# CHAPTER 3

# *Results and Discussion*

# RESULTS AND DISCUSSION

## I. AN ECOLOGICAL PERSPECTIVE :

### A. Distribution :

Mangrove formations are a major feature of many coastal zones in the tropics and subtropics. Though the surface area they cover is relatively small, mangroves are important to tropical countries for multiple reasons. This ecosystem is considered to be one of the best but fragile natural productive system of renewable resources, along the coastal belt of the world. Besides productivity it maintains very rich bio-diversity with highly important food chain producing both terr strial and aquatic flora and fauna and ultimately regulating available oxygen, carbon and nutrients.

India stands as the 6th nation covering total mangrove area 4.87% of the globe. Indonesia is having the height mangrove areas about 41.16% followed by Australia (15.94%), Malaysia 9.45%, Burma 6.86% and Bangladesh 5.88%.

In India, West Bengal mangrove belt is the bigest area covering 62.31% of the total mangrove areas of India. Then follows Andaman and Nicobar groups of Islands with 17.66% area. The other states in India cover not more than 5% of the total mangrove area. Maharashtra 4.90%, Gujarat 3.86%, Andhra Pradesh and Goa 2.97%, Orissa and Tamil Nadu about 2.22%. ( Bhadury, 1991). All over the world the mangroves are represented by 16 families 27 genera and 60 species (Mall et al 1986).

The most common and systematically troublesome species is Avicennia. The genus Avicennia L. shows considerable morphological variation, especially in leaves and flowers. The genus Avicennia (Avicenniaceae) in the world is represented by 11 species (Chapman, 1970). Out of 11 species 6 are distributed in West Pacific, 3 in Pacific America, 3 in Atlantic America and only one in West Africa. The 3 species of Avicennia such as A. eucalyptifolia, A. marina, and A. officinalis are distributed in Australia ( Field and Dartnall, 1985). Moldenke (1960, 1967, 1975) recognized 7 Australian taxa with five species while Tomlinson (1986) described four species.

The genus Avicennia in India is represented by 3 species A. officinalis, A. alba and A. marina with two varieties : A. marina var. acutissima, and A. marina var. resinifera.

In India Avicennia is distributed along East and West Coast. Along west coast the genus is distributed in Gujarat, Maharashtra, Goa, Karnataka & Kerala and along East Coast it is present in West Bengal, Orissa, Andhra Pradesh, Tamilnadu, Andaman and Nicobare Isands. The mangroves are found in five coastal districts of Maharashtra where A. officinalis and A. marina var. acutissima are common . Table 1 shows distribution of Avicennia along west coast of Maharashtra. Along the west coast of Maharashtra. A. officinalis and A. marina var. acutissima are dominant species which are found distributed in almost all surveyed areas. It is observed from table 1 that A. marina var. resinifera is restricted to only very few areas. However, in the present work much attention is paid on another Avicennia species which is also restricted to certain areas. There are 2 Avicennia species that occur uniquely on either the

Table - 1 : Distribution of *Avicennia* Along West Coast of Maharashtra

| Sr. No. | Location | Species | | | |
|---|---|---|---|---|---|
| | | *A. officinalis* | *A. marina* var. *acutissima* | *A. marina* var. *resinifera* | *Avicennia* species |
| 1 | Ganapatipule | + | + | - | + |
| 2 | Are | + | + | - | - |
| 3 | Bankhind | + | + | - | ? |
| 4 | Shirgaon | + | + | - | - |
| 5 | Sakhartar | + | + | - | - |
| 6 | Bhatye | + | + | ? | - |
| 7 | Tarkarli | + | + | + | - |
| 8 | Kolamb | + | + | + | - |
| 9 | Terekhol | + | + | - | - |
| 10 | Vengurla | + | + | - | - |
| 11 | Mochemad | + | + | - | - |
| 12 | Kelus | + | - | - | - |
| 13 | Dabhol | + | + | - | - |
| 14 | Khavane | - | + | - | - |
| 15 | Thane | + | + | - | - |
| 16 | Mahim | + | + | - | - |
| 17 | Juhu | + | + | - | - |
| 18 | Bombay | - | + | - | - |

east or west coast. It is evident from table that even along the west coast the species distribution is not that uniform. This may be attributed to the tolerance and sensitivity of the species as well as sediment composition (Bhosale et al, 1983) and also stabilization. The sediment stabilization depends on various natural factors and human activities. Siltation is one of such factors which determines the species that occur at a perticular site. Along Bhatye estuary Avicennia, marina are found growing in medium tree form but huge trees of A. marina are also found growing in the knee-deep mud of Girya estuary. It is observed that in very few estuaries the vegetation is dense and that is because of muddy substratum unless human activities. The destruction of Avicennia species reflects changing in the floral and faunal composition. The study of remarkable distribution of mangrove species in old and new world done by Chatterjee (1958) mentions that as the degree of salinity varied from the sea water line to the landward side, was correlated with frequency and the distribution of mangroves. It is suggested by Clarke and Hannon (1971) that the distribution of mangroves appear to be closely related to topography and tidal amplitude, which inturn determine the degree and pattern of tidal inundation.

In Australia and New Zealand Avicennia is found as far as south $37^{o}$ (Chapman 1970).

The distribution of Avicennia is also classified on the basis of thermal groups. Avicennia marina is classified as a cool temperate species with shoot growth threshold of $10^{o}$C. Davie (1982) measuring shoot grwoth distict from leafing in Mareton Bay showed growth in local populations of A. marina in mean daily temperatures of 18 to $24^{o}$C with an optimum of

20 to $22^{o}C$. It is also useful to hypothesise distribution of species on the basis of temperature optimum latitudinaly and this appears to explain different species distribution pattern quite well. However, some studies by Davie (1982) at different locations suggest that the distribution may vary depending upon local climatic and edaphic conditions. Several factors influence the distribution and abundance of Avicennia species. From the present study it can be inferred that sediment/edaphic factor plays the key role in favouring the distribution of Avicennia. A. marina species can withstand high currents and high salinity, whereas A. officinalis is distributed inwardly. Though the distribution pattern of species of Avicennia is different, the species are able to locate maximum salinity condition of the areas with the help of salt excreting glands or by increasing water storage tissue in their leaves (Chapman, 1976).

The species forming the communities vary in different regions as shown in Table 1, and distribution of Avicennia seems to be ruled by both the pattern of succession and accidentalism depending on the topography and soil condition.

## B. Zonation

Mangrove species form distinct zone on the shore according to their salt tolerance, nature of substratum, resistance to flooding, strong wave action and exposure to wind. Condition aspect has been studied by many investigators (Watson, 1928; Davis, 1940; Chapman, 1977; Walter; MaCnae, 1968; Joshi, 1976; Bhosale, 1974). Snedaker (1982) has identified four reasons for mangrove condition viz., plant succession, geomorphology, physiological ecology and population dynamics.

There is a variation in zonation pattern in different parts of the world. According to Singh et al (1986) the mangroves of Andaman shows proximal middle and distal zone patterns. In the present study area the formation of this species is simple. Plants grow commonly upto 1 to 2 m high and upto 4 m high for well protected plants. (Figure 1) As a result of suffering, cutting from time to time and also due to grazing. The community has a toughty form. In the community. Avicennia marina grows on a front side where there is great tidal current and A. officinalis on the back side where there is less tidal current. At Ganapatipule area the pioneer species is Avicennia (dwarf). This zone is purely occupied by Avicennia dwarf patch. The middle zone is towards interior, which constitutes mixed mangrove vegetation zone with six mangrove species viz., Bruguiera gymnorrhiza, Ceriops tagal, Lumnitzera racemosa, Aegiceras, Sonneratia, Rhizophora. The third zone towards landward fringe is occupied by Avicennia officinalis, and Excoecaria agallocha.

At Are estuary the 1st zone is of mixed vegetation viz., Lumnitzera, Ceriops, Avicennia (dwarf), and Sonneratia. No distinct zonation pattern is seen. In area along the Shirgaon estuary there is no definite kind of zonation. At this site there is contineous grazing. Here the zones can be made on the basis of dominance of perticular species. Avicennia zone and Sonneratia zone are prominant. Similar pattern of zonation was studied by Radhakrishnan (1984) along the Achra estuary. A. officinalis is found to occur in all parts of estuary while the remaining species have restricted distribution. The unique pattern of distribution of species has made it convenient to classify mangrove vegetation into different zones and this demarcation is made on the basis of dominance of perticular

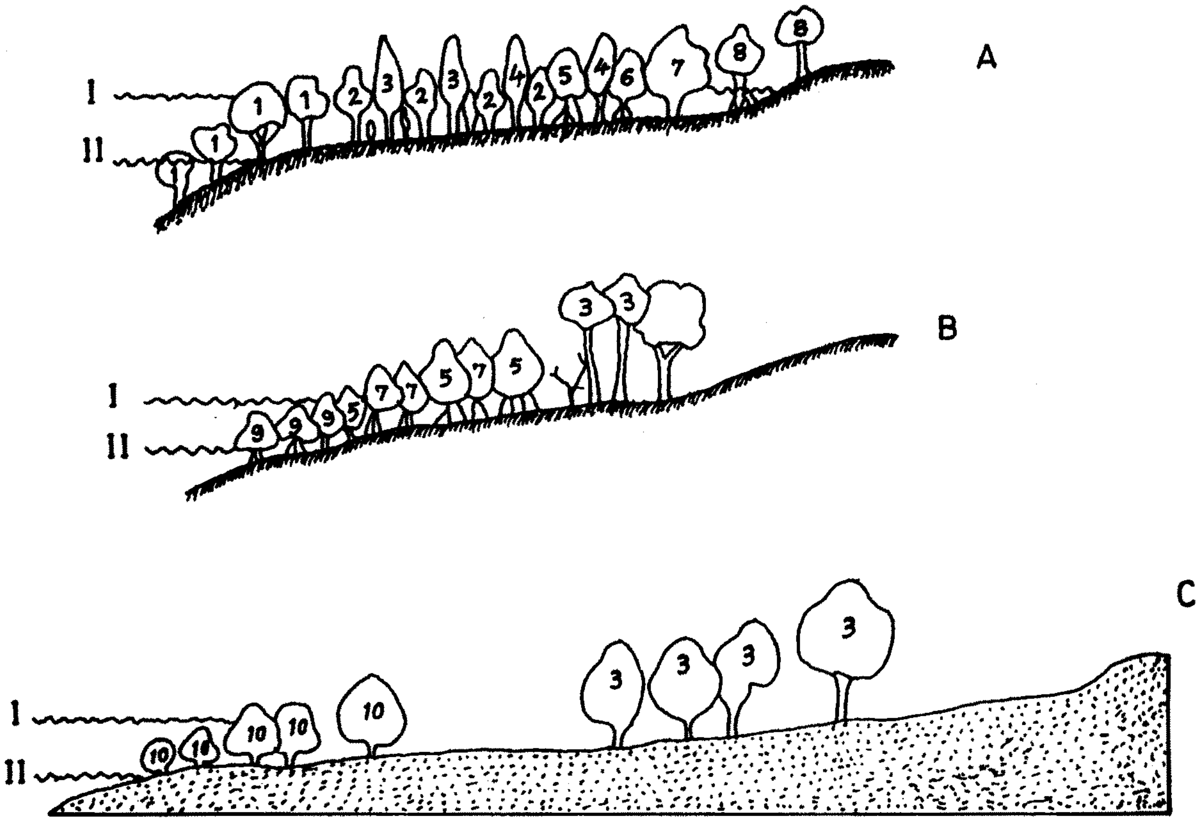



Fig. 1 – Zonation in mangrove stand on the cost of Ganapatipule and Ratnagiri estuaries.

A – Ganapatipule
B – Are
C – Shirgaon
I – High tidal line
II – Low tidal line

1. *Avicennia* dwarf species
2. *Aegiceras corniculatum*
3. *Sonneratia alba*
4. *Avicennia officinalis*
5. *Ceriops tagal*
6. *Rhizophora mucronata*
7. *Lumnitzera racemosa*
8. *Excoecaria agallocha*
9. *Avicennia* (dwarf)
10. *Avicennia marina*

species, viz., Rhizophera zone, Avicennia zone, Sonneratia zone, Excoecaria zone and fringing zone. Down the east coast of India the mangroves of Godavari estuary have been described by Puri and Jain (1960), Rao (1958), Sidhu (1963), Raju (1968). Along the banks the pioneer species are A. marina and A. alba. Behind this the frontal belt is of mixed vegetation comprising R. mucronata, B. gymnorrhiza, C. decandra, X. granatum and S. apetala. Along these estuaries the land cover is large, therefore in some estuaries mangroves can be seen in zones or bands if the available area is large.

Along most coasts on which mangroves occur the most seaward zone of trees is made up of a stand of one of the Avicennia species. And those are flooded by all medium high tides. Avicennia sp. along with Sonneratia sp. are the pioneers of mangrove swamp along Shirgaon estuary. Seedlings of Avicennia marina and Avicennia officinalis colonise the new banks develop into saplings and finally well developed zone of Avicennia is established. The situation is seen along majority of estuaries. Along Ratnagiri estuaries A. marina colonises the fringe of the swamp facing the sea rather than channel of creek giving way to Avicennia officinalis and Rhizophora sp. along entrance channels. The variation in zones occur depending on the type of soil present.

In recent years there has been a greater concern with the basic question of mangrove zonation, involving a shift from mere discription to a more functional approach. Although there have been many discriptions of likely causes for zonation (Floyd, 1977; Paijmans and Rollet, 1977; Lugo, 1980; Woodroffe, 1983 and Johnstone and Frodin, 1982) have attempted more thorough analysis. Johnstone and Frodin (1982) have proposed 6 classes of likely causes.

1. Inundation and water depth
2. Wave action
3. Drainaing
4. Salinity and fresh water regime
5 Substrate
6. Biota and biotic interactions

The last name has been relatively neglected elsewhere, and as a theme is more fully developed with reference to the Hood Lagoon area by Johnston (1983). Bird and Barson (1982) have also studied zonation and some of its controlling factors.

The studies both descriptive and analytical of the problem of zonation are still needed in India. West coast of Maharashtra where there are number of raised islands offers a most interesting potential study area in this respect. Because mangrove zonation in the country is truely varied and purified base line studies are yet few. Cragg (1983) states that most recent transect studies are too small to provide an insite into the large scale pattern of distribution of mangroves in P.N.G. (Papua New Guinea).

Snedekar and Parkinson (1986) pointed out that mangrove forest occur in a large variety of structural types with different species composition and levels of productivity. Further they stress the point that although species zonation has been traditionally used to define types of mangrove forests, it has proven to be of value only in areas where monospecific zonation does in fact occur. Vannucci (1989) found well marked zonation along prograding coasts where year classes of one and the same species were clearly distributed in bands parallel to the coast or inplaces where the topography, soil, pH and other environmental conditions delineats jigsaw-like patterns and this is the distribution pattern of species that are linked to some environmental factor and therefore their presence indicates characteristics of environment. Remote sensing imageries and aerial photographs are best indicators of such studies.

The work of Robinowitz (1975) added new perspective to the mangrove zonation debate. Through carefully designed reciprocal planting experiments in Panamanian mangrove forest using species of Rhizophora, Laguncularia, Pelliciera and Avicennia. She demonstrated that each species could grow well within any of the mangrove zones. In other words, physical and chemical factors such as soil salinity or frequency of tidal inundation, within each zone, were not solely responsible for excluding species from zone. To explain zonation Robinowitz proposed tidal sorting of propagules based upon propagule size rather than habitat adaptation, as the most important mechanism for zonation control.

The recent piece to be added to the zonation/succession puzzle comes from the work of Ball (1980). Based upon research of Florida mangrove, she made a strong case for the importance of interspecific competition in controlling zonation. She found that white mangroves found to grow best in intertidal areas, do not occur consistantly in the intertidal zone of mature mangrove strands. Instead, white mangroves dominate higher, dryer locations above mean high water where the red mangrove does not appear to have a compitative advantage. In the present study Avicennia grow best in intertidal areas at few sites but as she suggested the competition is not so important during the early stages of succession but it becomes critical as individual trees reach maturity and require more space and other resources.

Zonation of mangrove species does not appear to be controlled by physical and chemical factor directly, but by the interplay of these factors with interspecific competition, possibly, through tidal sorting of propagules. Once succession in a mangrove zone reaches an equilibrium state, change is unlikely unless an external perturbation occurs. There is some evidence in South Florida that hurrican perturbations occur on a fairly regular bases, creating a pattern of cyclical succession. Although understanding of zonation and succession in mangrove ecosystems remains contradictory, a clearer picture is emerging slowly.

Contrary to early suggestions, mangrove species zonation does not appear to the present seral stages of succession except, perhaps, for locations of recent colonization or where sediment is accumulating rapidly.

C. Association

Association is floristic structural unit which gives satisfactory level of community description for discussing pattern and the distribution of the vegetation complex. Each association will reflect significant differences in the environmental conditions in which it grows and can therefore be regarded as an ecosystem in terms of its functional integrity (Lugo, 1980). In the present investigation attempt has been made to study the association of the species by recording the associate members. Avicennia officinalis was found associated with different species and the association at different places can be considered in following groups :

I. 1. A. officinalis - A. marina
   2. A. officinalis - Lumnitzera racemosa, Aegiceras corniculatum
   3. A. officinalis - A. corniculatum, Excoecaria agallocha

4. A. officinalis - Rhizophora mucronata, Ceriops tagal
5. A. officinalis - E. agallocha, R. mucronata, L. racemosa, C. tagal, Acanthus ilicifolius, Bruguiera gymnorrhiza

II.
1. A. marina - E. agallocha, A. officinalis
2. A. marina - E. agallocha, C. tagal, A. corniculatum
3. A. marina - L. racemosa, C. tagal, R. mucronata
4. A. marina - Sonneratia alba.

III.
1. Avicennia (dwarf) - L. racemosa
2. Avicennia (dwarf) - C. tagal, L. racemosa, A. corniculatum
3. Avicennia (dwarf) - A. officinalis, S. alba and R. mucronata
4. Avicennia (dwarf) - A. officinalis, C. tagal, S. alba and A. ilicifolius
5. Avicennia (dwarf) - E. agallocha

It is clear from the above interspecific relationship that the association suits the growth of both the species. It is also evident from this that it is not sufficient to know merely that a species is present, common or forming a monospecific zone. Table 2 shows association of Avicennia species at different sites.

Avicennia species (dwarf) form an accurate assessment of its status. At Ganapatipule region dwarf species form a mono-specific zone. Dwarf shrubby communities less than 0.25 m in ht. are found at the landward margins of the estuary where there is moderate to high tidal range. This community of dwarf species is restricted to this site only. Similar type of observations are described by Dieter (1984) with respect to A. eucalyptifolia. The nature of the association pattern may be covered by many

Table 2 : Association of *Avicennia* species at Different Sites

| Association | Geographical Areas | | | |
|---|---|---|---|---|
| | Ganapatipule | Are | Sakhartar | Shirgaon |
| *A. officinalis* | | | | |
| *A. marina* | + | + | | + |
| *L. racemosa* | + | | | + |
| *A. corniculatum* | | | | + |
| *E. agallocha* | + | | + | |
| *C. tagal* | + | | | |
| *R. mucronata* | + | + | + | |
| *B. gymnorrhira* | + | | | |
| *A. ilicifolius* | | | | |
| *S. alba* | + | + | + | + |
| *A. marina* | | | | |
| *E. agallocha* | + | | + | |
| *C. tagal* | | | + | |
| *A. corniculatum* | | + | + | |
| *L. racemosa* | | | | |
| *S. alba* | | + | + | + |
| *R. mucronata* | | + | + | |
| *A. ilicifolius* | | + | | + |
| *A.* (dwarf) | | | | |
| *C. tagal* | + | | | |
| *L. racemosa* | + | | | |
| *A. officinalis* | + | | | |
| *S. alba* | | | | |
| *A. ilicifolius* | + | | | |
| *E. agallocha* | + | | | |
| *A. corniculatum* | + | | | |

factors including timing, frequency of climatic extends, availability of seed stalk, biotic factors including human activities (Beeflink, 1977).

A few mixed communities in association with Kandelia candel are also found at Bhatye estuary of Ratnagiri district. Similar type of association were also found with Bruguiera gymnorrhiza at Ganapatipule. Associations with Rhizophora mucronata, Ceriops tagal, Lumnitzera racemosa and Aegiceras corniculatum appear to represent later stages in mangrove succession.

D. Phenology

Though phenology works is a small part of vegetation analysis process, a study of mangrove phenology have useful spin offs for the manager. In areas where there are considerable climatic variation in mangroves, phenological information is vital for both taxonomic and community studies. The flowering and fruiting times of Avicennia species in India is helped taxonomic judgement to decide the validity of varietal and sub-specific taxa. It works like indicator in suggesting the appropriate time to monitar for recruitment in populations. It is useful tool in analysing interspecific seedling competition. Documentation on fruiting times is useful for rehabilitation work. Phenological variations may be due to the species position in the community (Bridgewater, 1987). The present study is undertaken to compare different phenophases of Avicennia species. Table 3 records the difference in phases of the three species of Avicennia. It is seen that the average length of reproductive cycle is more in Avicennia dwarf species (from December to September). In Avicennia dwarf species reproductive stage initiates two months earlier than A. marina and A. officinalis. the initiation observed in the dwarf is in December and January.

Table - 3 : Phenophases of Avicennia Species

| Species | Stage | J | F | M | A | M | J | J | A | S | O | N | D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Initiation | | + | + | | | | | | | | | |
| | Budding | | + | + | + | + | | | | | | | |
| A. officinalis | Blooming | | | + | + | + | + | | | | | | |
| | Fruiting | | | | | | | + | + | + | | | |
| | Seedling | | | | | | | + | + | + | | | |
| | Initiation | | + | + | | | | | | | | | |
| | Budding | | + | + | + | | | | | | | | |
| A. marina | Blooming | | | + | + | + | + | | | | | | |
| | Fruiting | | | | | | | + | + | + | | | |
| | Seedling | | | | | | | + | + | + | | | |
| | Initiation | + | + | | | | | | | | | | + |
| | Budding | + | + | + | | | | | | | | | |
| Avicennia species (dwarf) | Blooming | + | + | + | + | + | | | | | | | |
| | Fruiting | | | | | | + | + | + | | | | |
| | Seedling | | | | | | | + | + | + | + | | |

Budding stage starts from January. The maximum blooming is recorded from March to May. It ceases at the end of May and commences fruiting It is an interesting observation while comparing the other two species. Phenological characteristics of Avicennia species are related to different environmental factors particularly temperature, soil and water conditions. An extensive flowering in A. officinalis and A. marina is during March to June, may be attributed to higher temperature and longer duration of light (photoperiod). Extensive blooming of A. dwarf species is from February to April, decide the varietal and sub-specific taxonomic position of this species in the ecosystem. The dwarf species initiates flowering two months earlier than the other two species. It seems that the dwarf species have longer reproductive cycle than vegetative phase. This means that light intensity and high temperature may be responsible for excretion of chemical in the growing primordium which induce flowering.

A. officinalis and A. marina show different patterns in their phases The phenophase of A. officinalis reveals that the flowering period is short as compared to other genera. From September to December there is complete vegetative stage of the plant. In contrast to this the vegetative stage is very short when compared to Avicennia dwarf species. In A. marina floral initiation is observed from February to March, at some sites it is observed from January to April. Flowering begins in early March, reaching maximum in May. Fruit initiation starts in early May and extends upto September i.e. flowering and fruiting come to an end towards late September. Variable leafing and shedding, marked depression of leaf formation occurs during flowering and fruiting or during dry months in A. marina (Saenger and Moverley, 1983).

The three species of Avicennia analysed in the present investigation have revealed various patterns of phenophases. In Rhizophoraceae members all stages of developments are recorded throughout the year (Mulik and Bhosale, 1989). In Avicennia species stages of development are restricted to particular season. Different species of mangroves have adapted differently. The occurrance of propagules in mangroves in Ratnagiri district is maximum in summer. In some species the period from flower to mature propaogules varies greatly. Leaf production in Rhizophora is also seasonal, with a maximum during summer (Christensen and Wium-Anderson, 1977; Gill and Tomlinson,1971b), it seems that fruiting is limited to the period most favourable for growth.

Phenological rhythms such as flowering, fruiting vary from one species to another in a given locality (Blasco, 1984). From the present work it is evident that the phenological pattern not only vary from one species to another but also from one genus to another genus. There is response to longitudinal distribution by mangrove species with respect to flowering and phenological characteristic of each species is related to various environmental factors.

Several species of Avicennia grow together, there is evidence of non-synchrony in flowering times, which might minimise the competition for pollinators and at the same time spread the availability of nector over more period.

In Malaysia three species of Avicennia ( A. alba, A. marina and A. officinalis ) grow together and each species was found to have different stages of reproductive cycle (Tomlinson, 1986). Similar observations are recorded for the three species of Avicennia. Mature flowers were recorded for one species at a time. This may possibly be part of reproductive isolating mechanism for these species.

