seedlings show significant difference. Maximum value is recorded at

Are estuary and minimum at Ganapatipule estuary. Mature leaves contain high levels of polyphenol than seedlings. The amount of polyphenols in the leaves of species is dependent upon age of the leaf and polyphenol degrading enzymes. It is clear that polyphenol contents and the response to salinity is dependent upon the species.

Carbohydrates :

In the present work carbohydrates are estimated in different parts of the plant (leaf, stem, pneumatophore). The levels of carbohydrates in these species are species dependent. It is seen that the carbohydrates are more in the leaves and pneumatophores than stem. In Avicennia dwarf species lowest values for starch (for leaf, stem and pneumatophore 6.3 g/100 g, 6.8 g/100 g and 6.7 g/100 g respectively) are found at Ganapatipule during winter. The highest values are 15.5 g/100 g, 17.4 g/100 g and 16.6 g/100 g for leaf, stem and pneumatophore respectively. Carbohydrates are higher in fruits than leaves.

Proteins :

The protein content of leaf is found higher than stem and pneumatophores. The highest protein value is seen for Avicennia dwarf species. The values do not differ much. The highest value of protein is 2.95 g/100 g obtained in the fourth fruit stage.

Elements :

Seasonal variations in sodium, potassium, calcium and chloride from leaf, stem and pneumatophores of different estuaries show that the values of sodium are low in monsoon. Highest values are seen at Shirgaon

estuary. It is observed that values of potassium are more during monsoon. Sodium and potassium values are similar and calcium values are very low. When salinity of soil decreases, the species reduce sodium and chloride accumulation and increase calcium and potassium uptake. These elements show variation in different species of Avicennia. This is due to different environmental conditions of the species where internal salt contents differ depending upon locality. It is seen that pneumatophores contain more sodium than stem.

Energy content :

Coastal people use the mangrove twigs for fuel, the energy content is estimated from different species of Avicennia. The calorific valuesd range from 2242.50 cal/g - 3668.69 cal/g for leaves while the range is 3380.02 cal/g - 5922.12 cal/g for stem of Avicennia. The highest value is recorded for A. officinalis. The calorific value of pneumatophare of Avicennia dwarf species is higher than stem and leaf. Calorific value of leaves indicate the energy source for detritus based food chain while that of stem indicate energy content available for fuel.

The present work on ecology of Avicennia species adds to the existing knowledge of the species. The autecology of Avicennia species is entirely a new contribution which gives an interesting ground for further probe of investigation. The chemotaxonomical aspect throws light on characteristic feature of Avicennia species.

1. Distribution, association and zonation of Avicennia species reflect significant difference inenvironmental condition.

2. An additional species of Avicennia has been identified. The population is located and restricted only to Ganapatipule estuary wehich is a new record. The species has its own characteristic of environ mental variables.

3. Avicennia dwarf is distinct with respect to flower, pollen trichome and pneumatophore morphometrics.

4. The leaf area, weight and thickness are well co-related which are dignostic for different species of Avicennia.

5. The stunted deformed Avicennia species are seen everywhere along the west coast of Manarashtra. This changing nature is due to illicit cutting, grazing and human activities (pollution). It has been confirmed that the dwarfs are nothing but A. officinalis and A. marina forms. Such dwarfs bear heteromorphic leaves. These ecotypes are different than the species found at Ganapatipule which does not bear heteromorphy.

6. Soil characteristic play key role for the distribution of Avicennia species.

7. Leaf behaviour forms an important character. Only for Avicennia dwarf species high rates of transpiration are seen both for upper and lower leaf surface which is related to the structural set up of the species.

8. Pneumatophores, trichomes, salt glands of this species differ from other Avicennia species.

9. Phenology of this species has been studied for the first time from west coast of Maharashtra.