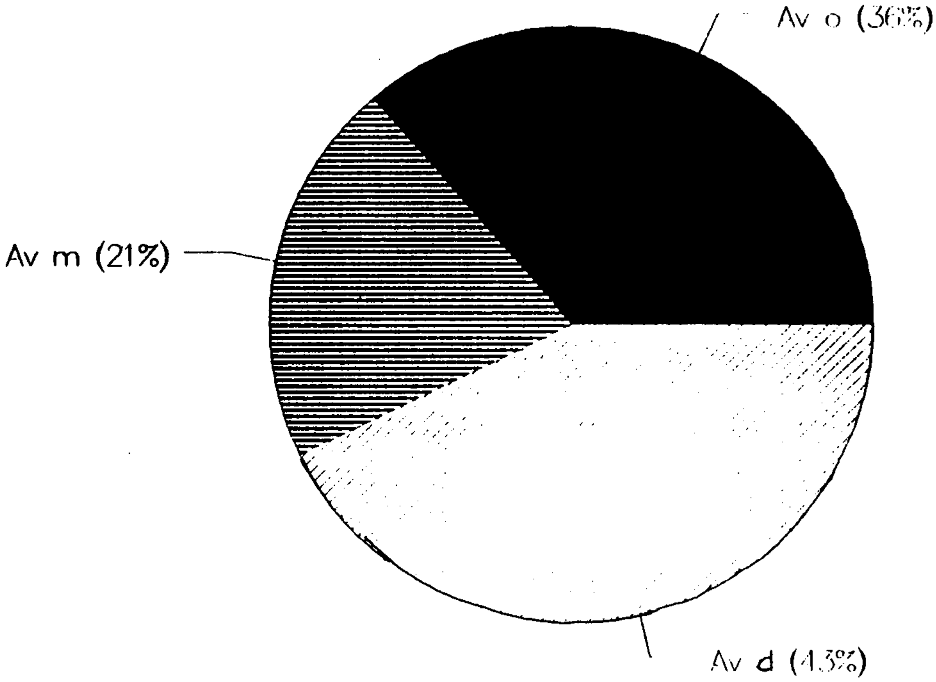
The propagules of the three species of Avicennia are easy to differentiate, Avicennia species propagules are small and flattened; A. marina propagules have medium size and A. officinalis propagules are larger and bigger. The propagules of all three species remain viable for extended periods of time. Propagule size and seedling mortality rates are particularly important in considerations of succession and replacement in established mangrove forest. Savage (1972) mentioned that on the Florida Gulf coast Red mangrove propagules mature and fall from the tree from July to September. Within the Everglades National, Black mangrove flowers from May untill July and bear fruits from August untill November while white mangrove flowers from May to August and bear fruits from July to October (Loope 1981).

In Bangladesh Siddiqi et al (1993) have recorded fruiting period for A. alba and A. marina from July to August and for A. officinalis during only August. It is clear from the above observations that there is change in the phenophases of Avicennia species from Bangladesh and west coast of Maharashtra.

## E. Leaf Behaviour

Stomata are restricted to the lower leaf epidermis (Sidhu 1975a, Joshi et al 1975a) despite comments to the contrary in Mullen (1931a) and Walter and Steiner (1936). Many genera show stomata some beneath the level of epidermis while sub-stomatal chembers are present in many genera ( Avicennia, Ceriops ), these are lacking in Xylocarpus and Excoecaria (Sidhu, 1975a).

Fig. 2 – Diffusive conductance for $CO_2$ of three *Avicennia* species.




Diffusive resistance for $CO_2$ of three *Avicennia* species.

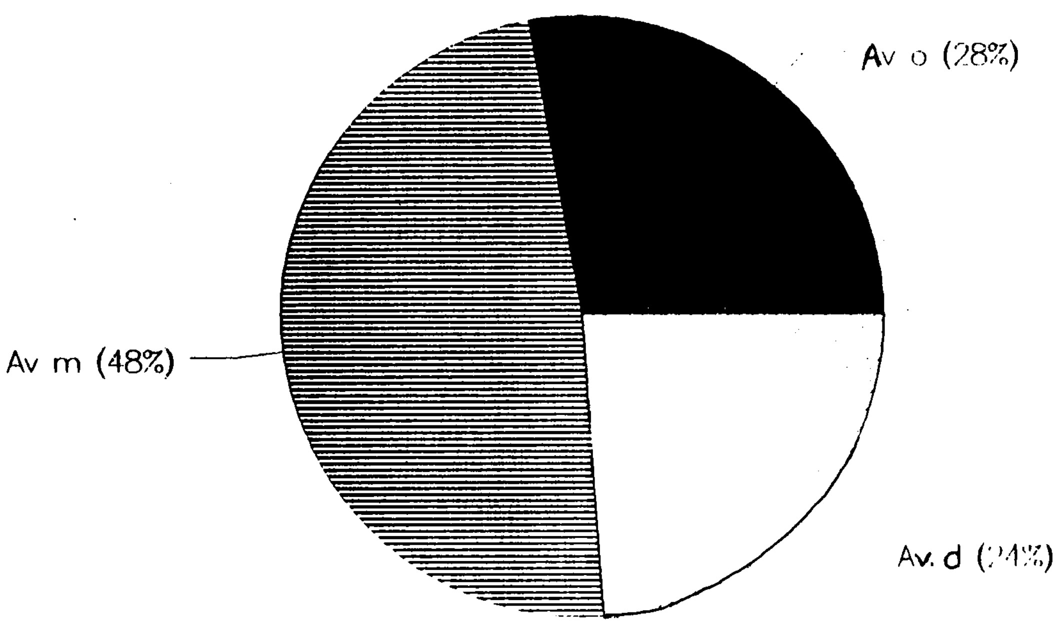


Fig. 3 — Diffusive resistance for water vapour and transpiration rate in different *Avicennia* species.

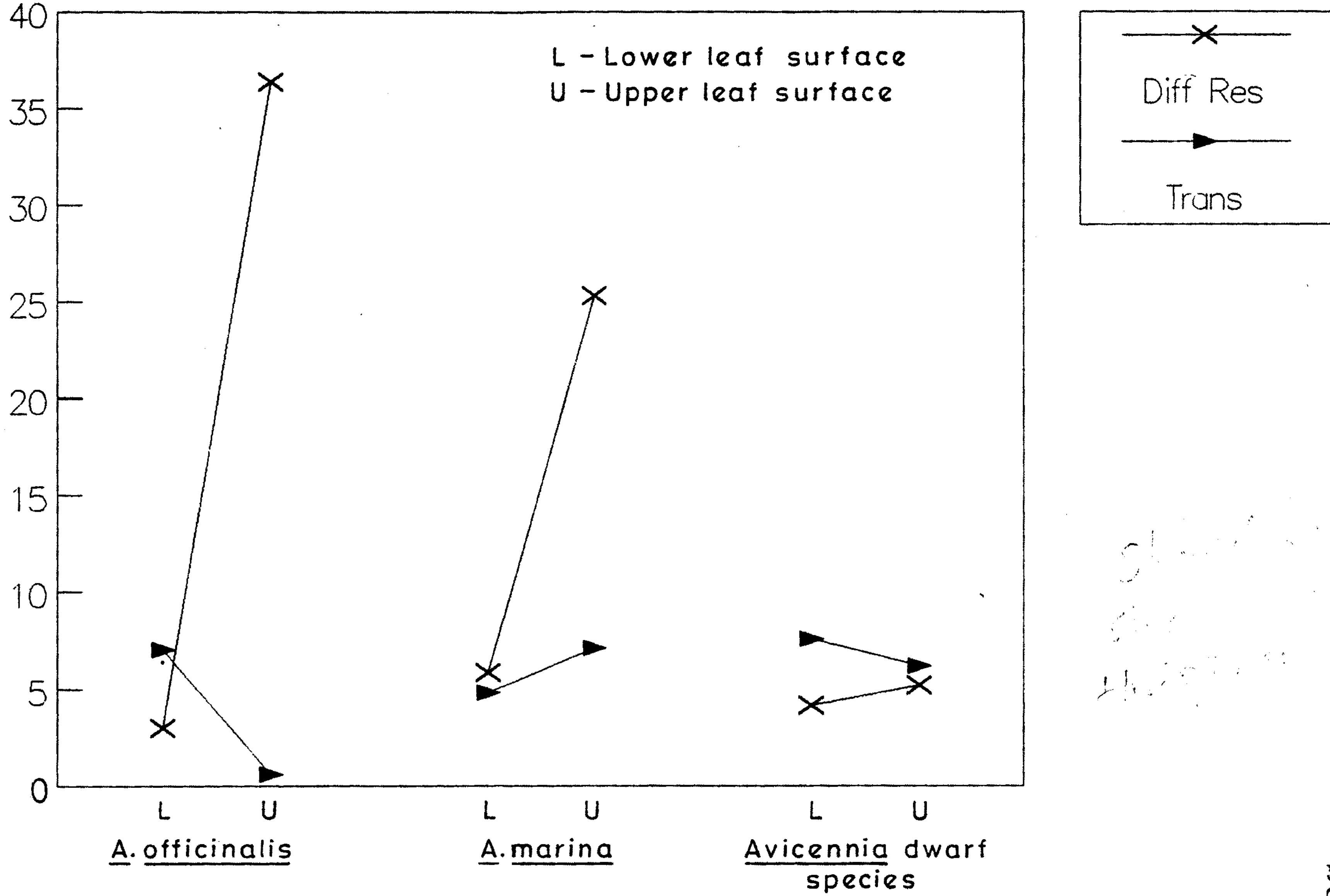
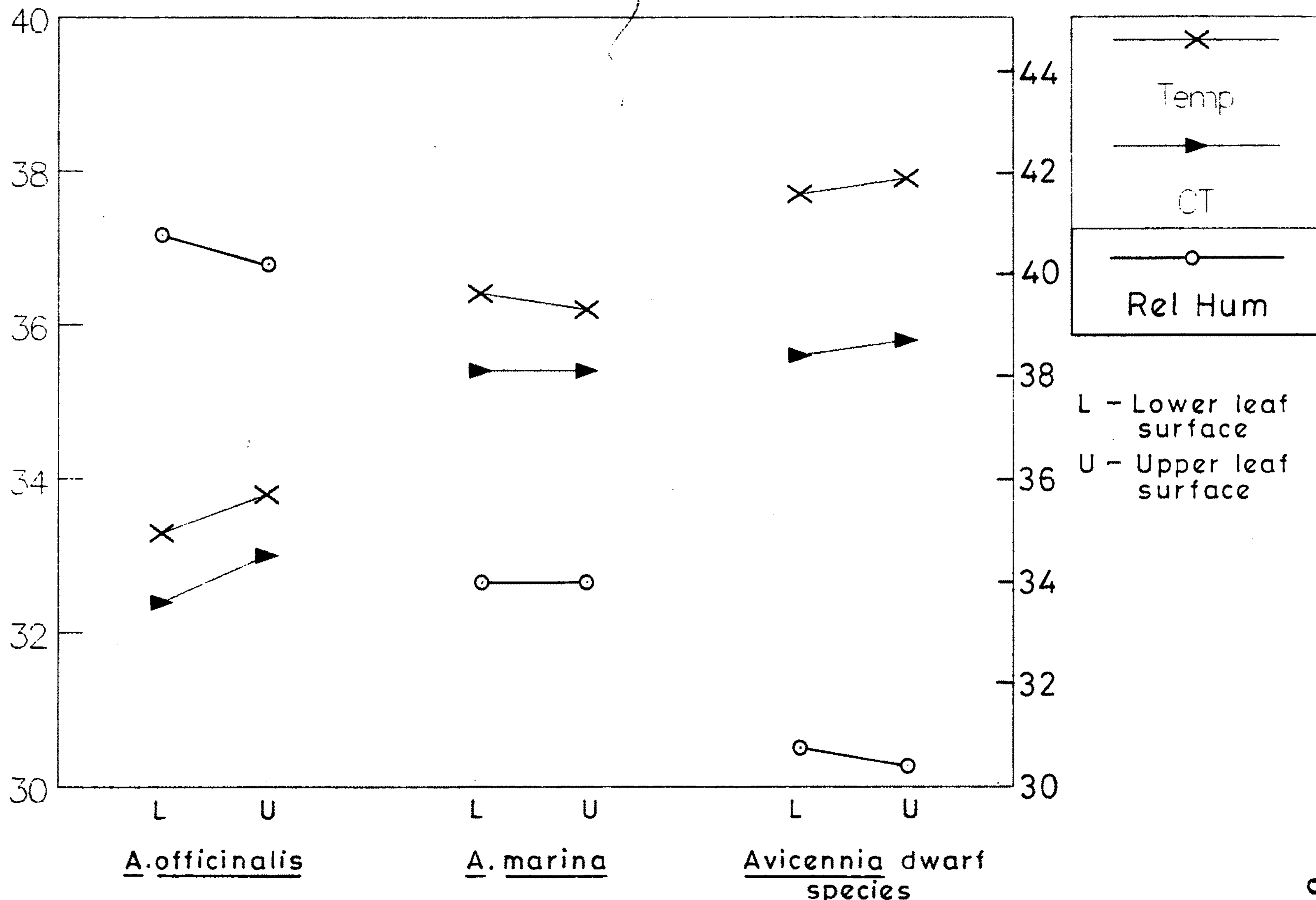


Fig. 4 – Leaf temperature, cuvette temperature and relative humidity of three *Avicennia* species.



Three stomatal types (Caryophyllaceous, Ranunculaceous, Rubiaceous) have been reported from mangroves but Siddhu (1975a) was unable to attach any ecological significance to them. The stomata of mangroves show considerable variation in behaviour. Joshi et al (1975a) reported that in a number of species stomata are wide open between 4 a.m. and 10 a.m., remain close in the early afternoon and again slightly open in the evening. On the other hand, photosynthetic studies with Avicennia and Rhizophora in Australia have shown that stomata remain open throughout the day (Clough, 1979). Response to high temperature is probably involved (Zeliten,1971).

Leaf behaviour studies cover different parameters viz. relative humidity, quantum, leaf temperature, transpiration rate, diffusive resistance for water vapour, diffusive conductance and resistance for $CO_2$.

The results are presented in the figure 2 to 4 Leaf behaviour parameters are studied in three different species of Avicennia i.e. A. officinalis, A. marina and Avicennia dwarf species. From figure 3, it is clear that diffusive resistance for water vapour is more for upper than the lower leaf surface. The value of diffusive resistance is less in Avicennia dwarf species than other two species.

From Figure 4, it is clear that leaf temperature is also more for upper leaf than the lower leaf. The maximum leaf temperature recorded is for Avicennia dwarf species. The maximum relative humidity recorded is for lower leaf surface than upper leaf surface but it is higher in A. officinalis.

Figure 2 shows values of diffusive conductance and diffusive resistance for $CO_2$. Diffusive conductance for $CO_2$ is maximum for Avicennia dwarf species (0.69 cm $s^{-1}$) and minimum for A. marina (0.34 cm $s^{-1}$). The diffusive resistance is higher in A. marina (2.94 s $cm^{-1}$) and lower in Avicennia dwarf species. The values remain intermediate for A. officinalis.

Transpiration is controlled collectively by the stomata. The interpretations and generalizations are supported by knowledge of morphology, structure of mangrove species and the measurements by Scholanders (1962). Water loss is most immediately controlled by stomatal closure. There is come contraversy as to whether mangroves have high or low rates of transpiration. High rates would reflect the high insolution of the mangal environment and the continued availability of water, eventhough it may have to be absorbed against a considerable negative substrate water potential. Low rates would reflect the general physiognomy of mangrove plants, which suggest that they conserve water as 'physiological xerophytes' i.e. they grow in an environment of low water availability entirely because the substrate water potential would tend to extract water from root tissues. The mangrove environment is unique and have unique physiological mechanisms to adapt to it. The controversy about the rate of transpiration genuine, since it depends upon the true direct measurement of a functional process. Early estimates of low transpiration rates in mangroves (Faber 1913, 1923) were somewhat contradicted by later workers (Walter and Steiner, 1936). Scholander et al (1962) measured transpiration rates indirectly by ingenious method of comparing the amount of salt excreted at leaf surface with concentration of sap in xylem sap. This gave values (10 to 55 $mg/dm^2/minute$) significantly lower than those that typically occur in terrestrial trees. Scholonder et al,(1962) suggested that the effect of permanently sequestering salt by transferring it to leaf or other tissue would constitute a larger error for non secretors than for secretors.

In A. officinalis and A. dwarf species the values are similar which shows high transpiration rates than A. marina for lower leaf surface while for upper leaf surface high values are recorded for A. marina and Avicennia dwarf and very low transpiration rate in Avicennia officinalis. It is interesting to note here 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 the species. The modifications for the leaves of mangroves seem to be related to the nature of leaf surface which include a thick cutinized outer epidermal wall, elaborated stomata, well developed mesophyll or hypodermal layers tracheid cluster and presence of scleroids.

## II. SEDIMENT CHARACTERISTICS :

Mangroves are found on a wide variety of substratum including fine inorganic muds, muds with high organic content, sand, even rock and dead coral, if there are sufficient crevices for root attachment. Understanding mangrove-substratum relationship is complicated by the ability of mangroves to grow on many types of substrates. The soils are characterised by high salt content, a high water content, abundent hydrogen sulphide, calcarious material and low oxygen content. For an adequate study of physiology and ecology of plant, sediment characteristics should be taken into consideration, because soils exert a profound influence on the distribution of plants. Plant growth and structure are largely controlled by the nutrient status and physical nature of soils (Chirputkar, 1969). The changing important component is soil. Thus analysis of soil is done to understand the status of Avicennia species. The present study includes different physical and chemical parameters.

### A. Physical

#### a. Texture

Texture determines the particle size of the soil which gives idea about grain size distribution. For this parameter 100 g of air dry soil was sieved through sieves of different pore size, namely 2000 microns, 212 microns and 25 microns (filter Well make). The international system of classification is followed.

Table - 4 : Grain Size Distribution of Soil from Avicennia Zone

| Season | Site | Gravel | Coarse sand | Fine sand | Silt + clay |
|---|---|---|---|---|---|
| Winter | Ganapatipule | 35.42 | 43.05 | 21.2 | 0.20 |
| | Are | 0.50 | 18.75 | 80.85 | 0.32 |
| | Shirgaon | 15.95 | 74.05 | 9.45 | 0.15 |
| Summer | Ganapatipule | 43.17 | 41.30 | 15.37 | 5.12 |
| | Are | 13.47 | 33.62 | 52.55 | 0.25 |
| | Sakhartar | 14.95 | 27.70 | 55.77 | 0.30 |
| | Shirgaon | 25.15 | 44.75 | 26.60 | 3.35 |
| Monsoon | Ganapatipule | 63.25 | 23.60 | 13.10 | 0.05 |
| | Are | 0.95 | 20.90 | 77.39 | 0.76 |
| | Sakhartar | 10.12 | 21.99 | 61.13 | 6.76 |
| | Shirgaon | 20.19 | 52.09 | 23.85 | 3.89 |

Values expressed as percentage

| Type | Size |
|---|---|
| Gravel | >2.00 mm |
| Coarse sand | 2.00 - 0.2 mm |
| Find sand | 0.2 - 0.02 mm |
| Silt | 0.02 - 0.002 mm |
| Clay | <0.002 mm |

On this basis soil from different sites along Ganapatipule, Are, Sakhartar and Shirgaon estuaries is classified (Table 4). The results indicate that major portion of the soil is of coarse and fine sand at Ganapatipule estuary. Silt and clay percentage is very low. The clay fraction cannot be determined with the help of sieves therefore silt and clay fractions are presented together. Kotmire and Bhosale (1980) have presented granulometry of soil from the root zones of A. marina and A. officinalis from Bhatye estuary. They recorded more percentage of sand in the soil. Sand percentage is more in the soil from the Shirgaon and Sakhartar estuary except Ganapatipule. Similar observation was due to Kotmire and Bhosale (1979) on the soils from Deogad and Mumbra estuaries. Silt and clay percentage is comparatively higher along Ganapatipule estuary during summer. Blasco (1975) have reported the texture of soil of Kavery delta where he recorded more percentage of fine sand and clay that means there is great variability from one region to another. From the observations it is clear that mangrove soil undergoes continuous change in physical characteristics of soil, as well as in the chemical composition of soil water. Mangrove ecosystem is dynamic, the plant species inhabiliting it adapt to these frequent changes and it is thus adaptibility which enables them to withstand a variety of environmental stresses. The differences are due to two main reasons. Soils are exposed to the vagaries of weather resulting in a dilution of the available salts in the environmental water during rainy season and 2. their concentration in the summer months due to high rate of evaporation.

In the present observation, the soil from the root zone of Avicennia dwarf species show higher percentage of gravel (63.25%) which indicates the change in the grain size distribution pattern. In Florida, the primary mangrove soils are either calcarious nuds or calcarious sands in the southern part of the state and silicious sands in the North (Kuenzler, 1974). Sediment distribution and hence, mangrove development is controlled to a considerable extent by wave and current energy. Soils around A. marina and A. officinalis contain 80-85% of sand (Status Report, Govt. of India) which is very contradictory. At Ganapatipule site, Avicennia dwarf species show almost equal distribution of sand, Gravel, silt and clay. Thus, it is clear that the species can growt on a wide variety of substrates including mud, sand and rock.

For the distribution of dwarf Avicennia species substratum may play key role. This community type is limited to the flat fringe of Ganapatipule which has its own characteristic set of environmental variables such as soil type and salinity range.

b. Organic matter

Organic matter content is also an important parameter which determines its productivity. In mangrove ecosystems, the soils are generally young soils and have been well sorted before deposition. There is a big food chain which is detritus based. Obviously, organic matter content becomes important aspect of soil study. This parameter is altered sometimes due to organic pollution. The soils are characterised by high salt

Table - 5 : Physico-Chemical Parameters of Soil from different sites.

| Season | Site | Ec | pH | Organic matter |
|---|---|---|---|---|
| Winter | Ganapatipule | 2.89 | 6.34 | 6.3 |
| | Are | 3.51 | 6.12 | 6.65 |
| | Shirgaon | 4.50 | 4.2 | 2.8 |
| Summer | Ganapatipule | 2.34 | 6.42 | 1.5 |
| | Are | 2.47 | 6.00 | 1.35 |
| | Sakhartar | 3.12 | 4.8 | 1.3 |
| | Shirgaon | 7.13 | 5.65 | 10.5 |
| Monsoon | Ganapatipule | 1.45 | 6.6 | 3.0 |
| | Are | 2.41 | 6.45 | 2.2 |
| | Sakhartar | 2.5 | 4.85 | 2.0 |
| | Shirgaon | 4.50 | 5.9 | 4.5 |

Ec - Values are expressed in mS/cm

Organic matter - Values are expressed as percentage content, a high water content and low oxygen content and only the surface layers of the soil are well oxygenated. In an oxygen rich environment, organic materials are rapidly decomposed by micro-organisms and by physical oxidation. The source of organic material generally is the net production and mortality in the root system beneath the surface of the substratum. In the aerobic upper fraction of the soils, leaf litter old roots, rootlets and wood debris are decomposed and remineralization process provide for some internal recycling of nutrients. In the present investigation attempt has been made to find out organic matter from different soils.

Table 4 represents variation in organic matter occuring as a function of seasonal changes. The lowest value recorded is 1.3% at Sakhartar in summer, the maximum record is for Shirgaon site (10.5%). According to Parulekar (1986) maximum organic matter content goes upto 52.92% where low level is 8.68%. In this comparison, the present range is low. After Shirgaon the next maximum value recorded is 6.3-6.6%, for both Ganapatipule and Are site during winter.

Banerjii and Rao (1985) studied organic matter content from different zones of soil where values range in between 2.9 and 4.8%. Rao (1987) found a very low range of 0.84 - 1.69% as a seasonal aspect. In the present study high organic matter is found at Shirgaon which can be attributed to litter fall and organic matter from detritus, while for other sites, it may be due to organic pollution. It is interesting to note here that the maximum value for Shirgaon site is 10.5% during summer and the minimum values are recorded for all other sites during the same season. The decomposition occurs insitu, assisted in large part by soil invertebrates usually. These processes of concentration and aggregation of organic matter within an estuary suggest that little of the organic load ever reaches distant areas of the ocean and therefore the marine species depend upon estuaries in some phase in their life cycle and the variable salinity in an estuary not only favours utilization by a wide spectrum of aquatic species but also is responsible, in part, for the concen tration of mangrove derived organic matter in a form that serves as an enriched food substrate.

Some times differences in the organic matter content level may possibly due to some seasonal periodicity associated with the quantity of detritus available to the consumers. The mangrove soil inspite of its water logged condition and poor aeriation does not accumulate too much of humus this is probably due to washing away of the decaying organic matter by the tides (Chirputkar, 1969). This is the reason for the lower levels of organic matter content. Lee (1969) recorded typical Eh values in mangrove peats such evidence of strongly reducing condition are not surprising considering the fine grained, high organic nature of most mangrove sediments although mangroves occur in low organic sediments ( less than 170 organicmatter), typical values for mangrove sediments are 10 -20% organic matter.

B. <u>Chemical</u>

a. <u>**Electrical Conductivity**</u>

Electrical conductivity is usually caused due to water soluble solids. It is the measure of the electrolyte present in the soil. It goes parallel with salinity. In the present study, electrical conductivity is recorded seasonally and is expressed in terms of mS/cm. The seasonal variations are recorded in table 5 from different sites. In this study, a range of

1.45 - 2.90 mS/cm. For Ganapatipule, 2.41-3.51 for Are and 4.50-7.13 mS/cm for Shirgaon esdtuary are recorded. Lower values are observed during monsoon while higher levels in summer season for Shirgaon estuary. Blasco (1975) reported electrical conductivity of Indian mangrove soils as 4 mS/cm At Shirgaon estuary same value is seen during winter and monsoon. It seems that electrical conductivity is also caused perhaps by organic constituents. Sah et al (1986) have reported the electrical conductivity of mangrove soils from Sundarbans ranging between in 2.97 and 11.47 mS/cm. Bhosale (1990b) have reported a range of 0.61 - 49.44 mS/cm for Kalbadevi and 0.44 - 7.85 mS/cm for Are estuary. For Bhatye estuary the range in the electrical conductivity is given by Bhosale (1990a) (0.7-88.53 mS/cm). As compared to these reports, present investigated values are low. Possibly because of different levels of total dissolved solids in different estuarine water. Kadam and Bhosale (1986) reported electrical conductivity for Ratnagiri coast (0.12 - 3.87 mS/cm) during rainy season. The present values during monsoon are similar.

**b.** pH

Another important parameter is the pH of soil. The soils supporting the mangroves are broadly distinguished into sandy loams and silty loams, but there is great variability from one region to another. Changes in pH, chloride contents etc. in relation to tides, rainfall and rate of evaporation add to this variability (Navalkar, 1941 and 1973), Navalkar and Bharucha 1948, 1949, 1950, Bharucha and Navalkar, 1942). In general the pH varies between 7 and 8, but in the Kaveri delta region *Avicennia marina* occurs in acidic soil having a pH between 3.4 and 4.5 (Blasco, 1975).

Table 5 represents seasonal variation in pH of soil. The values range between 4.2 to 6.6, high value of pH is 6.6 at site Ganapatipule in monsoon, while lower values are seen from Sakhartar and Shirgaon sites. Looking to the seasonal changes, the variation is negligible, but comparing sites, pH of soil shows great variability. These differences in pH arise on the account of human activity and difference in the topography and possibly inputs of pollutants into the estuary. Narayanan and Sivdas (1987) reported pH values in the range of 8 - 8.2 from sandy beach at Kavaratti atoll. Bhosale (1990a) have reported pH values in the range of 3.4-8.6 for Ratnagiri estuaries. Kotmire and Bhosale (1979) studied two estuarine ecosystems along west coast of Maharashtra. They reported soil pH in acidic range.

The present values are within the range of earlier reports. Bhosale (1990b) have reported seasonal variation which shows higher levels in winter except for Kalabadevi sites.

The soil pH in mangroves is about 8.5 and goes upto neutrality (Kotmire and Bhosale, 1979; 1980; Kadam and Bhosale, 1986; Karkar and Bhosale, 1986). Sathe (1991) reported highly acidic pH for *Avicennia* zone, whereas *Rhizophora* grows on the soil with pH nearly neutral. Sometimes pH goes beyond 7 as has been reported by Rao et al (1966). According to Rao and Shanaware (1967) low pH indicates disturbance in the substratum. Occasionally low pH has been also noted by Bhosale (1990a) at Ratnagiri which is not regular feature of mangrove soil. Sah et al (1986) observed that the soil pH of Sundarbans mangrove ranges from 6.85 - 7.80, this is because of high contents of soluble salts present in the substratum. Not only this but from the present observation it is clear that the pH of the soil changes in relation to tides, rainfall, rate of evaporation etc. According to Rao et al (1966) the soil of Saurashtra is sandy loam to silty loam with moderately alkaline reaction with 8.5 - 9.8 pH. Mall et al (1986) studied pH from different zones of Andaman where pH ranges in between 4.3 - 7.8 from proximal to distal zones.

c. Chlorides

The chloride content of mangrove water and soil have been reported by several workers (Joshi et al, 1975; Kotmire and Bhosale, 1979; 1980; Bhosale et al, 1983; Bhosale, 1990a; Blasco et al, 1986; Mall et al, 1986; Sah et al, 1986. The present record is important with respect to species distribution at specific areas. The results are depicted in table 6. High value of 1.18 g/100 g is observed in summer at Shirgaon and lower of 0.25 g/100 g observed in monsoon at Ganapatipule. The monsoon season show low values which spread all over the season. A range of 0.40-0.61 g/100 g and 0.25 - 0.49 g/100 g is obtained from Are and Ganapatipule estuaries respectively. The fluctuations in the levels are similar to that observed in Kalbadevi estuary. Bhosale (1990b), and Bhosale et al (1983) reported chlorides from mangrove soils, the higher values being 21.6 mg/g compared to this, higher levels are obtained in the present investigation. The chloride values are 1336.37 mg/100 g for Tarkarli creek and 230.75 mg/100 g for Kolamb creek (Sathe and Bhosale, 1991). The present results are on the similar line. Chlorides of Shirgaon soil are higher than other sites because this area receives direct estuarine water. The chloride content of the mangrove soil thus fluctuates with the seasons.

The seasonal variation in chloride is also recorded by Joshi and Kumar (1986). The determination of chloride content of soil under different mangrove species are characteristics and confirm the different stages of succession (Chirputkar, 1969). From the present study it is evident that

Table - 6 : Chlorides and Salinity of Soil at Different Sites of Estuaries

| Season | Site | Chlorides g/100 g | Salinity ‰ |
|---|---|---|---|
| Winter | Ganapatipule | 0.49 | 0.91 |
| | Are | 0.61 | 1.13 |
| | Shirgaon | 0.77 | 1.42 |
| Summer | Ganapatipule | 0.35 | 0.66 |
| | Are | 0.40 | 0.75 |
| | Sakhartar | 0.46 | 0.86 |
| | Shirgaon | 1.18 | 2.16 |
| Monsoon | Ganapatipule | 0.25 | 0.48 |
| | Are | 0.40 | 0.75 |
| | Sakartar | 0.52 | 0.97 |
| | Shirgaon | 0.40 | 0.75 |

chloride content of mangrove soil in different estuaries varies according to season which determines the sediment characteristic of site and species as it is a major constituent anion.

d. Salinity

Mangroves accommodate fluctuations and extremes of water and soil salinity through a variety of mechanisms, although not all mechanisms are necessarily present in the same species.

In the present study, seasonal variation in salinity level is recorded for soil. Soil salinity is calculated from values obtained from chloride. The range of soil salinity for Ganapatipule is 0.482 - 0.91‰ and for Shirgaon is 0.97 - 2.16‰. The higher level of salinity is 2.16‰ observed at Shirgaon site during summer. The lower levels of salinity are observed in monsoon months and high levels are observed in winter and in summer (Table 6). Naidoo (1989) has reported that for mangrove swamp in Durban South Africa, soil salinity showed distinct seasonal trends, being lower during the hot wet summer and two to three-fold higher during the cool dry winter. The salinity mainly is in response to evaporation and input of fresh water as well as effluents. Bhosale (1990a) recorded the lowest value of salinity which is 0.2% in July for Bhatye estuary. It is reported by Murty and Kondala Rao (1987) that fluctuations in salinity of Rambho Bay are low. They stated that summer evaporation plays important role in raising the salinity. Bhosale (1990b) observed the range of soil salinity for Kalabadevi and Are is 0.93 - 67.30‰ and 1.25 - 25.6‰ respectively. Blasco et al (1986) reported that all profiles of Pichavaram mangrove swamp soil shows high salinity which range from 1.40 to 26.9 meq/100 g of dry soil. Teas (1979) reported dwarf and black and white mangrove occuring in Florida where salinity is 80 ppt.

Salinity is a problem for mangroves only under extreme hypersaline conditions. Such conditions sometimes occur naturally in irregularly flooded areas of the high swamp above the normal high tide mark which are accompanied by high soil salinities. On the basis of salinity, species can be listed in order of increasing salinity tolerance.

**e. Elements**

Sediment is the sole source of mineral nutrition for plants. In estuarine environment, the major constituent of water and soil is sodium and other major elements are potassium, calcium, magnesium etc. They vary with change in the surrounding conditions. To know the status of minerals in mangrove soils, it is intended to study sodium, potassium and calcium. These elements are detected from soil which gives seasonal variation in Figures 5, to, 8.

**Sodium**

The lowest value for sodium is 1.1% in winter at Ganapatipule site. The highest value being obtained in summer at Shirgaon site (4.6%). The seasonal range along different sites is from 1.1 to 4.6%. The sodium from Kalbadevi ranges in between 0.7 mg/g of soil and 42 mg/g (Bhosale 1990b). Blasco et al (1986) reported the values of sodium from soils of Pichavaram mangroves. The range of sodium from Pichavaram mangrove soils was 7.452 to 280 meq/100 g. During monsoon and winter the values of sodium for all sites remain same but the values fluctuate during summer (2 to 4.6%) sodium values reported earlier (Bhosale et al 1983) for mangrove soils at Deogad and Mumbra are 1.08 and 1.72%. It is clear from the observations that the sodium content from different sites differ greatly. Sodium content from two sites Ganapatipule and Are do not show

Fig. 5 — Variations in Na content of soils at different sites.

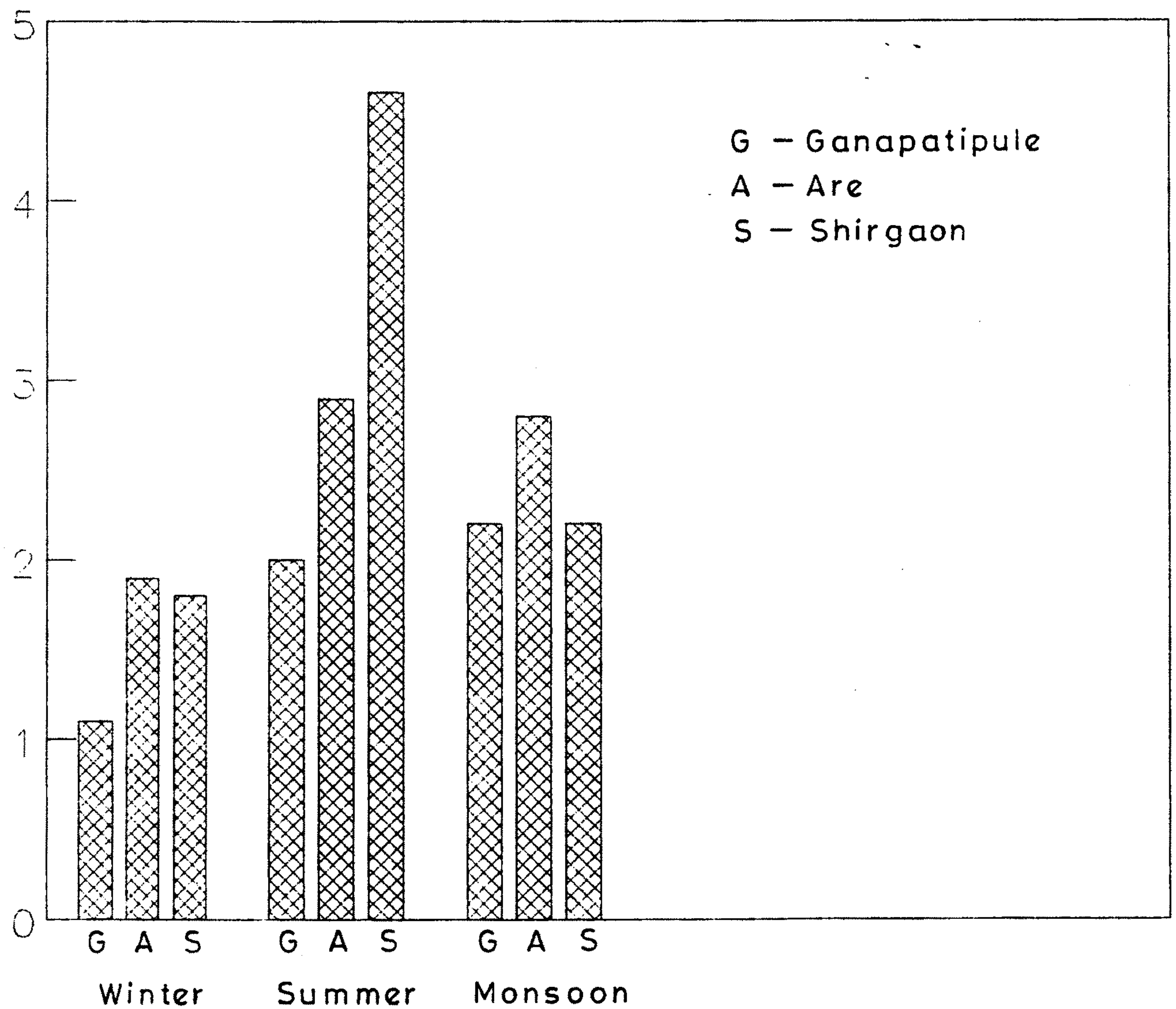


Fig. 6 — Seasonal variation in K content of soils at different sites.

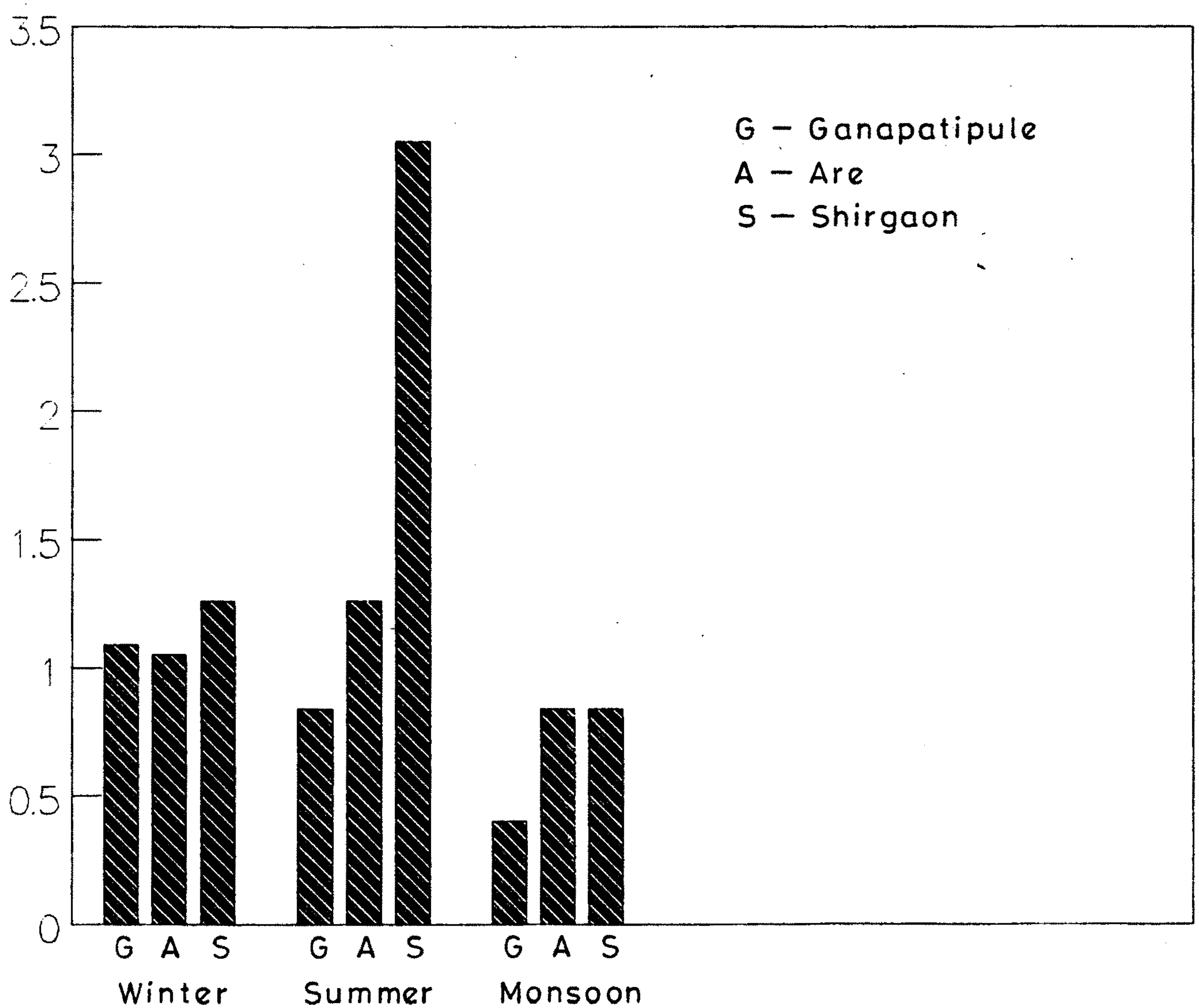
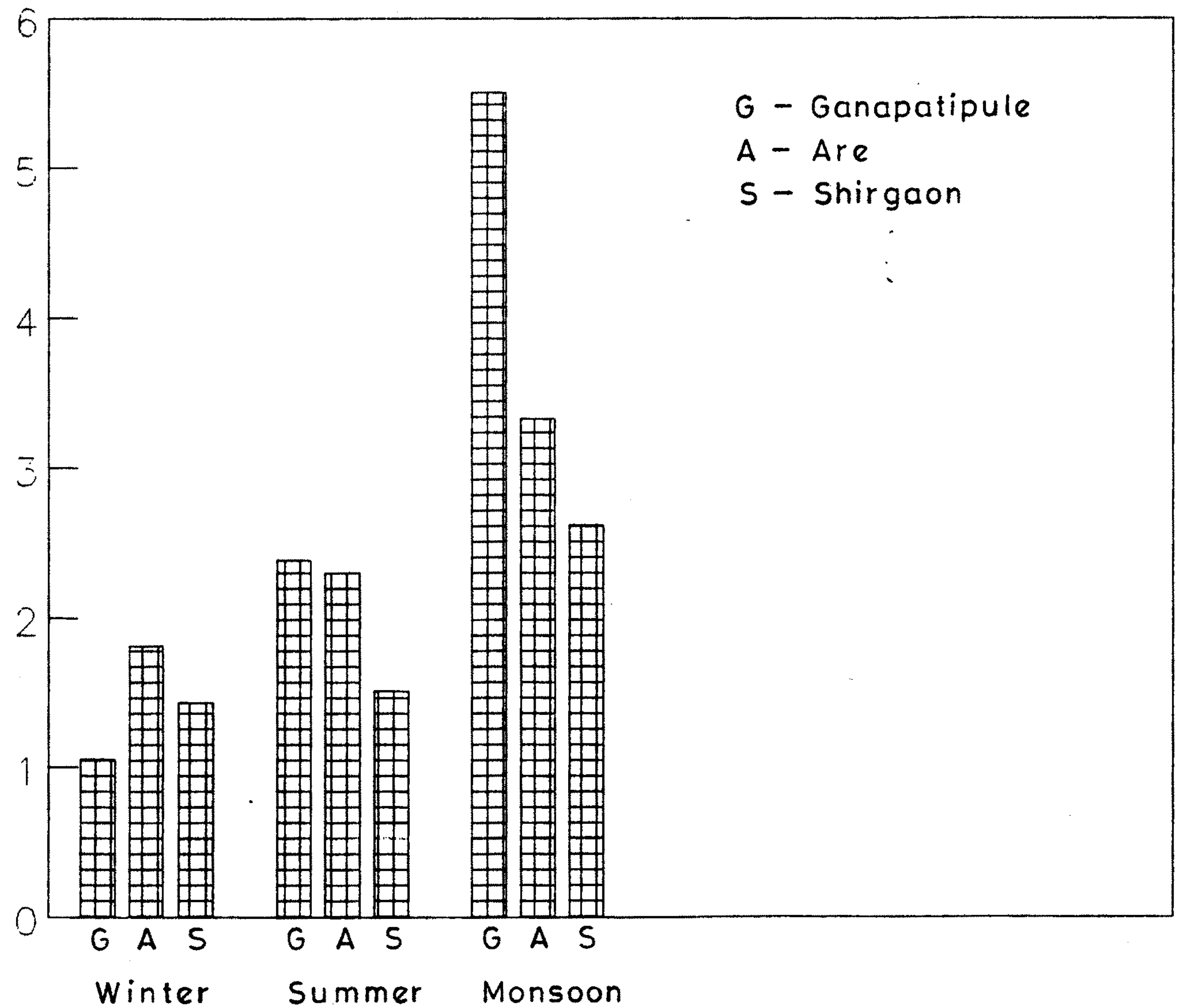


Fig.7 – Na/K ratio of soiles at different sites.



much difference but Shirgaon and Sakhartar esturies show significant difference in sodium levels.

**Potassium**

Another important macroelement ranges from 0.40 - 3.05%, during winter the values for potassium remains same for all the sites. Highest values for all the sites are obtained during summer (0.62 to 3.05%). The highest value is for Shirgaon site. Potassium values of 0.75 and 0.85% are reported for mangrove soils at Deogad and Mumbra (Bhosale et al, 1983). The values for potassium are low during monsoon and then start increasing in winter. Reverse trend is seen for levels of sodium.

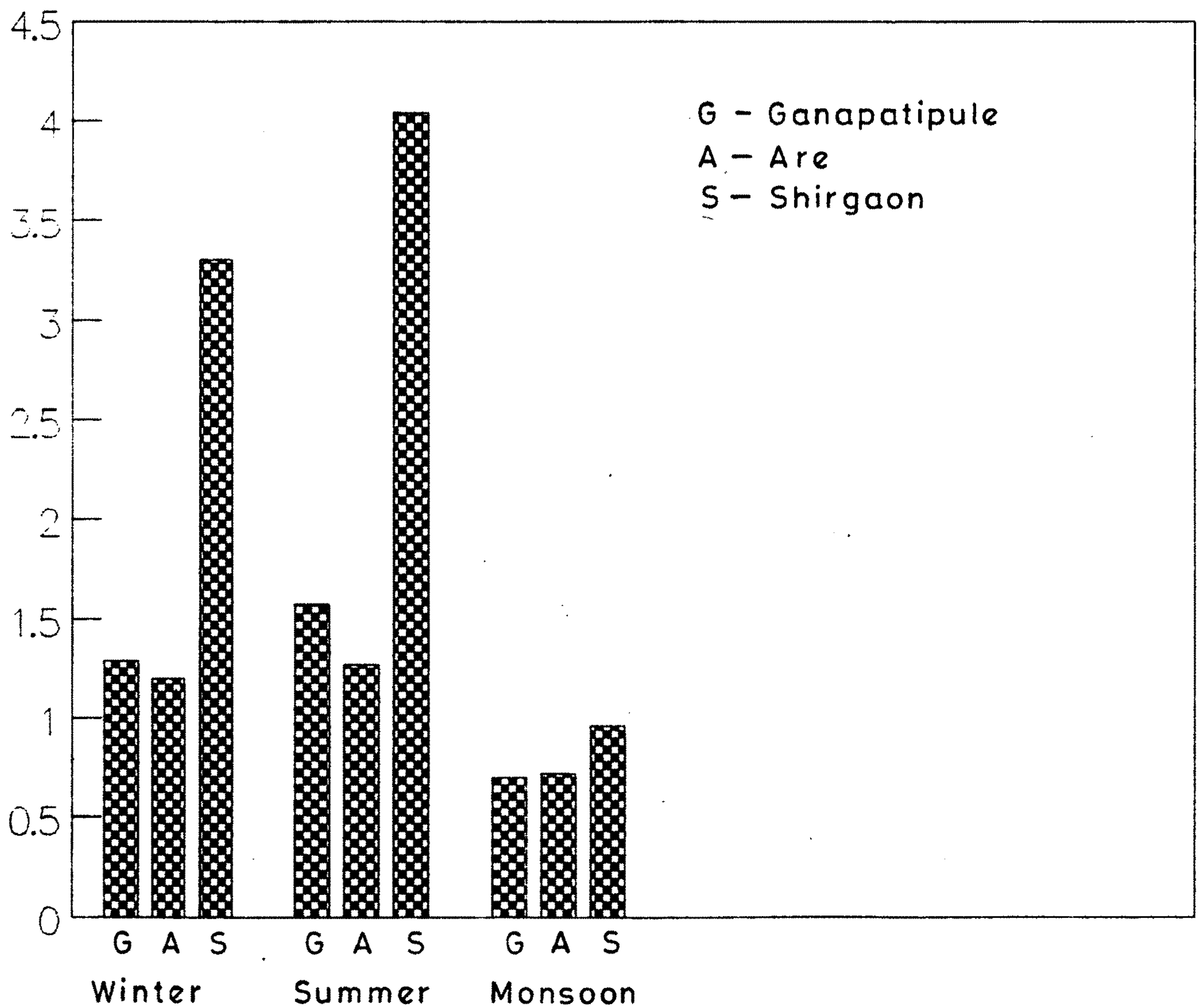
During rainy season, heavy rainfall is in the month of July, which causes more leaching in the soil and more dilution of estuarine water. Therefore, values recorded in monsoon are low.

It is important to note the Na/K ratio. It is higher in monsoon at Ganapatipule which drops down to 1.05 in the soil at Ganapatipule during winter. This shows retaintion of sodium and potassium in the soil. Although the flooding water has very high amount of sodium, in relation to potassium this proportion is maintained in soil.

**Calcium** .

It is one of the major elements found in soil. The range obtained in present study is very wide. (Figure 8) Ganapatipule estuary shows a range of 0.70 to 1.57% throughout the seasons. The highest value is recorded at Shirgaon site during summer while lowest is at Sakhartar during monsoon (0.68 and 4.04% resp.). In the earlier reports (Bhosale et al, 1983) calcium from soils is reported as low as 2.9 mg/g of air dry soil, the higher level of which goes to 7.5 mg/g for Mumbra estuary. Bhosale

Fig.8 – Seasonal variation in Ca content of soils at different sites.



(1990a) has reported calcium values for sediments as 0.307 to 6.68% for Bhatye estuary. In this comparison the present values are low.

# III. MORPHOLOGY, ANATOMY AND CHEMOTAXONOMY

## A. Morphology

### a. Leaf Characteristics

There is general pattern due to uniform leaf shape and texture of mangroves coupled with the evergreen habit even the leaflets of the compound leaves of Xylocarpous match this general pattern well (ovate to elliptic outline). Neverthless, there is sufficient variation that shape can be diagnostic, it can be used to distinguish species of Avicennia where the range of leaf form in the indopacific species closely matches that of Atlantic species (Tomlinson 1986).

Leaf morphology is particularly uniform in Rhizophoraceae members but there are differences in texture and average size. A hybrid between species of the conteasted groups (Rhizophora x Selala) has an intermediate leaf tip morphology showing that leaf apex morphology is genetically controlled (Tomlinson 1979). Leaf tip morphology varies in three Avicennia species. In A. marina leaf tip is acute while in A. dwarf species it is ovate.

Another important leaf characteristic is succulence (thickness) which varies according to degree of salinity and also the leaf age. The anatomical basis for this is the differential expansion of mesophyll cells (Walter and Steiner, 1936). There is experimental evidence to show that increased succulence is associated with increased salinity, as also are certain other features of halophytes (Weighe, 1964). Areschoug (1902) suggested that only the thick cuticle, the sunken or chambered stoma and mesophyll were related to water conservation.

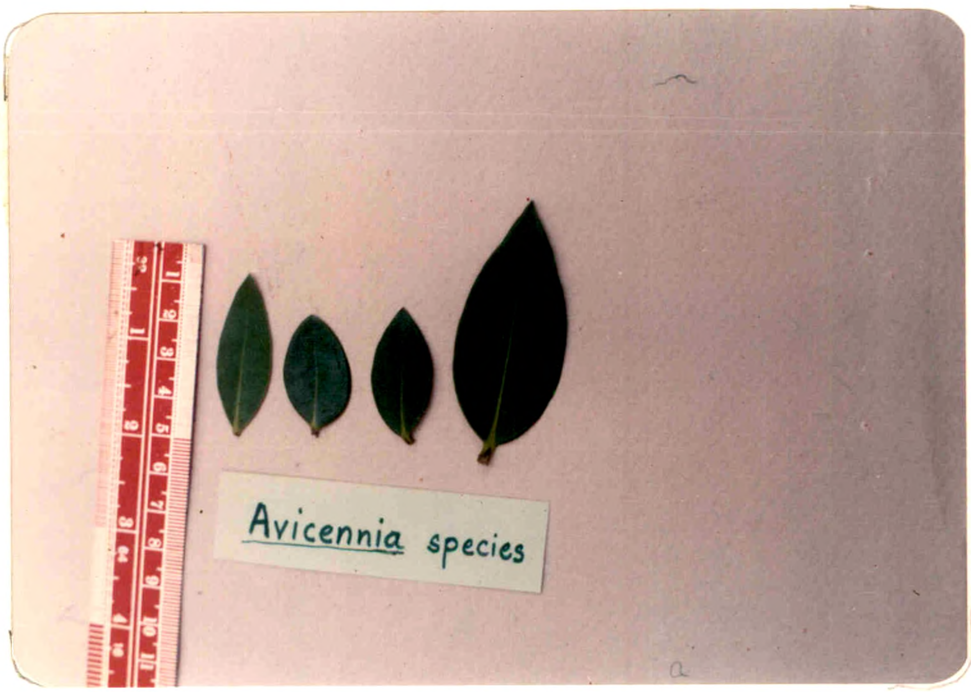
## PLATE - 2

Leaf characteristics

A. Variation in leaf of

*Avicennia* dwarf species

Plate - 2




A

The tissue organization in species was determined in terms of cell layers present and their relative thickness. Leaf thickness ranges from 0.33 - 0.51 mm. Leaf structure and its ecological significance is much more important and is studied in certain mangrove plants by Rao and Hugh Tan (1984).

Leaf succulence in Avicennia has an explanation in terms of salt balance. The osmotic potential of leaf cells of mangroves is high, as measured in the epidermis by plasmolytic methods (Walter and Steiner, 1936; Scholander et al, 1964). High osmotic potential is essential if mangroves are to draw water from the sea with its high negative water potential. However several other authors noted that the salt concentration of mangrove leaves remain constant and independent of leaf age. Mangrove accumulate salt. Accumulation is in part compensated by salt secretion via salt glands in the less efficient salt excludes, otherwise salt is sequestered and can be avoided only when the leaves eventually fall. Since salt concentration is constant and independent of leaf age, salt must accumulate by an increase in volume of leaf cells inducing succulence because this is correlated with water relations and different salt concentrations would complicate the balance of water potential in adjuscent leaves.

Leaf succulence in mangroves in these simple terms, may therefore be accepted as a consequence of life in an environment that provides ample water at the expense of some compensation for that waters high salinity. Further evidence comes from the observations of Camilleria and Ribi (1983) that leaf thickness is correlated with soil salinity, since leaves were thicker in sites of constant high salinity. These authors deny that

Table - 7 : Correlation Coefficient Values for Three Leaf Characters Along Different Sites.

| Season | Site | Leaf position | Area thickness | Area weight | Thickness weight |
|---|---|---|---|---|---|
| Winter | Ganapati pule | Apex | 0.45 | 0.98 | 0.56 |
| | | Middle | 0.15 | 0.86 | 0.20 |
| | | Base | 0.32 | 0.97 | 0.43 |
| | Are | Apex | 0.11 | 0.80 | 0.37 |
| | | Middle | 0.13 | 0.96 | 0.32 |
| | | Base | 0.09 | 0.95 | 0.33 |
| | Shirgaon | Apex | - 0.38 | 0.51 | 0.11 |
| | | Middle | 0.19 | 0.86 | 0.40 |
| | | Base | 0.54 | 0.95 | 0.64 |
| Summer | Ganapati-pule | Apex | 0.22 | 0.77 | 0.30 |
| | | Middle | - 0.23 | 0.90 | - 0.26 |
| | | Base | - 0.46 | 0.88 | - 0.46 |
| | Are | Apex | 0.82 | 0.99 | 0.82 |
| | | Middle | - 0.18 | 0.96 | - 0.14 |
| | | Base | 0.36 | 0.98 | 0.30 |
| | Sakhartar | Apex | - 0.30 | 0.05 | 0.19 |
| | | Middle | - 0.35 | 0.96 | 0.20 |
| | | Base | 0.06 | 0.97 | 0.02 |
| | Shirgaon | Apex | - 0.5 | 0.83 | - 0.03 |
| | | Middle | - 0.41 | 0.94 | - 0.43 |
| | | Base | - 0.21 | 0.96 | - 0.25 |
| Monsoon | Ganapati-pule | Apex | 0.23 | 0.94 | 0.64 |
| | | Middle | 0.34 | 0.83 | 0.37 |
| | | Base | - 0.23 | 0.80 | - 0.09 |
| | Are | Apex | - 0.91 | 0.93 | - 0.86 |
| | | Middle | - 0.28 | 0.97 | - 0.18 |
| | | Base | 0.05 | 0.93 | 0.30 |
| | Sakhartar | Apex | - 0.24 | 0.97 | - 0.13 |
| | | Middle | - 0.25 | 0.97 | - 0.24 |
| | | Base | 0.12 | 0.95 | 0.18 |
| | Shirgaon | Apex | 0.39 | 0.96 | 0.49 |
| | | Middle | 0.38 | 0.82 | 0.59 |
| | | Base | - 0.22 | 0.76 | - 0.01 |

Table - 8 : Seasonal Variation in Moisture Percentage from Leaves of <u>Avicennia</u> species Along Different Sites.

| Season | Site | Leaf position | Moisture % |
|---|---|---|---|
| Winter | Ganapatipule | Apex | 73.85 |
| | | Middle | 70.99 |
| | | Base | 68.37 |
| | Are | Apex | 69.41 |
| | | Middle | 70.47 |
| | | Base | 69.81 |
| | Shirgaon | Apex | 63.10 |
| | | Middle | 64.28 |
| | | Base | 66.81 |
| Summer | Ganapatipule | Apex | 58.45 |
| | | Middle | 54.69 |
| | | Base | 60.26 |
| | Are | Apex | 48.47 |
| | | Middle | 42.72 |
| | | Base | 45.91 |
| | Sakhartar | Apex | 56.12 |
| | | Middle | 30.57 |
| | | Base | 48.79 |
| | Shirgaon | Apex | 49.71 |
| | | Middle | 49.94 |
| | | Base | 39.90 |
| Monsoon | Ganapatipule | Apex | 58.72 |
| | | Middle | 62.30 |
| | | Base | 60.91 |
| | Are | Apex | 63.90 |
| | | Middle | 65.48 |
| | | Base | 61.72 |
| | Sakhartar | Apex | 60.81 |
| | | Middle | 60.85 |
| | | Base | 61.33 |
| | Shirgaon | Apex | 69.90 |
| | | Middle | 67.52 |
| | | Base | 70.88 |

succulence is simple function of leaf age, but these symplastic conclusions avoid the developmental question of how succulence is induced in conditions of high salinity. In the present observation the leaf thickness not correlated with area and leaf weight. The area and the weight are diagnostic for different species.

Succulence is a feature common in mangrove leaves and it is generally associated with xeromorphy. Based on studies of Rhizophora (Bowman 1921) and Sonneratia (Walter and Steiner 1936) growing in saline and fresh water conditions, it appears that succulence is a response to the presence of chloride.

Constancy of leaf appearance is not matched by structural characteristics, leaf dry weight per unit area in different species differ over the range 6.4 - 21.6 $mg/cm^2$ (Johnstone 1981). Correlation coefficient values of leaf characteristics like area, thickness, weight are depicted in table 7. The leaf of A. marina shows heteromorphy, therefore, leaves from different position are considered for morphometry (Apex, middle, base). The keys in Moldenke (1960) emphasize leaf morphology as a dignostic feature. Examples from Indo-Malayan species and New world give some indication of the range. In the present study the species are best distinguished by combination of leaf shape (Plate 2 ). Table 8 depicts the moisture percentage from Avicennia dwarf species during different seasons.

**b. Seedling Morphology**

The genus Avicennia has cryptoviviparous mode of reproduction. It means that the fruit contains well developed seedling inside the pericarp

## PLATE - 3

Morphological details of *Avicennia* dwarf species.

A. Entire seedling with roots and pneumatophore

Plate - 3


A

Fig. 9 - Root shoot ratio at seedling stage of _Avicennia_ dwarf species.

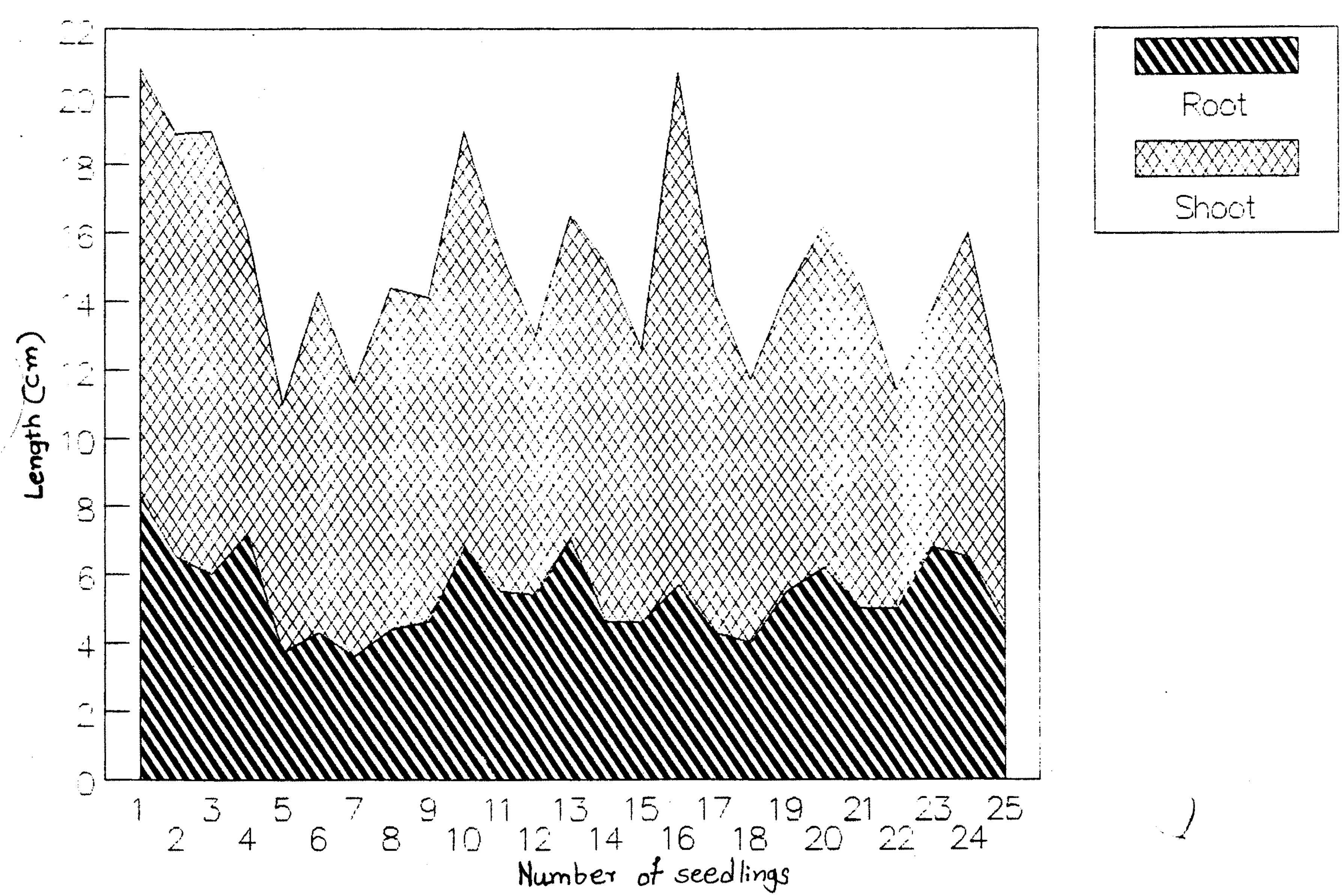
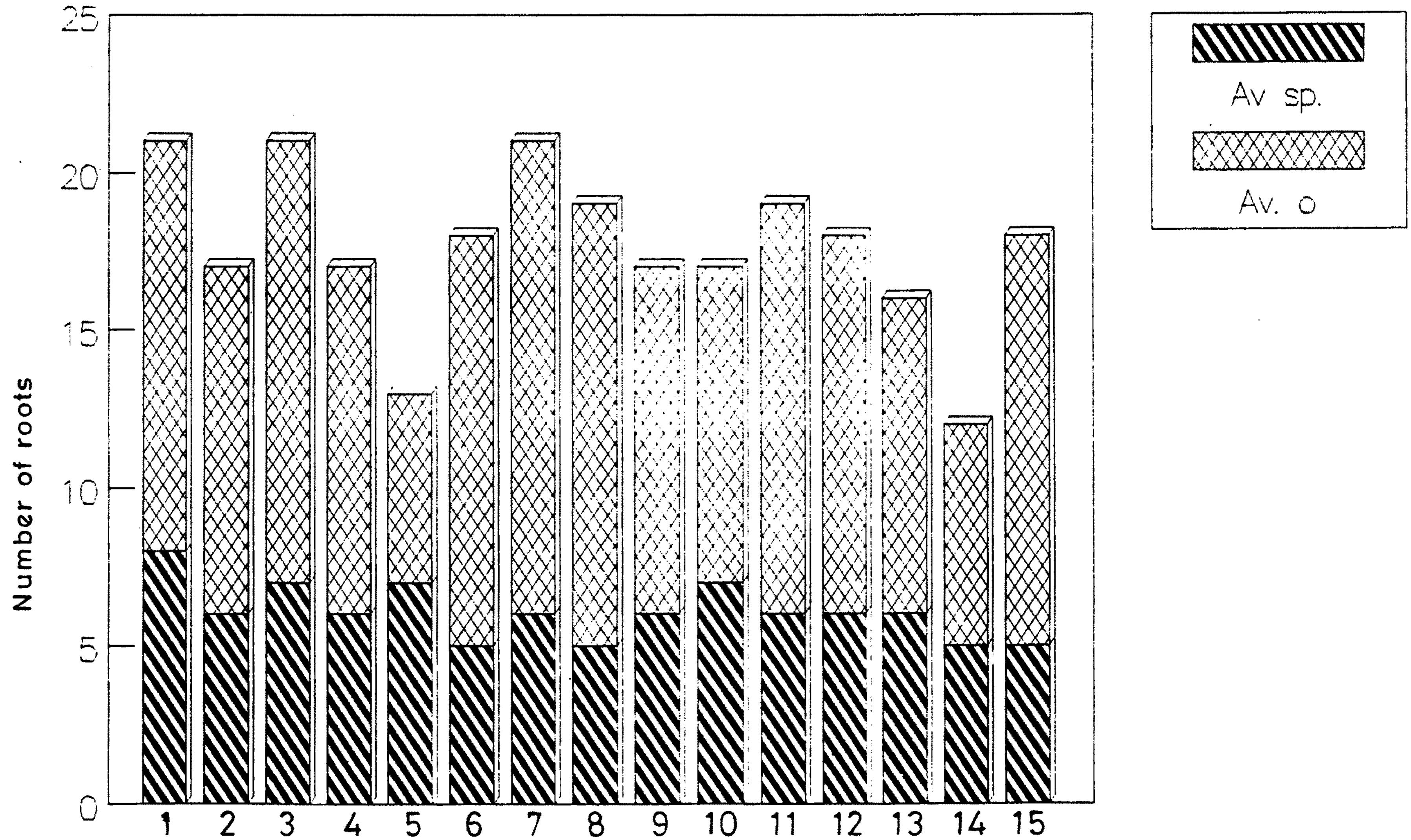


Fig. 10 – Variation in number of roots of two *Avicennia* species at seedling stage.



but it is not externally visible. Thus the 'fruit' is actually a 'propagule' or the unit of propagation.

Since fruit is cryptoviviparous the embryo is ready to germinate immediately as soon as it gets moisture and sometimes even at the time of detachment of fruit, pericarp is seen dehisced. The unit of dispersal is the embryo, which roots immediately on becoming stationary. The size and shape of embryo sac are characteristic for different species (Plate 3 The cotyledons are thick, fleshy and folded in opposite directions which also differs appreciably in shape. The radicle and hypocotyl are well developed, the radicle is densly hairy and protruding slightly in the fruit. The distinction between embryos with and without plumule used as a key character by many authors. In the present investigation seedling characters like shoot length, root length and number of leaves also vary as per the species Figures 9 to 14.

Germination is epigeal, the hypocatyl extends; the radicle also contribute to extension, since the hairy region becomes longer notably in A. officinalis. The shoot length in young seedling varies from 13-20 cm. in A. officinalis (after establishment) At the same time the root length varies from 3.0-6.3 cm; number of leaves observed during this stage are 4-6 while in Avicennia dwarf species shoot length varies from 6.4-12.5 cm. root length from 3.6 - 8.3 cm and number of leaves varies from 4-10. The cotyledons expand during seedling extension but never become completely flattened. The first pair of plumular leaves have short stipule and are borne at the end of long internode.

Fig.11— Root length variation of two species of <u>Avicennia</u> at seedling stage.

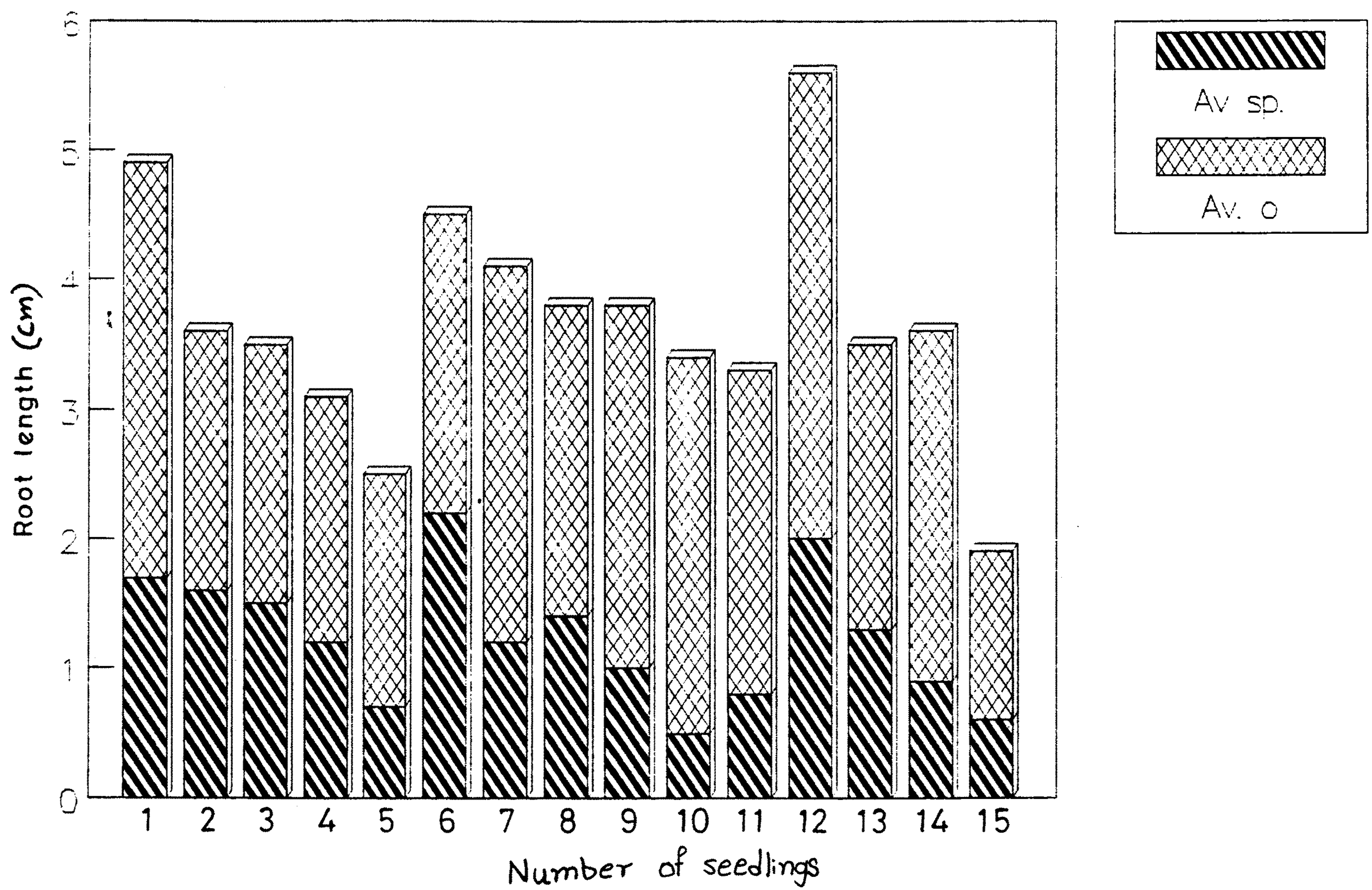


Fig.12 – Length variation of cotyledons of two species .

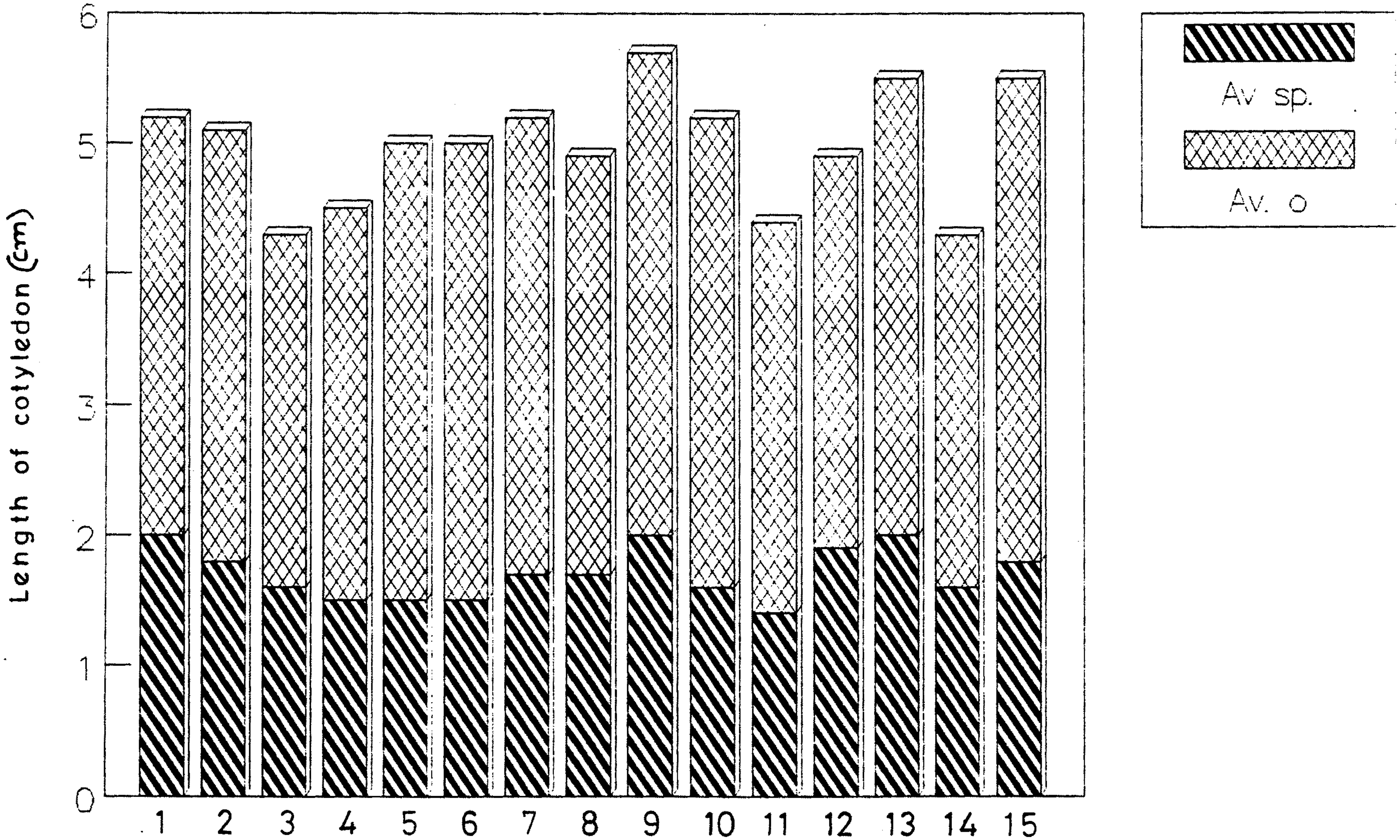


Fig. 13 – Root shoot ratio at seedling stage of <u>Avicennia</u> dwarf species.

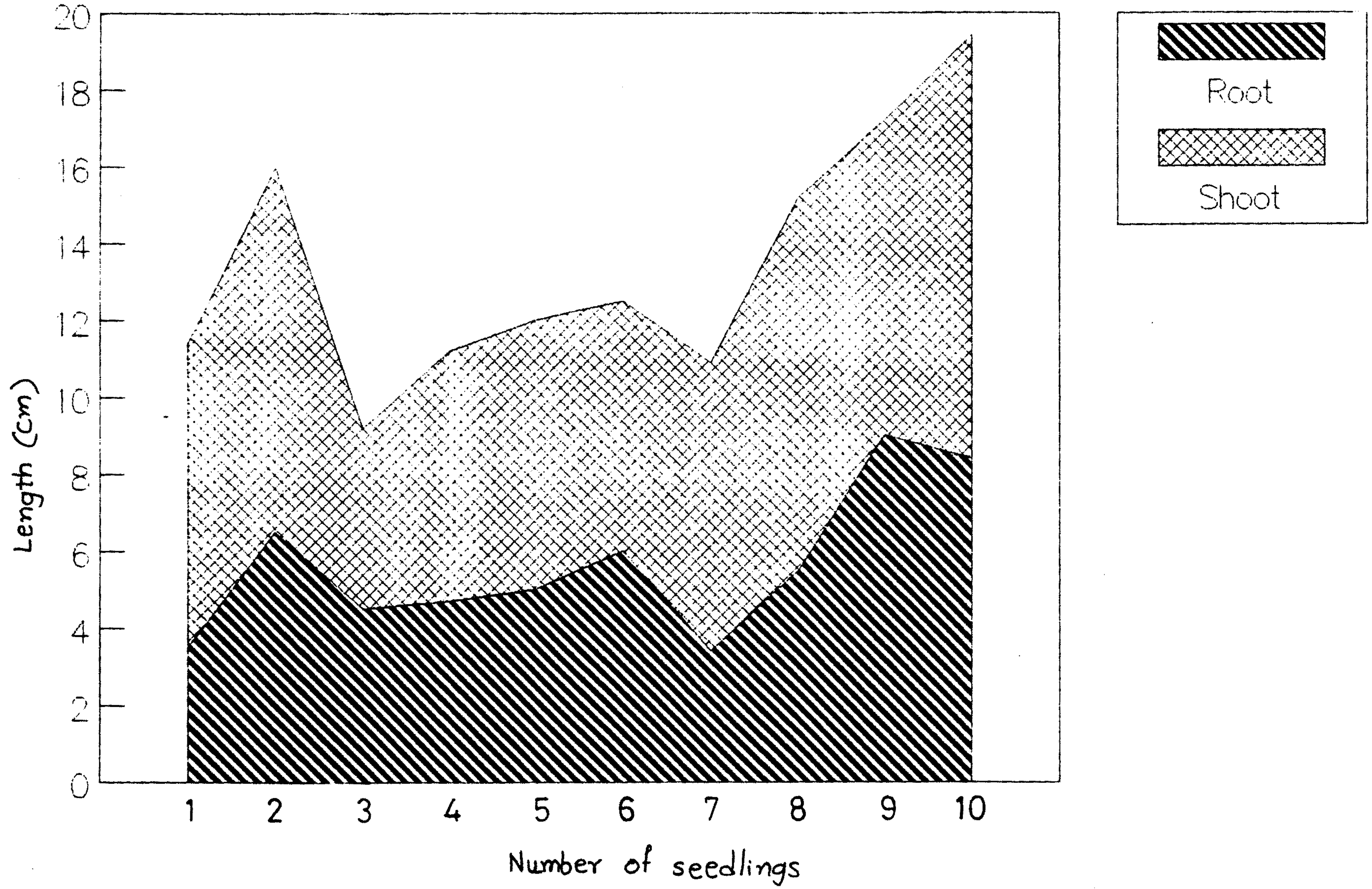
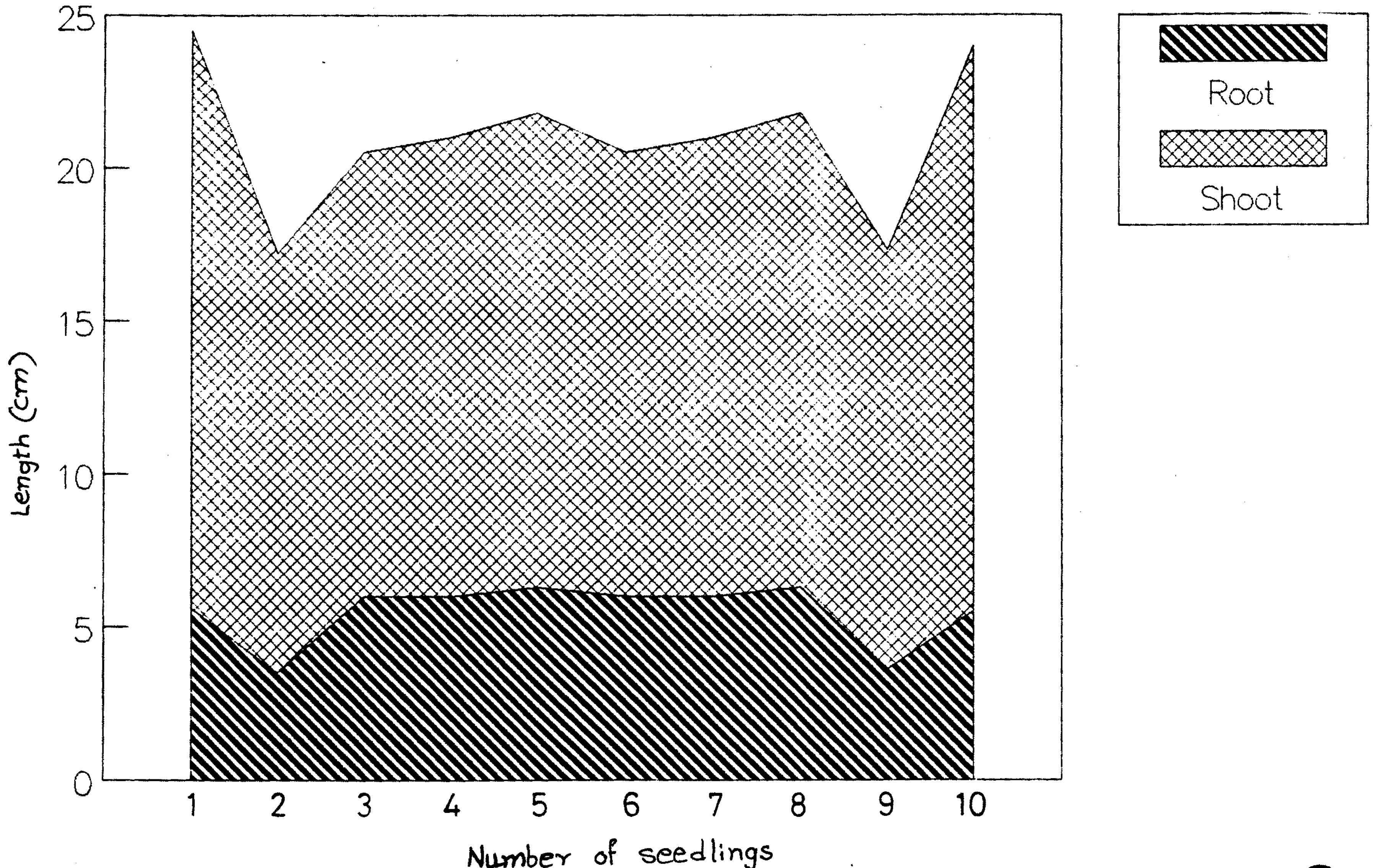


Fig.14 — Root shoot ratio at seedling stage of <u>*Avicennia officinalis*</u>.



c. <u>Adaptations</u> :

i. <u>Salt Glands</u>

Only a few genera of mangroves ( Avicennia, Aegiceras, Aegialitis, Acanthus ) appear to possess salt secreting glands in their leaves. The structure and function of these glands has been studied by a number of investigators (Scholander et al, 1962; Atkinson et al, 1967; Cardale and Field, 1971; Bostrom and Field, 1973; Cardale and Field, 1975; Saenger 1982).

Salt secreting species, including black and white mangroves (Scholander, 1968) have salt glands on the leaf surface to excrete excess salt. The process appear to involve active transport with a requirement for biochemical energy input. As a group, the salt secretors tend to have sap salt concentrations approximately ten times higher than that of salt excluders. Individual species utilize a variety of mechanisms to maintain suitable salt bealnce (Albert, 1975). Most salt secretors including white and black mangroves are capable of limited salt exclusion at the root surface, the white mangrove, that expose to hypersaline condition, not only eclude some salt and secrete excess salt through its salt glands, but also develops thickened, succulent leaves and discards salts during leaf fall of senescent leaves (Teas, 1979). There appears to be some variation in the salinity tolerance of Florida mangroves.

There may be an additional factor involved in salinity tolerance of mangroves. Mc-Millan (1975) found that seedlings of black and white mangroves survived short term exposures to 80 ppt and 150 ppt sea water, if they were grown in a soil with a moderate clay content. They fail to

## PLATE - 4

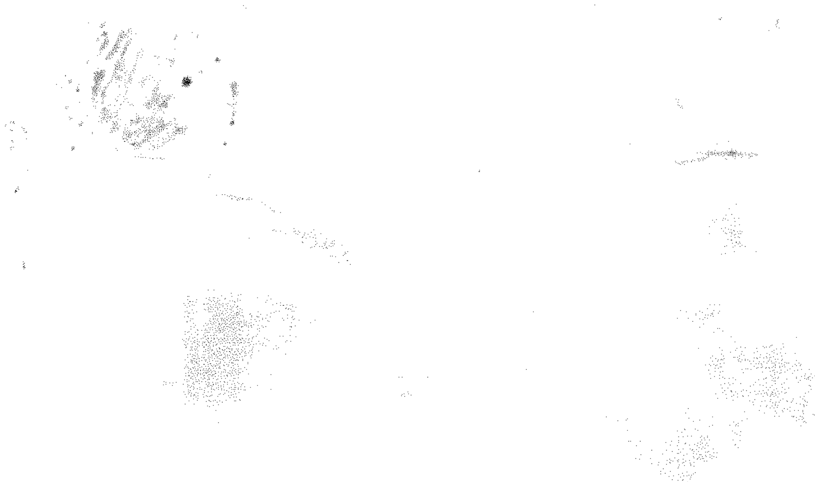
A comparison between salt glands of two *Avicennia* species.

A. *Avicennia* dwarf species(25X/0·50 ∞/0 - A 1·25X)

B. *Avicennia marina* (12·5X/0·25 ∞/A 0·8X)

Plate - 4

A



B

survive these salinities, however, if they were grown in sand. The salt glands occur in Acanthus, Aegiceras, Avicennia control their salt balance by secreting sodium chloride. The salt evaporates and crystalizes in a conspicuous manner. Salt glands are abundent on leaves of Avicennia species, recently Fahn and Shimony (1977) have accounted on Avicennia salt gland. Shimony et al (1973) summarized the relevant literature and presented detailed structural, developmental and physiological information.

Plate 4 shows salt glands of three different species. The cells of the salt glands differ in many respects from the surrounding epidermal or parenchymatous cells. At the top of the gland cuticle is traversed by many narrow pores in the salt gland of A. marina (Shimony et al, 1973) the cuticle is frequently separated from walls of secretory cells along the outer surface of the gland creating a large generally electron transperent cavity or collecting compartment between secretory cells or cuticle The inner portion of cuticle is loosely organised along the summit of the cuticular cavity. The walls of collecting cell or sub basal cells do not appear to be cuticularised at any point in near the transperent zone (Poljakoff Mayber and Gole, 1975).

Salt glands in Avicennia species are scattered in individual shallow pits on the upper leaf surface and much more densely within abaxial indumentum where they are not sunken. The structure of salt gland varies in Avicennia species. As leaf age increases, leaf area increases so also the salt glands on leaf. Fully expanded leaves have 12-16 salt glands per $mm^2$ for three Avicennia species. The gland is 5-8 celled in A. marina and A. officinalis but it is 4-7 celled in Avicennia dwarf species. Diameter of salt gland is about 40 $\mu$ in A. marina while it is 28-35 $\mu$ in Avicennia dwarf species.

Bhosale (1974) studied salt glands of A. officinalis. In T.S. of the leaf, the gland appears to be two celled, at the base of which paranchymatous cells get somewhat stretched the epidermis is disrupted and the cuticle from two sides invades in the cavity. In case of Avicennia dwarf species salt glands are numerous and comparatively less in number in A. officinalis and A. marina. In the present investigation, salt glands are studied to confirm the position of the dwarf species as salt excreting type. It is found that the structure of the gland is similar to that of A. officinalis but size, shape and number of cells differ.

## ii. Trichomes

All unicellular and multicellular appendages of the epidermis are designated by the term trichome. The use of trichomes in taxonomy is well known. Some families can be identified by the presence of particular type or types of hair. The hairs are important in the classification of genera and species (Metcalfe and Chalk, 1950; Metcalfe, 1963).

The epidermal trichomes usually develop early in relation to the growth of the organ. They persist throughout the life of an organ or they are ephemeral. Some persisting hairs remain alive; others become devoid of protoplast and are retained in dry state. Trichomes may show wide variations within families and the smaller plant groups and even in the same plant. On the other hand, there is sometimes considerable uniformity in trichomes within a plant group. Several types have been successfully used in the classification of genera and even of species in certain families and in the recognition of interspecific hybrides (Rollins, 1944; Heintzelmann and Howard, 1948; Cowan, 1950; Metcalfe and Chalk,

Table 9 : Morphological Characterization of Trichomes of *Avicennia* species.

| Trichome Species | Head Breadth | Head Length | Stalk Breadth | Stalk Length | Height |
|---|---|---|---|---|---|
| *A. officinalis* | 18.48 | 38.41 | 22.11 | 44.57 | 63.41 |
| *A. marina* | 22.68 | 66.86 | 24.64 | 75.02 | 97.70 |
| *Avicennia* species (dwarf) | 15.40 | 49.11 | 21.56 | 64.70 | 80.10 |

Values are expressed in µm.

1950; Hummel and Staeshe, 1962). Variations in degree of complexity may be found in closely related species and appear to be of phylogenetic significance (Cartquist, 1959 a,b).

Trichomes may be classified into different morphological categories (Foster, 1949) and into several types (Salerader, 1908; Foster, 1950; Metcalfe and Chalk, 1950; Uphof, 1962). In the present investigation three species of Avicennia show wide variation which is very interesting (Table 9). The characters which are found may be helpful in identifying different genera. The trichomes are simple, multicellular, glandular hairs consist of a stalk and unicellular 'T' shaped head.

Trichomes initiate as a protuberance from an epidermal cells. Further the protuberance elongates and develops into multicellular structure The cell walls of trichomes are made of cellulose and are covered with cuticle.

In the present investigation both leaf surfaces are studied with respect to trichomes. It is seen that the trichomes are spread densely for all the three species. Trichomes show variation between the three species. Some of such leaf characters exhibited by most of the mangrove species appear to be an ecophysiological adaptations. Multicellular glandular hairs are found in A. alba, A. corniculatum, A. marina and A. officinalis ( Mullen, 1932, 1933; Metcalfe and Chalk, 1950; Tan and Keng, 1969). Rao and Hugh Tan (1984) observed that the glandular hairs function as salt excreting hydathodes.

Trichome of the three species of Avicennia differ in size and shape. The length of the trichome of A. officinalis is less than that of A. marina and Avicennia dwarf species while the breadth of trichome of

## PLATE – 5

Leaf section showing trichomes of different *Avicennia* species.

A. *Avicennia* dwarf species (25X/0.50 ∞/0-A 1.25X)

B. *Avicennia marina* (12.5X/0.25 ∞/A 0.8X)

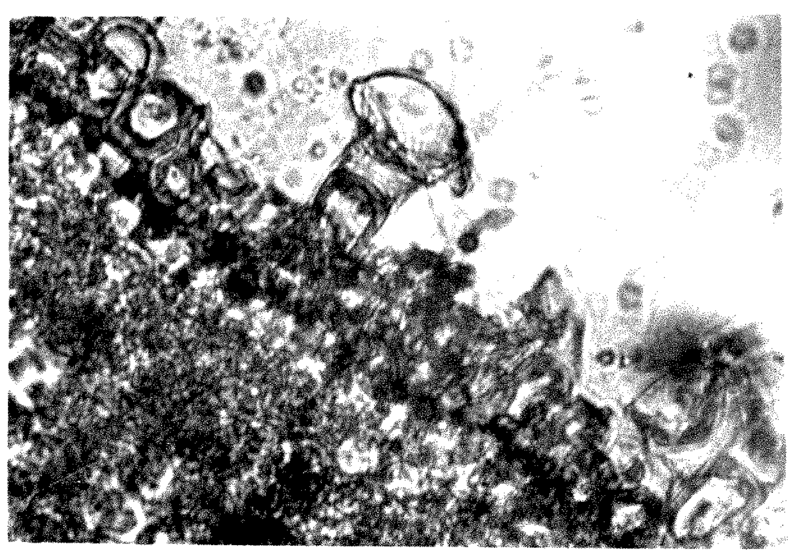
C. *Avicennia officinalis* (12.5X/0.25 ∞/A 0.8X)

Plate - 5

A

B

C



A. officinalis is more than Avicennia dwarf species. The total length of trichome is 63.41 µm, 97.71 µm and 80.10 µm for A. officinalis, A. marina and A. dwarf species respectively. The length of trichome of Avicennia dwarf is intermediate between A. officinalis and A. marina. Thus the values of trichomes for total length and its breadth suggest significant relationship among the species.

### iii. Pneumatophores

The morphological and physiological characteristics of plants and animals of the mangrove show convergent adaptations to the peculiar environment in which they live. These adaptations give to the mangrove ecosystem, its unique appearance. Among plants, one of the most striking features described repeatedly in both the scientific and popular literature are above ground roots of all types (aerial roots, proproots, buttress roots, Pneumatophores etc.) that serve the mechanical purpose of anchoring the trees in the soft and mobile substratum. These roots are usually coated with a spongy tissue called aeronchyma that facilitates the exchange of gases to inner tissues; lenticells on the tree bark serve the same purpose of admitting air. Pnumatophores are aerial roots which develop from the underground horizontal cable roots (amin roots) and produce within the uppermost layers of soil a large number of nutritive roots. As the soil accrues the pnumatophores grow upward keeping above the soil and keeping the nutritive roots in the upper soil stratum. The form of pneumatophore can varywidely. The term pnumatophore has no precise morphological connotation. Quite different developmental types can be recognised, each characteristic of genus or group of species. Pneumatophores provide the key to existance upon unfriendly substratum. In the present investigation

Fig. 15 — Observations on pneumatophores of *Avicennia* species at Ganapatipule and Ratnagiri sites.

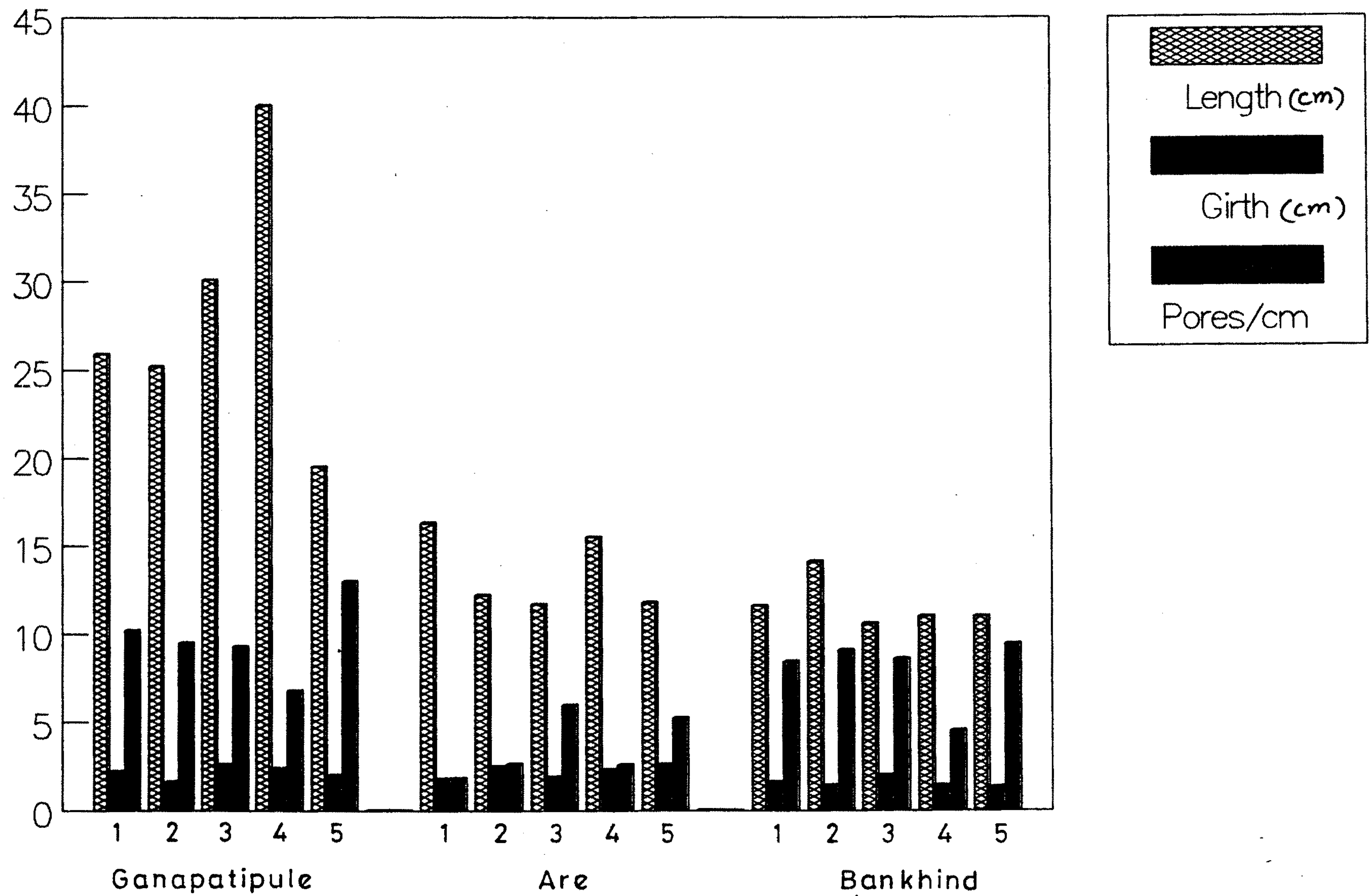
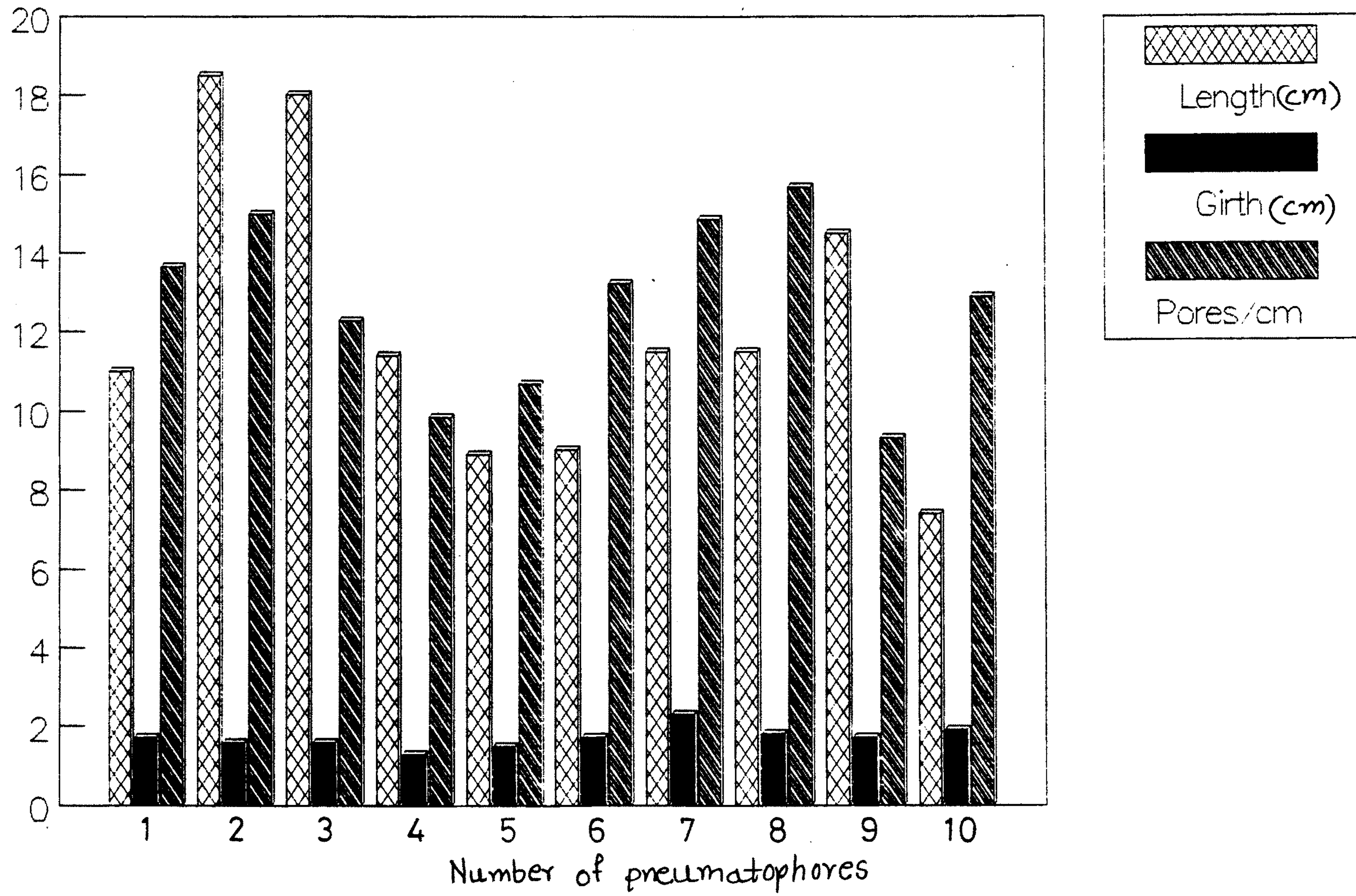


Fig. 16 — Observations on pneumatophores of <u>Avicennia</u> dwarf species.



pnumatophores of three Avicennia species are studied with respect to length, girth and number of pores ( lenti cells) from four different sites. It is found that the length of pneumatophores varies as per the species and site. Figures 15, to 18 record the measurements of different species at different sites. It is evident from figures that, the highest length of pnumatophore of A. officinalis is 18.8 cm, the length ranges from 7.5 to 18.8 cm but the length of the pnumatophores of A. marina ranges from 11 to 22 cm and for Avicennia dwarf species the range is 19-30 cm. Mangroves achieve structural stability in atleast two ways. Species such as the red mangroves use the system of proproots to provide a more or less firm foundation for the tree and other mangrove species including, the black mangrove, obtain stability with an extensive system of shallow underground, "cable roots" that radiate out from the central trunk; the pneumatophores extend upward from these cable roots. The variation in the length is to accommodate fluctuations and extremes of water and soil salinity and shifting, anaerobic substrates. The black mangroves do not have proproots but have pneumatophores which extend vertically upward to a height of 20-30 cm. At low tide, air travels through pneumato phore into the aerenchyma systems and then to all living root tissues.This mechanism depends on each species to achieve structural stability. The other species "white mangrove" does not have either prop-roots or pnumato phores, but utilises lenticells in the lower trunk to obtain oxygen for the aerenchyma system. "Peg roots" and pneumatophores may be present in certain situation Jenik (1967).

The three species also show variation in the pneumatophore girth. Though A. offici nalis and A. marina show differences in length of pneumatophore, the

Fig. 17 — Observations on pneumatophores of <u>Avicennia</u> <u>marina</u>

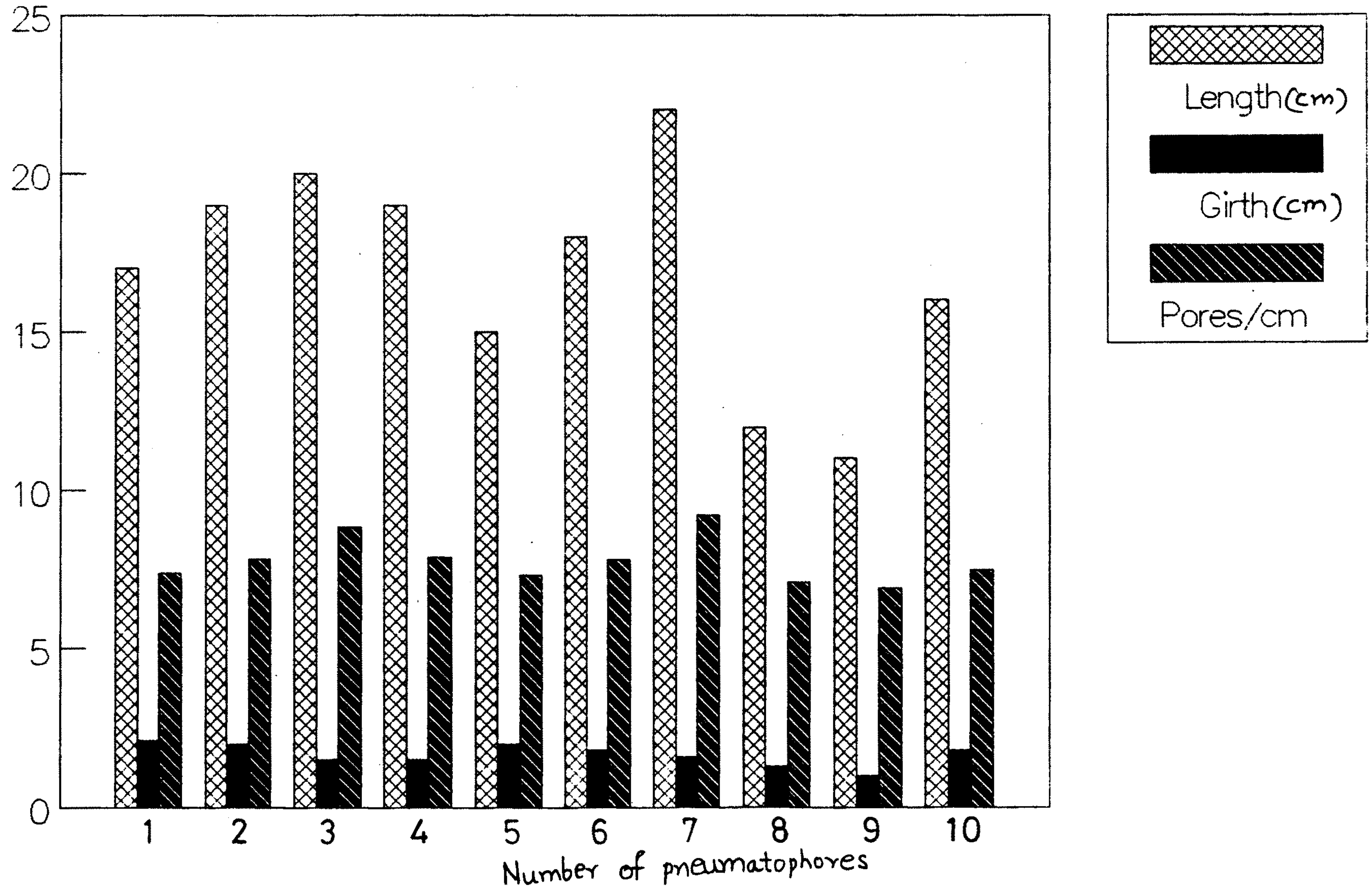
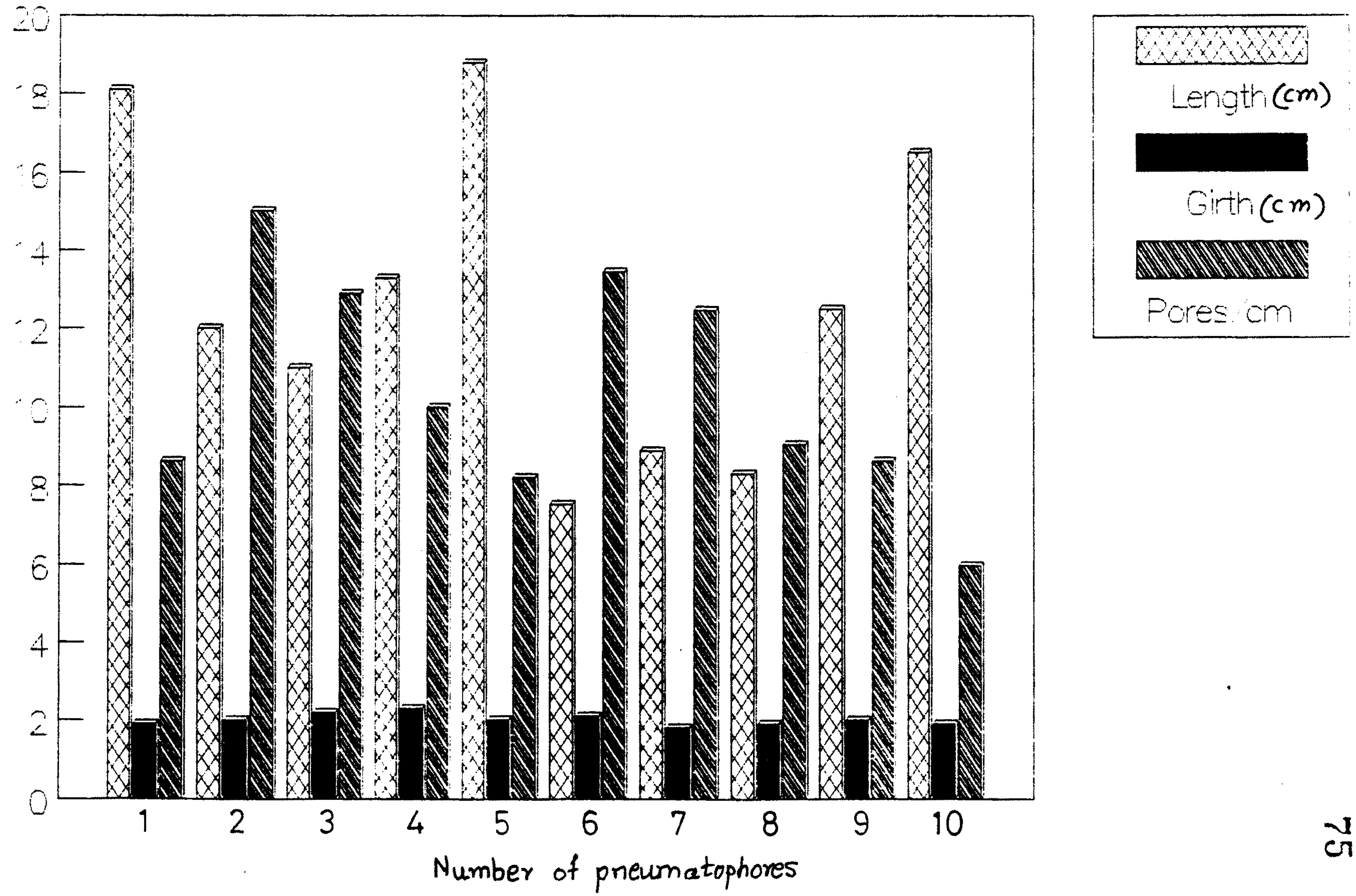


Fig. 18 — Observations on pneumatophores of *Avicennia officinalis*.



girth remains same (1.5 - 2.1 cm) but the girth of Avicennia dwarf species ranges from 1.6 to 2.2 cm.

The surface of pneumatophores is covered by corky layer penetrated by large number of lenti cells (pores) which at low tide allow oxygen to diffuse into the plant and down to the underground roots by means of open passages (Scholander et al, 1955). The lenti cells are highly hydrophobic and prevent water penetration into aerenchyma system during high tide (Waisel 1972). In Avicennia oxygen and $CO_2$ exchange is thought to occur through pneumatophores (Allaway et al, 1985). Baker (1915) describes the lenticells occuring on the pneumatophore of A. marina as raised black spots scattering over the surface, a section, showing three layers of cells to be raised over what is a vacant cavity or air space in direct communication with ventilating system. He concludes that they may be secondary organs of ventillation. Though it is so the difference (numbre of pores) may probably be due to species specific mechanism to maintain the suitable balance in ecosystem. Number of pores per cm. differs as per the species. Like girth there is no significant difference in number of pores in A. marina and A. officinalis. The range for number of pores for A. marina is 7.4 - 8.8 pores/cm, while the range of variation is broad in Avicennia dwarf species 9.3 - 15.65 pores/cm. This characteristic of species is important to know the requirement of the species as a function of different ecological factors, thus the study helps to find out a range of number of pores required by pnumatophore of that species.

Quite different developmental types can be recognised each characteristic of genus or group of species. The essential features are seen in figure . In Avicennia the roots are of limited height and develop little secondary thinking while in Sonneratia the roots have a much longer period of development and undergo secondary thickning so they become quite tall. The surface texture in Avicennia species remains smooth and spongy and in Sonneratia a characteristicly flaky bark develops in younger roots; in older roots the bark is smoother. The existance of pneumatophore in Lagun culeria sometimes goes unrecorded (Allen, 1956).

Generally two types of pneumatophores can be recognised, the smooth and rough. The former has few lenticells which do not project and the root remains firm and compact on drying; later has numerous projecting lenticells and it wrinkles on drying. Chapman (1976) suggested that the soil type is more important in determining the nature of the pneumatophore, the smooth type being associated with loose sand and rapid accretion and long air exposure, and the rough type with compact sand, firm mud, peat or persistant water immersion.

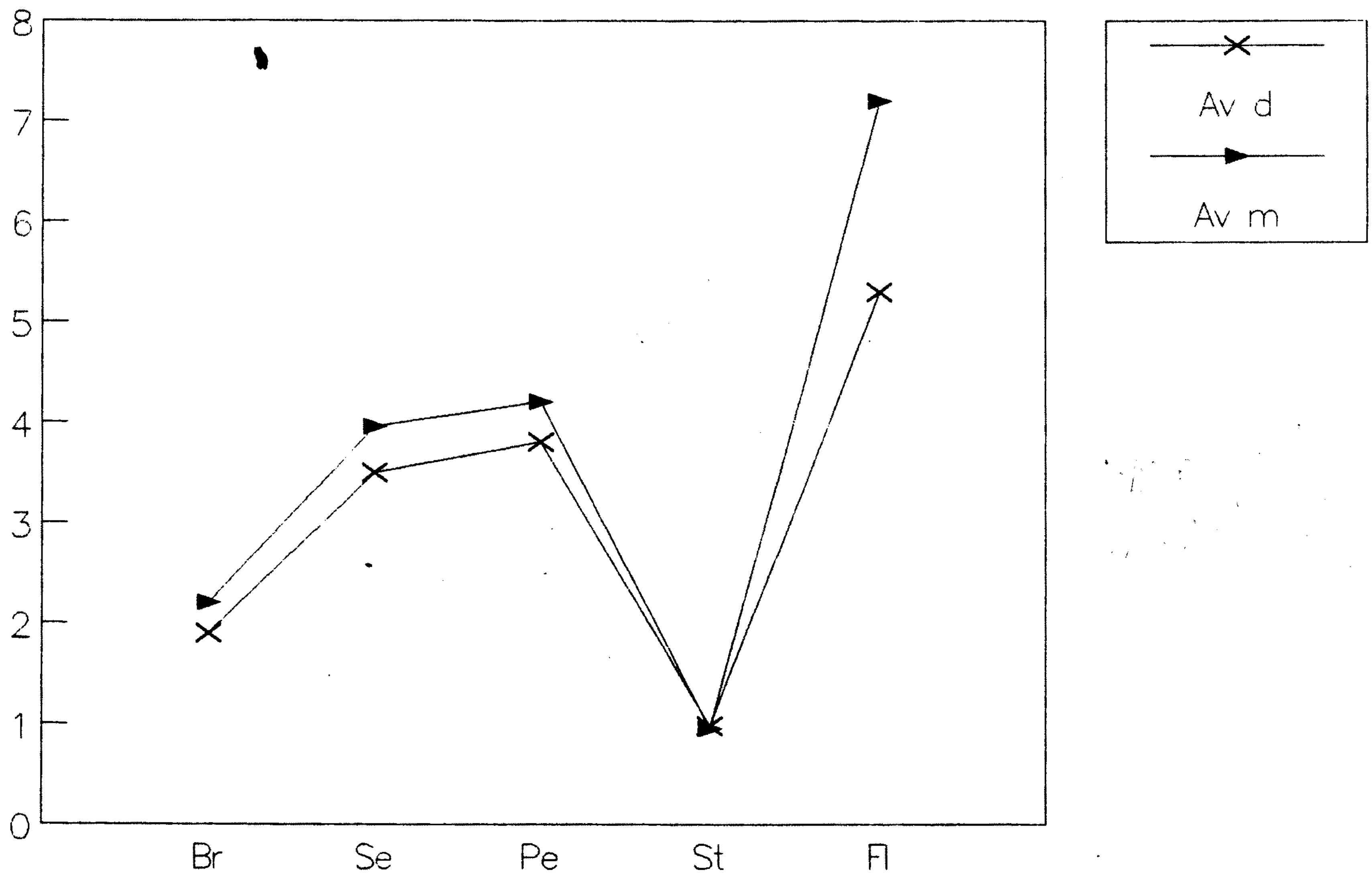
## d. Reproductive Strategies

### i. Flowers

Flowers of Avicennia species conjested into a head. The inflorescence are borne in the upper axiles and are peduunchel, usually umbellate or paniculate, head like or spike like. The single flower is sessile, opposite yellow coloured with bracts and bracteoles. The flowers of three species show wide variation. Therefore to find out accurate differences present study is carried out.

The inflorescence of Avicennia officinalis is head like with 2-14 flowers conjusted into a head and the lowermost pair of flowers often distant from the others. The petals are subtended by brownish tipped green bracteoles the corolla is yellow tomentose often on both surfaces with lobes 4-7 mm long, the expanded flowers are 10-15 mm across, the

Fig. 19 – Variation in floral parts of *Avicennia* dwart species and *A. marina* .



filaments are 3 mm long with yellow anther one mm long, the style is pubescent and is 2-4 mm long. Stigmatic lobes are shorter.

Avicennia marina flowers are in 2-12 flowered peduncled heads, the heads being 0.5-1.5 cm long bracts and bracteoles are present, calyx lobes are 3-4 mm long, tomentose towards base, the corolla tube is glabrous and the lobes are 3-4 mm long, yellow to orange in colour, the stamens are dark in colour, the anthers are 0.5-1 mm long; the style is 0.5 to 1.5 mm long and appears to be glabrous, stigmatic lobes are short.

Avicennia dwarf species flowers are in more or less spike, like cymes (1.5-2 cm long) and composed of 10-20 opposite flowers, the peduncles are 1-2 cm long, bracts and bracteoles are present at the base of each flower. The flowers are small and sessile compared to A. marina and A. officinalis. Calyx has 5 lobes, green, ovate 2-3.5 mm long, the corolla is small yellow to orange with lobes 2-4 mm, long the corolla tube is glabrous, stamens are yellow 0.5-1 mm long, the anthers are yellow and 1 mm long, style is very short, the entire flower in this species is 4-4.5 mm long.

Figure 19 shows variation in floral parts of Avicennia dwarf species and A. marina.

## ii. Pollens

The study of pollen grains of mangroves may appear to be a somewhat arbitrarily selected topic, since it deals with pollen from an unrelated group of plants, but it has several important applications. First, fossil pollen is the most extensive and systematically reliable source of information about the ancestry of individual mangroves. The dispersibility of mangrove pollen is relevant to the study of fossil mangal (Muller, 1981).

Table - 10 : Morphological Features of Pollen of *Avicennia* Species

| Pollen<br>Species | Shape | Size<br>(Diameter) | Aperature status | Exine pattern |
|---|---|---|---|---|
| *A. officinalis* | Prolate spheroidal | 32-38 | 3-colpate | Reticulate |
| *A. marina* | Prolate spheroidal or oblate spheroidal | 32-37 | 3-4-colporate | Reticulate |
| *Avicennia* sp. (dwarf) | Spheroidal | 36-48 | 3-colparate | Reticulate |

Size of pollen is expressed in µm.

Pollen structure is related to the floral mechanism and its analysis may be an important adjunct to a study of floral biology and may give some indication of pollen vectors.

Study of the morphological characters of the pollen grains associated with honey is a prerequisite for the identification of its pollen contents. It is essential for detecting the species as well as geographical source of honey. The present study is taken up to facilitate the identification of the species on the basis of pollen characterization.

The morphological characterization of pollen grains is presented in table 10. Pollen morphological characters such as shape, size, aperature status and exine pattern are depicted in tabular form for easy reference and identification. The study is helpful for identification of pollen grains of Avicennia species and also for identification of pollen grains associated with honey. The shape of the pollen of A. officinalis is prolate to spheroidal while A. marina shows three patterns prolate, oblate or spheitoidal and Avicennia dwarf species pollen is seen spheroidal. Apperature status varies slightly, the three species show similar exine pattern. Chaubal and Kotmire (1986) studied melisopalynological aspects of mangroves from different localities of west coast of Maharashtra. The study indicates the geographical source of honey. Mondle and Mitra (1980) have similarly presented the pollen spectrum of honey samples from Sundarban region. Variation in mangrove pollens is of systematic significance and relates to the taxonomic status of each group and information tends to support that the most specialised mangroves are taxonomically isolated. The useful survey of North Queensland mangrove pollen flora are studied by Wright (1977) is helpful because it deals with common genera of old world mangroves.

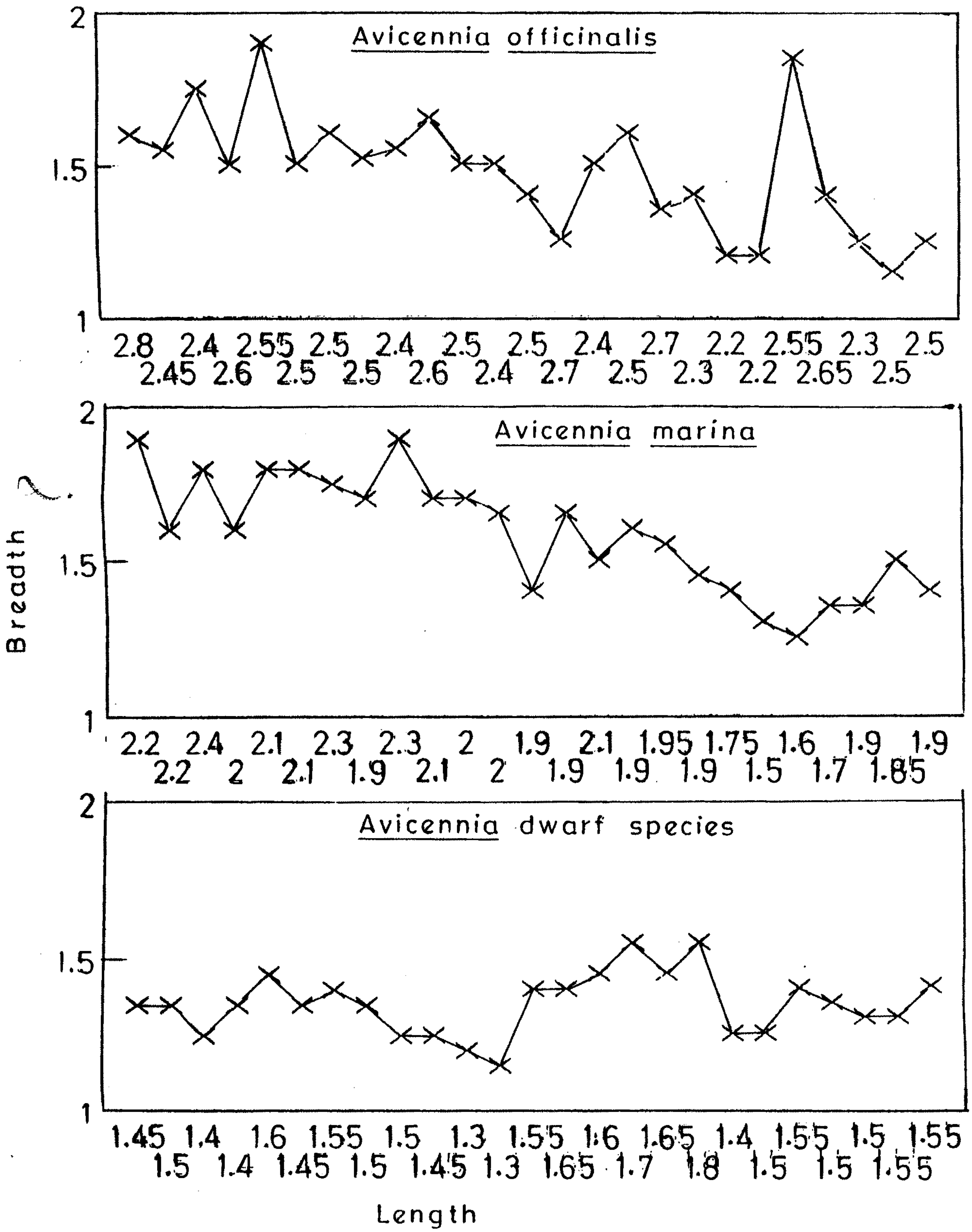
The present observation suggest that the species of Avicennia can also be distinguished by pollen. This information is helpful in clarifying the subgeneric classification of this genus because the pollen size varies considerably.

### III. Fruits

As pointed out by Robinowitz (1978a), all mangroves share two common reproductive strategies; dispersal by means of water (Vander Pijl, 1972) and vivipary (Macnar, 1968; Gill and Tomlinson, 1969). Vivipary means the embryo develops contineously while attached to the parent tree. There is uninterrupted development from zygote through the embryo to seedling without any intermediate resting stage. Therefore, the word "seed" is inappropriate for viviparous species. The term "propagule" is generally used in its place.

Mortality of established seedlings seems to be related to propagule size. The propagule size and seedling mortality rates are particularly important in consideration of succession and establishment of mangrove forest. Keeping this ecological view in mind and also to differentiate species of Avicennia, the present piece of work is undertaken. Fruit measurements (length and breadth) are taken as per the season (Figure 20). The propagules of the three Avicennia species are easy to differentiate considering the size of fruit. In Avicennia it is noted that the seed inside the fruit germinates before the fruit attains its maximum size. In this case growth of embryo sac as well as enlargement of fruit wall continues simulteniously till embryo is mature. Therefore, the fruit wall does not get a crack through which radicle can protrude. At this mature stage

Fig. 20 – Variation in fruit morphology of three *Avicennia* species.



length and breadth measurements were compared in all the three propagules. Figure shows the differences in properties of fruits of Avicennia species. It is seen that the average length of propagules is 2.2-2.8 cm for Avicennia officinalis; for A. marina 1.5-2.4 cm and it is less 1.3-1.7 cm for Avicennia dwarf species. The maximum length is recorded in Avicennia officinalis fruit while it is intermediate in A. marina. The increase in breadth shows that the highest value is for A. marina (1.9 cm) while the lowest record is observed for Avicennia dwarf species (1.45 cm.). It is clear that the significant difference is seen in length of propagules of A. officinalis, A. marina and Avicennia dwarf species, are thus important in finding out suitable mature propagules. In other words the propagules which mature and attain the size of 2.5-1.5 cm (l x b); 1.6-1.8 cm (l x b); 1.5-1.8 cm (l x b) are suitable for plantation. Another difference in propagule of the three species is its shape. A. officinalis propagules are pulpy and pea green coloured whereas A. marina propagules are flattened and Avicennia dwarf species propagules are intermediate with tapering end. The fruit morphology of these species indicate the species and varietal difference.

A. officinalis fruit is broadly ovate, densely short hairy, with long accuminate apex, while the fruit of A. marina is ovoid with pointed apex, green to pale green in colour and the fruit of Avicennia dwarf speciesd is greenish yellow, obliquely or narrowly oblong, ovoid somewhat flattened, buff to yellowish green.

Working in Panama, Robinowitz (1978b) found that the mortality rate of mangrove seedlings was universely correlated with initial propagule size. The white mangrove, which has the smallest propagule has the highest rate of seedling mortality. The black mangrove has an intermediate mortality rate while the red mangroves, with the largest propagule, has the lowest seedling mortality rate. She concluded that species with small propagules established new cohorts annually but die rapidly, while species such as red mangroves may have long lived and often overlapping cohorts. Investigations on this line with respect to Avicennia species are under progress.

## B. Anatomy

### a. Leaf

The leaves of Avicennia are dorsiventral and hypostomatic (Seshavatharam and Srivalli, 1989).

The T.S. of leaf of three Avicennia species show thick epidermal cuticle. Just below the cuticle there is epidermis. Both upper epidermis and lower epidermis are presented in the leaves of three Avicennia species Here lower epidermis is not clearly visible due to presence of trichomes. Upper epidermis have a thick epidermal cuticle and it is one layer in thickness which bear salt glands. The epidermal cells are polygonal with more or less straight walls. Waisel (1972) considers the cuticle of the mangrove leaves as an adaptive feature and being highly hydrophobic repelling the spray droplets. Sharma and Dunn (1968), Van Cothem (1970) and Sidhu (1975) have suggested that the size and shape of the epidermal cells vary according to conditions where the plant grow. Just below the upper epidermis there are three to four layers of hypodermal cells.

In Avicennia hypodermal cells (water storage tissues) are present on the adaxial side only. Chapman (1975) considered water storage tissue as a characteristic of nearly all mangrove leaves and recognized four different categories viz., i) water storage tissue exclusively hydermal, ii) water storage tissue derived from hypodermis plus subsiquently modified assimilatory tissue, iii) water storage tissue exclusively deep seated and iv) leaves without specific water storage tissue. Walsh (1974) and Waisel (1972) consider water storage tissue as an important ecophysiological adaptation of the mangroves playing an important role in regulating water loss and the transpiration process. The presence of hypodermal water storage tissue must reduce gas exchange and possibly transpiration rate as water storage tissue is a characteristic feature of all mangrove leaves. In A. officinalis water storage tissue formed 1/4th of the leaf thickness whereas in Avicennia dwarf species it is upto 50%. In the present investigation specific differences are seen (Plate 7 ).

**Palisade mesophyll** is well developed in all the three species. The palisade tissue ranged from one to many layers in thickness in mangroves. Shields (1950) remarked that the development of palisade at the expense of spongy mesophyll is one of the important characters for leaf xeromorphy as related to water loss. The succulence of leaves recorded in species of mangroves could be attributed to the increase in the cell enlargement/cell layers of the mesophyll as well as the hypodermal layers of water storage tissue. Similar situation has been reported by Rao and Hugh Tan (1984). Strogonov (1964) and Walsh (1974) have observed a salt content of the soil as the chief factor responsible for succulence in halophytes. Shields (1950) attributed the increased thickness of xeromorphic leaves to the greater development of palisade elongating vertically at the expense of lateral expanding spongy mesophyll. However, Sehavatharam and Srivalli

(1989) have found no positive correlation between the lamina thickness and palisade thickness. In the present study thickness of the lamina varies but not the spongy layer.

Just below the palisade cells near lower epidermis there is spongy tissue. According to Seshavatharam and Srivalli (1989) the thickness of the palisade tissue was less than that of spongy. Spongy cells are parenchymatous in nature.

Trichomes are with short stalk and pear shaped terminal cell attached horizontally and excentrically to the stalks giving shite or dull appearance to the leaf surface. Trichomes are present on the lower leaf epidermis. Trichomes of the three species of Avicennia differ in size.

Salt glands are present on the upper leaf epidermis. In Avicennia salt glands have been studied by Bhosale (1974), Kulkarni (1983). According to Kulkarni (1983) in Avicennia marina glands are composed of an indefinite number of cells usually between 5 to 9 arranged in a group of 4 or more cells located on the top of one stalk and two to four collecting cells. In A. offinalis and Avicennia dwarf species this number varies.

Leaves of most mangroves exhibit a range of xeromorphic features (Stace 1966) although this is disputed by some (Uphof, 1941) and there are some experimental studies in support of their water conserving functions (Miller et al, 1975). All genera of mangroves have a thick walled epidermis which, on the upper surface of the leaf, is covered by a thick, waxy cuticle (Stace 1966, Sidhu 1975a) or by a tomentum of variously shaped hairs.

b. Stem :

The anatomy of mangrove woods have been studied extensively in part because of their economic importance and in part to correlate wood structure with physiological specialization towards the mangrove habitat (Jansonnius, 1950 ; Panshin, 1932) and for the Rhizophoraceae alone (Mullan, 1931; Van Vilet, 1976). Panshin (1932) described wood anatomy of Philippine mangroves in considerable detail, mainly from the point of view of commercial use.

One of the most complete accounts of stem anatomy is that by Chapman (1944) for Avicennia germinans ( A. nitida ) with a more general account for the genus by Van Tieghem (1898).

The present attempt is made to find out differences in anatomy of Avicennia species. Plate 8 shows T.S. of stem of Avicennia dwarf species which show outermost layer made up of epidermal cells. Epidermis is made up of polygonal cells (2-3 layers). Below the epidermis, there is cortex. Outer cortex is made up of compact cells whereas inner cortex is with air spaces. Endodermis follows by cortex. Below this there is phloem which continues xylem. The stem of Avicennia is uniform but with anamolous growth rings, which consists of bands of xylem, including radical multiple of wide vessels, alternating with bands of conjuctive tissue which include strands of phloem. Separating each band is a narrow strand of sclerenchyma, 2 or 3 cells wide. The bands are quite regular. It is now generally agreed (Studholme and Philipson, 1966; Zamski, 1979) that the rings are the products of division of successive cambia.

The first cambium is formed in the usual way for dicotyledons with secondary thickning, and it cuts off xylem internally and phloem externally. It ceases to function after a limited period of activity, although it may remain locally as a nondividing layer on the innerside of phloem strands. The second cambium is formed from the innermost cortical layers; the third combium is partly from cortical cells and partly from outer paronchyma derivatives of the previous cambium; and all later cambia are derived entirely from the outermost parenchyma layer produced by each previous cambium.

In the development of each ring, the cambium produces a broad band of xylem to the inside and 6 to 10 layers of parenchyma cells to the outside. The xylem differentiates immediately, but the parenchyma differentiates centripetally, with differentiation being completed only after the cambium has ceased to function. The product of the first differentiation to the outside of the cambium is the layer of sclereids; the phloem strands appear later by cell divisions within the conjunctive parenchyma. Cambial initials remain inactive on the inside of each phloem strand, but the rest of the cambium differentiates as conjunctive parenchyma. The new cambium is then initiated by dedifferentiation of parenchyma cells immediately outside the scleronchyma layer. Sclereids and the new xylem are always seperated by 2 or 3 parenchyma layers. Anatomical characteristic features are important to correlate species diversity. The detailed investigation by Gill (1971) clearly shows that they are correlated directly with the stem diameter in a linear way. The rings are nonannual therefore the number of rings cannot be used to determine age in <u>Avicennia</u>. Ring formation is related to endogenous activity.

The functional significance of this type of anomalous wood structure is not clear. The anomalous structure of the wood of Avicennia renders is unsuitable for constructional timber since the phloem decays relatively rapidly to leave extensive pores. The xylem however is persistent and quite hard.

A central portion of the section of stem is pith. Pith cells are rounded and parenchymatous.

In Sonneratia, the young stem is coated with wax granules while, in Aegiceras the primary hypodermal layer cells are rich in tannin and oil but these reaserves disappear in older stems. Secondary thickning in the stem of the genus Avicennia germinans is related to the development of successive rings of extrafascicular cambium, arising outside the ring of limiting fibers and beneath the endodermis. In some cases the rings do not completely encircle the stem. Chapman (1947) presented evidence from a dated plant in support of this view. The same is true for Avicennia marina var. resinifera (Baker, 1915) and there is no evidence for a suggestion by Lushington that the rings are produced on a monthly bases. The Avicennia stem thus form a very interesting object for a study of cambial development.

c. Pneumatophores

Goebel (1886) in his account of the pneumatophores of Sonneratia suggested that these and those of other mangroves were organs of gaseous change between the atmosphere and the internal tissues of the plant, and that this interchange would be important in a soil where the atmosphere could be oxygen deficient. The pneumatophores of Avicennia vary in length. Lenticells are only formed in the aerial portion.

T.S. of pneumatophore shows outer epidermis which is 2 to 3 celled in thickness. Just below the epidermis there is cortex. Cortex is made up of outer cortex and inner corter. Outer cortex is composed of 6 to 7 layers of cells while there is a development of air spaces in the inner cortex. Development of these cells appears also to start in the outer cortex and proceed inwards (Schenck, 1889; Bronner, 1902; Borgeson, 1909 and Mullan, 1931) have all described these cells as idioblasts, the term trichoblast used by Brenner (1902) scarcely seeming appropriate. Below the cortical tissue there is endodermis. Endodermis is 4 to 5 layered thick. Endodermis continuous with phloem cells and just below the phloem there is xylem. Secondary thickning̲s occurs but there is no evidence in A. germinans of annular rings comparable to those found in stem. According to Liebau (1913) upto 4 annular rings could be found in the pneumatophores of A. officinalis. The central portion of pneumatophore is pith. Pith cells are rounded. In young pneumatophores the cortex is often lacunose, in **Avicennia** the cells of the middle cortex became lobed, creating enlarged intercellular space and they are supported by bonds of wall thicknings. Pneumatophores of Avicennia have limited secondary growth, those of Sonneratia are made up of largely secondary tissue. Variation in species of Avicennia are seen in plate

The differences which occur between the pneumatophores of Avicennia species are probably correlated with their relative positions in soil of each species. Further study of the phenomenon is needed.

d. Starch Distribution Pattern

It may be noted that detection of starch is based on hydrolysis and determination of reducing sugars thereafter. The polysaccharides

## PLATE - 6

Fruits of different *Avicennia* species

Comparison between fruits of different *Avicennia* species.

A. *Avicennia* dwarf species

B. *Avicennia marina*

C. *Avicennia officinalis*

PLATE - 7

T. S. of leaf of three *Avicennia* species

A. *Avicennia* dwarf species (12.5 x/0.25 ∞/A 0.8x)

B. *Avicennia marina* (12.5 x/0.25 ∞/A 0.8x)

C. *Avicennia officinalis* (12.5 x/0.25 ∞/A 0.8x)

## PLATE - 8

T. S. of stem and pneumatophore of *Avicennia* dwarf species.

A. T. S. of stem (12·5 X / 0·25 ∞ / A 0·8X)

B. T. S. of pneumatophore (12·5 X / 0·25 ∞ / A 0·8 X)

**PLATE - 9**

Starch distribution pattern in three

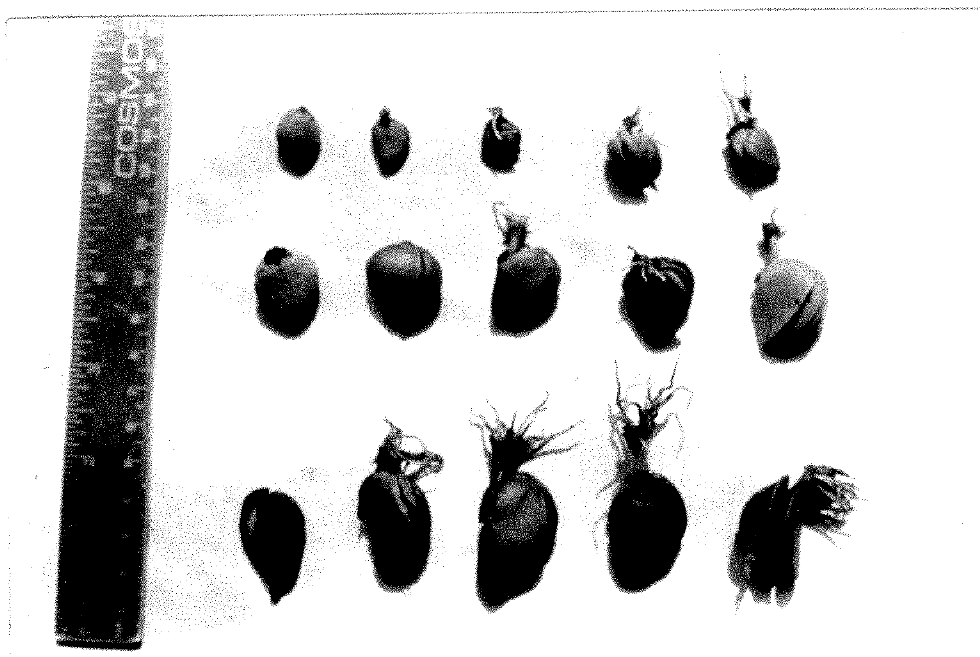
*Avicennia* species

A. *Avicennia* dwarf species (25x/0.50 ∞/0-A 1.25X)

B. *Avicennia marina* (25x/0.50 ∞/0-A 1.25x)

C. *Avicennia officinalis* (25x/0.50 ∞/0-A 1.25X)

Plate - 6



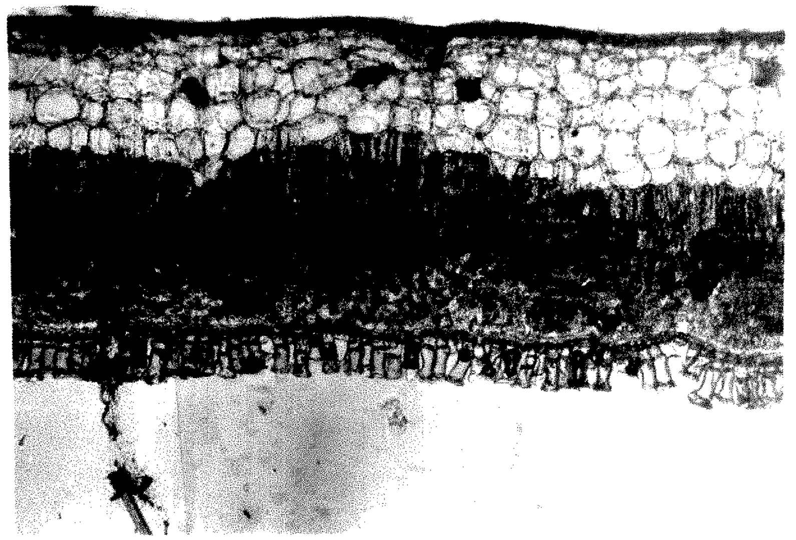

A

B

C

Plate - 7

A



B

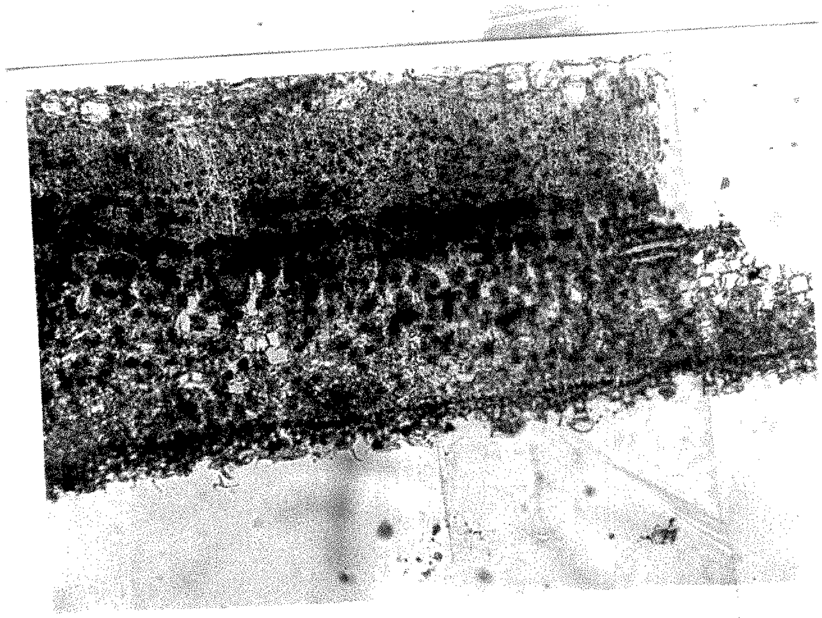
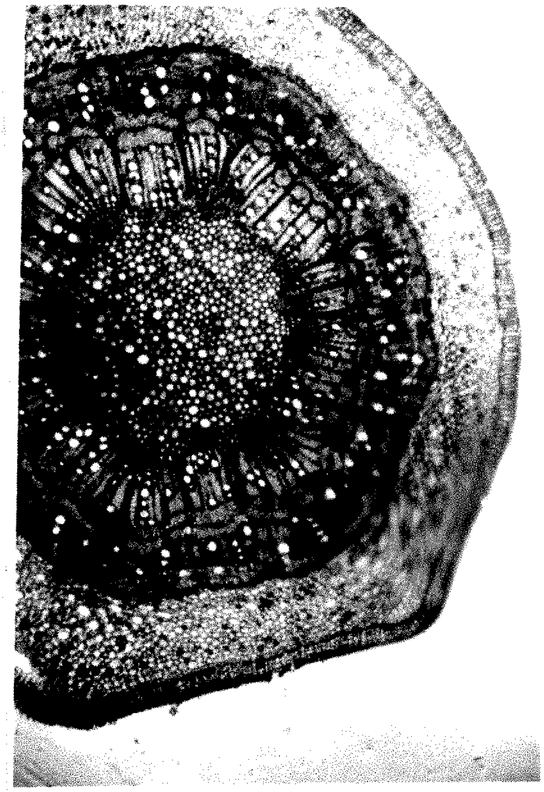


Plate - 8

A



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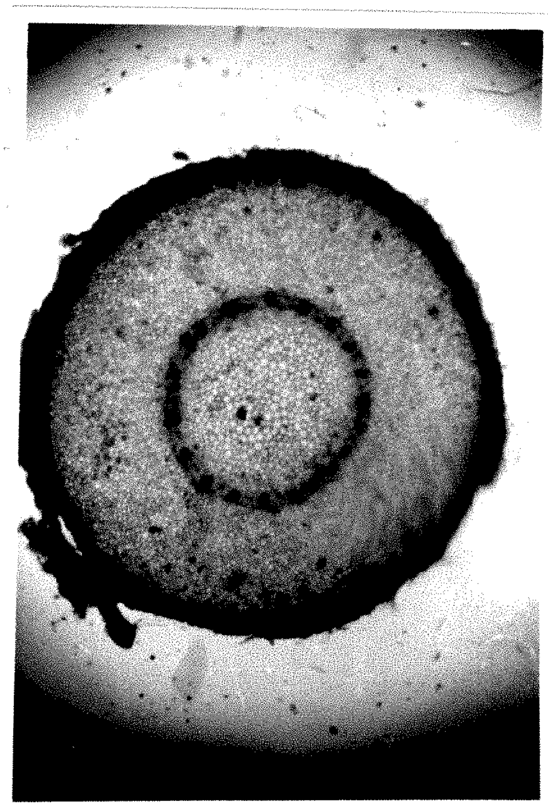
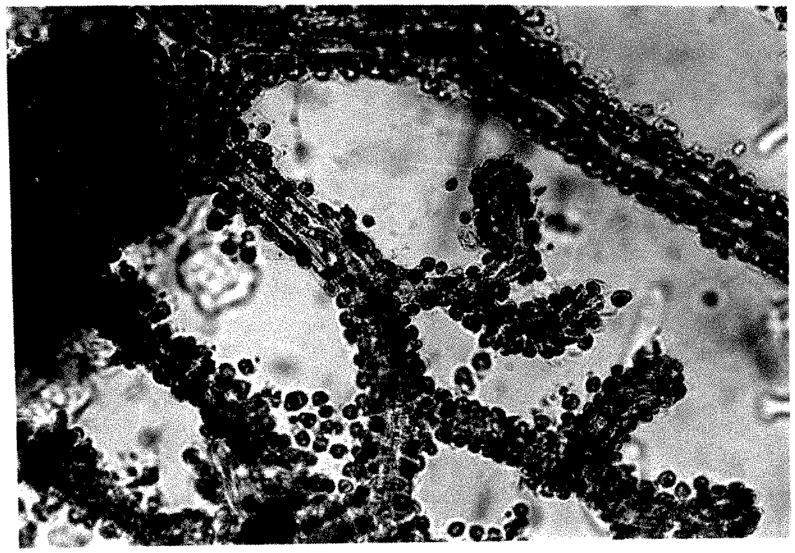
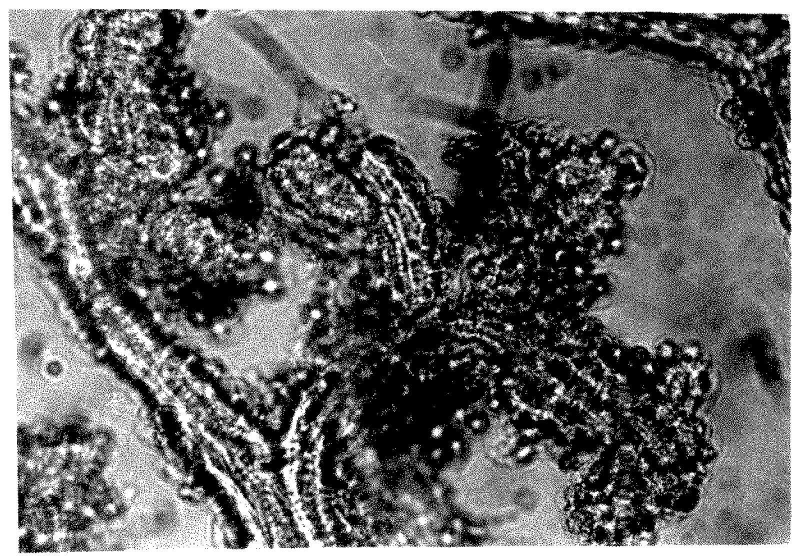


Plate - 9

A



B



C

other than amylose or amylopectins also give reducing sugars on hydrolysis and the amount of starch reported may also due to the presence of other, rather unusual, polysaccharides like xylans, arabinans etc. This may explain the faint, dark (brown, redish to blue) reactions to iodine in some of the plants.

A. marina, Aegiceras corniculatum, Acanthus ilicifolius reaction is slight on the mesophyll cells. Rhizophora mucronata and Avicennia officinalis show intense reaction in mesophyll cells, whereas starch distribution is recorded along the veins in Ceriops tagal (Mulik, 1987).

Plate 9 show the starch distribution pattern in three Avicennia species i.e. A. marina, A. officinalis and Avicennia dwarf species. The distribution pattern differs in Avicennia species. The mesophyll cells show intense blue colour reaction for A. dwarf species while it gives faint blue colour to A. marina. It is important to note the cells along the veins which differ in size and colour. Based on the pattern of starch distribution the species are classified as $C_3$ or $C_4$ types. The pattern seen in mangrove leaves seems to be of $C_3$ nature except species like C. tagal.

## C. Chemotaxonomy :

### a. Chlorophylls and Polyphenols

The green plants traps solar energy by leaves during photosynthesis to produce starch, the main source of metabolic energy. The photosynthetic process of the plant is dependent upon chlorophylls as antena molecules. Various aspects of plant growth and metabolism are dependent upon the energy captured by the chlorophyll pigments. These pigments mainly consist of chlorophylls a and b, carotenoids and xanthophylls, the level of chlorophylls differ greatly from species to species and within a species in different seasons of the year which seems to be related to environmental condition.

Table 11 depicts the comparative account of chlorophylls and polyphenols from the leaves of seedling and mature plants from four different sites. From the table it is clear that chlorophyll a and b are more in the leaves of mature plants than in the leaves of seedlings. The lowest value of chlorophyll a is 34.16 mg/100 g for mature plant which is recorded from the leaves from Bankhind site and the highest value of same is 49.44 mg/100 g which is recorded in the leaves from Ganapatipule site. Like this, the lowest value of chlorophyll b is 24.25 mg/100 g and is also found in leaves from Bankhind site, the highest value of the same is 41.77 mg/100 g which is recorded in leaves from Ganapatipule site. The ratio of chl. a/chl. b is highest at Bankhind site which is 1.409 g and that of lowest is 1.170 from Shirgaon site. No significant difference is observed in ratio. Thus from the table it is seen that the value of both chlorophyll a and chlorophyll b are maximum in the leaves from Ganapatipule site and are minimum in the leaves from Bankhind site.

Table 11 also depicts the values of chlorophylls from the leaves of seedlings from four different sites. The lowest value of chlorophyll a is 28.70 mg/100 g which is recorded in the leaves from Are site and the maximum value is 44.06 mg/100 g recorded in leaves from Bankhind site. Like this the lowest value of chlorophyll b is 24.42 mg/100 g in leaves from Are site and the highest is 34.41 mg/100 g in leaves from Bankhind site. Chl.a/chl.b ratio is maximum at Bankhind site which is 1.28 and is minimum at Are site which is 1.175.

Table - 11 : Chlorophyll and Polyphenol from the Leaves of Avicennia species from Different Localities

| Location | Chl. a | Chl. b | Chl. a+b | Chl a/b | Polyphenol |
|---|---|---|---|---|---|
| Ganapatipule | | | | | |
| Leaf | 49.44 | 41.77 | 91.68 | 1.19 | 1.75 |
| Seedling | 31.08 | 25.34 | 56.28 | 1.23 | 0.73 |
| Bankkhind | | | | | |
| Leaf | 34.16 | 24.35 | 58.35 | 1.41 | 3.43 |
| Seedling | 44.06 | 34.41 | 78.47 | 1.28 | 1.36 |
| Are | | | | | |
| Leaf | 37.36 | 27.64 | 65.01 | 1.35 | 3.92 |
| Seedling | 28.71 | 24.42 | 53.13 | 1.17 | 2.73 |
| Shirgaon | | | | | |
| Leaf | 43.26 | 36.97 | 80.23 | 1.17 | 3.15 |
| Seedling | 42.22 | 33.12 | 75.35 | 1.27 | 1.47 |

Chlorophyll : Values are expressed in mg/100 g of fresh tissue.

Polyphenol : Values are expressed in g/100 g of fresh tissue.

Table 11 also records polyphenol content from the leaves of mature plant and seedling. Here the maximum polyphenol content recorded in the leaves of mature plant is 3.92 g/100 g which is observed from Are estuary and the minimum 1.75 g/100 g recorded from Ganapatipule estuary.

In the leaves of seedling the highest value obtained is 2.73 g/100 g recorded in the leaves from Are site and the minimum one is 0.735 g/100g recorded at Ganapatipule estuary.

From the observations it is clear that maximum polyphenol value is recorded at Are estuary and minimum one is at Ganapatipule estuary. At Bankhind and Shirgaon estuary intermediate values are obtained.

Table 12 depicts seasonal variation in chlorophylls and polyphenols from leaves of Avicennia species (dwarf). According to Bhosale (1974) more chlorophyll synthesis takes place in monsoon in the mangroves except A. officinalis which shows more chlorophyll synthesis in summer. From table 12 it is clear that there is no much variation in chlorophyll values during summer and monsoon along four estuaries.

According to Bhosale (1974) increase of a salt in the soil decreases chlorophyll in the leaves. From table, it is seen that chlorophyll a is more than chlorophyll b. In summer the value of chlorophyll a is higher than in winter and monsoon but chlorophyll b is less in summer than winter and monsoon. There is no much difference in the values of total chlorophyll during summer and monsoon but the value of total chlorophyll is slightly higher in summer than monsoon. Chlorophyll a/b ratio is more in summer than monsoon and winter. At Ganapatipule estuary the value of total chlorophyll is more during winter and summer i.e. 76.5 mg/100 g and 75.54 mg/100 g but during monsoon the value of total chlorophyll at

Table - 12 : Seasonal Changes of Chlorophylls and Polyphenols from the Leaves of Avicennia species from Different Localities.

| Season | Site | Chl. a | Chl. b | Chl. a+b | Chl a/b | Polyphenol |
|---|---|---|---|---|---|---|
| Winter | Ganapatipule | 42.32 | 33.95 | 76.50 | 1.28 | 2.27 |
| | Are | 34.35 | 24.75 | 59.25 | 1.38 | 3.77 |
| | Shirgaon | 39.01 | 31.64 | 70.65 | 1.23 | 2.44 |
| Summer | Ganapatipule | 48.86 | 25.70 | 75.54 | 2.23 | 3.83 |
| | Are | 40.91 | 20.96 | 61.86 | 2.07 | 4.11 |
| | Sakhartar | 48.64 | 18.50 | 67.13 | 2.97 | 3.29 |
| | Shirgaon | 46.49 | 22.36 | 68.83 | 2.29 | 3.08 |
| Monsoon | Ganapatipule | 33.17 | 25.35 | 58.50 | 1.31 | 4.25 |
| | Are | 43.67 | 33.75 | 77.39 | 1.29 | 4.46 |
| | Sakhartar | 17.96 | 22.67 | 50.61 | 1.123 | 3.97 |
| | Shirgaon | 40.93 | 31.69 | 72.60 | 1.29 | 4.06 |

Chlorophyll : Values are expressed in mg/100 g in fresh tissue.

Polyphenol : Values are expressed in g/100 g in fresh tissue.

Ganapatipule estuary is less. The value of total chlorophyll in monsoon ranges from 50.61 mg/100 g to 77.39 mg/100 g at Sakhartar and Are estuary. The highest value of chlorophyll a is 48.36 mg/100 g recorded in summer at Ganapatipule estuary and the lowest value is 27.96 mg/100 g obtained in monsoon at Sakhartar site. The maximum value of chlorophyll b is 33.95 mg/100 g obtained during winter at Ganapatipule site and that of minimum value is 18.50 mg/100 g recorded during summer at Sakhartar. The highest value of chlorophyll a/b ratio is 2.97 recorded during summer at Sakhartar estuary but the lowest value is 1.23 observed during monsoon at Sakhartar estuary.

The polyphenols are secondary metabolic products in higher plants. The mangroves are rich in polyphenols were restricted to the samples of bark as it formed the source of commercial tannins. Tannins are commercially important plant products and are also known to protect plant cell protoplasts against desication, decay or injury by animals (Lakshmanan, 1985). Rajangam (1984) has determined tannin context of mangrove leaves from Pichavaram forest. According to Sathe (1991) the polyphenols are also recorded from fruits and leaves which are good store houses of polyphenols. Humpries (1967) has reported polyphenol contents upto 35% and stated that mangroves, inspite of more salt concentration contain large amount of water soluble tannins. Jamale and Joshi (1978) showed that the amount of polyphenols in the leaves of mangroves is dependent upon the age of the leaves and polyphenol degrading enzymes. Effect of light, salt treatment on polyphenol biosynthesis has been recorded by many investigators. It has been also found that light intensity enhances polyphenol contents.

Jamale (1975) recorded enhancement of polyphenol synthesis at lower concentration of NaCl in Avicennia and has studied the activity of polyphenol oxidase in S. alba. It can be concluded that polyphenol contents and the response to salinity is dependent upon the species. In less salt tolerant species more polyphenols may be synthesized in response to increased salinity.

Table 12 also depicts the seasonal variations in total polyphenols in Avicennia dwarf species from four different estuaries. According to Bhosale (1974) monsoon is favourable for polyphenol synthesis in mangroves and in winter polyphenol values decrease considerably. However, there is gradual increase in the percentage of polyphenols during summer and highest values are obtained in monsoon.

From the table it is clear that the highest value of polyphenol is 4.46 g/100 g which is recorded during monsoon at Are site and the lowest value is 2.27 g/100 g obtained during winter at Shirgaon estuary. The polyphenol value is highest in monsoon and lowest in winter which gradually increases during summer.

Table 13 represents chlorophyll content of different species of Avicennia. It is observed that A. officinalis show highest chlorophyll contents. The values of total chlorophyll differ and highest value is 76.48 mg/100 g and the lowest is 49.71 g/100 g for four different species. The ratio of chlorophyll a/b does not vary significantly in first three species. But Avicennia dwarf species show lower value of chlorophyll a/b ratio.

Kotmire and Bhosale (1980) reported that A. marina var. acutissima shows highest chlorophyll content, but higher values are found for A. marina var. resinifera.

Table - 13 : Comparative Account of Chlorophyll and Polyphenols from Leaves of Different Avicennia species.

| Sr. No. | Name of the species | Chl. a | Chl. b | Chl. a+b | Chl.a/ Chl.b | Polyphenol |
|---|---|---|---|---|---|---|
| * 1 | Avicennia officinalis | 58.66 | 17.82 | 76.48 | 3.29 | 1.42 |
| * 2 | A. Marina var. acutissima | 37.76 | 12.04 | 49.71 | 3.13 | 2.50 |
| * 3 | A. marina var. resinifera | 53.85 | 17.40 | 71.25 | 3.09 | 1.70 |
| 4 | Avicennia species (dwarf) | 37.37 | 27.64 | 65.00 | 1.35 | 1.33 |

Chlorophyll - Values are expressed in mg/100 g in fresh tissue

Polyphenol - Values are expressed in g/100 g in fresh tissue.

* Values obtained from Sathe (1991)

Here the species selected grow in a close vicinity. A. marina var. acutissima shows greater resembalance with A. marina var. resinifera with respect to morphology but these two plants show a major difference with respect to chlorophyll amount.

Table 13 represents the polyphenolic contents of the leaves from four Avicennia species. Kotmire and Bhosale (1980) reported that A. officinalis show more polyphenols than A. marina var. acutissima leaves. From the table it is clear that the highest value obtained is for A. marina var. acutissima is 2.50 g/100 g and the lowest value obtained for Avicennia species is 1.33 g/100 g. Thus chlorophyll and polyphenol levels varies as per the species.

b. Carbohydrates :

Carbohydrates are complex in nature and consist of carbon, hydrogen and oxygen. Salinity in the substratum increases the percentage of starch in plants (Hayward and Long, 1941; Gauch and Eaton, 1992). Joshi et al, (1972) reported higher starch content in the leaves of mangroves. In general mangrove leaves contain higher levels of carbohydrates as compared to other glycophytes (Chirputkar, 1969; Bhosale, 1974; Bhosale et al, 1983).

In the present investigation carbohydrates are estimated from the different parts of plant i.e. leaf, stem and pneumatophore.

Table 14 depicts the seasonal variation in carbohydrate level from three different sites viz. Ganapatipule, Are and Shirgaon of Avicennia dwarf species. From table it is clear that starch percentage is higher in leaves, stem and pneumatophore than reducing sugars and total sugars. Carbohydrate content vary with sites. The values for sugars are low in

Table - 14 : Carbohydrates from Different Parts of *Avicennia* sp. for Different Seasons.

| Site | Season | Plant parts | Reducing Sugars | Total sugars | Starch |
|---|---|---|---|---|---|
| Ganapatipule | Winter | Leaf | 0.20 | 0.23 | 6.5 |
| | | Stem | 0.075 | 0.17 | 6.95 |
| | | Pneumatophore | 0.087 | 0.22 | 6.97 |
| | Summer | Leaf | 0.16 | 0.25 | 9.56 |
| | | Stem | 0.19 | 0.32 | 11.18 |
| | | Pneumatophore | 0.07 | 0.12 | 10.21 |
| | Monsoon | Leaf | 0.14 | 0.22 | 7.56 |
| | | Stem | 0.08 | 0.16 | 10.26 |
| | | Pneumatophore | 0.05 | 0.18 | 8.64 |
| Are | Winter | Leaf | 0.05 | 0.096 | 13.0 |
| | | Stem | 0.18 | 0.096 | 13.6 |
| | | Pneumatophore | 0.19 | 0.29 | 12.9 |
| | Summer | Leaf | 0.064 | 0.13 | 13.4 |
| | | Stem | 0.18 | 0.29 | 14.7 |
| | | Pneumatophore | 0.26 | 0.39 | 13.4 |
| | Monsoon | Leaf | 0.084 | 0.17 | 13.0 |
| | | Stem | 0.024 | 0.078 | 13.8 |
| | | Pneumatophore | 0.12 | 0.12 | 12.1 |
| Shirgaon | Winter | Leaf | 0.17 | 0.22 | 15.1 |
| | | Stem | 0.16 | 0.28 | 12.1 |
| | | Pneumatophore | 0.34 | 0.64 | 13.8 |
| | Summer | Leaf | 0.23 | 0.24 | 10.85 |
| | | Stem | 0.05 | 0.14 | 16.05 |
| | | Pneumatophore | 0.13 | 0.50 | 16.05 |
| | Monsoon | Leaf | 0.096 | 0.14 | 14.7 |
| | | Stem | 0.088 | 0.096 | 14.7 |
| | | Pneumatophore | 0.23 | 0.31 | 13.9 |

Values are expressed in g/100 g of dry tissue.

monsoon. According to Mishra (1967) salinity decreases the carbohydrate content in C. inerme. Baslavaskaya (1936) reported that sugar and starch content are directly proportional to Cl concentration. He found increase in starch/sugar ratio with accumulation of Cl in potato leaves.

Shinde (1981) also reported that saline plants contain high levels of starch. Bharucha and Shirke (1947) have estimated carbohydrates and proteins in the seedlings of Avicennia officinalis. It has been reported by Shetty (1971) an increase in starch content due to NaCl salinity in Acrostichum dureum and Portulaca oleracea. Storage of carbohydrates has been considered as one of the means of salinity tolerance (Ackerson and Younger 1975).

Carbohydrates are complex in nature and play important role in plant metabolism. Carbohydrates are the energy source and they also have osmoregulatory functions.

From table 14 it is clear that the highest value of reducing sugar in leaves is 0.23 g/100 g recorded at Shirgaon during summer while the lowest is 0.052 g/100 g recorded at Are estuary during winter. In stem the highest value is 0.19 g/100 g recorded at Ganapatipule during summer and the lowest value is 0.024 g/100 g recorded at Are estuary during monsoon. In pneumatophore the highest value is 0.34 g/100 g recorded at Shirgaon estuary during winter and lowest value is 0.07 g/100 g at Ganapatipule during summer.

The highest value of total sugar in leaves is 0.25 g/100 g recorded at Ganapatipule estuary during summer and the lowest one is 0.096. In stem the highest value is 0.32 g/100 g and the lowest is 0.078 g/100 g at

Table - 15 : Comparison of Carbohydrates from Leaves of Different Species of Avicennia

| Name of the species | Reducing sugars | Total sugars | Starch |
|---|---|---|---|
| * A. officinalis | 1.92 | 3.70 | 10.35 |
| * A. marina var. acutissima | 0.36 | 1.60 | 16.28 |
| * A. marina var. resinifera | 0.54 | 1.60 | 14.84 |
| Avicennia species (dwarf) | 0.25 | 0.28 | 10.4 |

Values are expressed in g/100 g of dry tissue

* Values obtained from Sathe (1991).

Are estuary during monsoon. In pneumatophore the highest value recorded is 0.64 g/100 g at Shirgaon estuary during winter while lowest one is 0.12 g/100 g at Ganapatipule.

The highest values for starch in leaves 15.1 g/100 g recorded at Shirgaon during winter and lowest one is 6.5 g/100 g during winter. In stem and pneumatophore the highest value is 16.05 g/100 g recorded at Shirgaon during summer while lowest one is 6.95 g/100 g and 6.97 g/100 g at Ganapatipule during winter. According to Bhosale (1974) maximum percentage of starch is observed in monsoon, reducing and total sugars are also more in monsoon.

Table 15 represents the carbohydrate values from four Avicennia species. The values of reducing sugar ranges from 0.25 g/100 g to 1.92 g/100 g in Avicennia dwarf species and A. officinalis respectively. The values for total sugars ranges from 0.28 g/100 g to 3.701 g/100 g in Avicennia dwarf species and A. officinalis respectively while the starch values ranges from 10.35 g/100 g to 16.28 g/100 g for A. officinalis and A. marina var. acutissima respectively.

Kotmire (1983) reported higher carbohydrates in A. marina as compared to A. officinalis which he attributed to higher salt content of leaves.

Table 16 depicts the carbohydrate values from fruit samples of six different stages. Bharucha and Shirke (1947) analysed the seedlings of A. officinalis at different age stages. They found that seeds contain highest percentage of starch which gradually decreases with the age of the seedling. According to Mulik (1987) carbohydrates are higher in seeds than leaves.

Table - 16 : Carbohydrates from Fruits of A. dwarf species

| | Stage | Reducing sugars | Total sugars | Starch |
|---|---|---|---|---|
| Fruit sample | 1 | 1.04 | 1.68 | 10.04 |
| | 2 | 1.16 | 1.38 | 10.42 |
| | 3 | 0.82 | 1.82 | 12.58 |
| | 4 | 1.12 | 1.96 | 19.6 |
| | 5 | 1.04 | 1.42 | 15.82 |
| | 6 | 0.31 | 1.42 | 11.88 |

Values are expressed in g/100 g of dry tissue.

Table - 17 : Different Levels of Proteins from Different Parts of *Avicennia* Species.

| Season | | Ganapatipule | Are | Shirgaon |
|---|---|---|---|---|
| Winter | Leaf | 1.6 | 1.86 | 2.03 |
| | Stem | 0.98 | 0.80 | 0.60 |
| | Pneumatophore | 1.49 | 1.09 | 1.42 |
| Summer | Leaf | 2.28 | 2.30 | 2.07 |
| | Stem | 1.20 | 1.10 | 0.93 |
| | Pneumatophore | 1.39 | 1.55 | 1.14 |
| Monsoon | Leaf | 1.87 | 2.21 | 2.52 |
| | Stem | 0.91 | 1.08 | 1.18 |
| | Pneumatophore | 0.98 | 1.13 | 2.23 |

Values are expressed in g/100 g of dry tissue.

From table it is clear that the values for reducing sugars ranges from 0.31 g/100 g to 1.16 g/100 gm recorded at 6th and 2nd fruit stage respectively. The values of total sugars ranges from 1.38 g/100 g to 1.96 g /100 g in 2nd and 4th fruit stages respectively and the starch values ranges from 10.04 g/100 g to 19.6 g/100 g at 1st and 4th stages respectively. The values of carbohydrates are high at 4th fruit stage.

c. <u>Proteins</u>

The proteins are complex organic compounds of high molecular weight. Protein is one of the major constituent of cells which makes up different tissues and organs in the body.

The approximate composition of proteins is nitrogen (16%), carbon (52.5%), hydrogen (7%) and oxygen (21.%) with remaining traces of sulphure phosphorus and iron.

Table 17 depicts the levels of proteins in various seasons from <u>Avicennia</u> species. From table it is observed that the protein content of leaf is higher than stem and pneumatophore. If protein levels are compared from leaf, stem and pneumatophore; the protein content is less in stem than leaf and pneumatophore. In leaf the protein value ranges from 1.6 g/100 g to 2.52 g/100 g during winter and monsoon. Likewise in stem protein value ranges from 0.69/100 g to 1.2 g/100 g during winter and summer, and for pneumatophore the range is 0.98 g/100 g to 2.23 g/100 g during monsoon.

It is interesting to find out further the role of proteins from pneumatophores, as the levels are higher.

Table - 18 : Leaf Protein Content of Different *Avicennia* species.

| Sr.No. | Name of the species | Proteins |
|---|---|---|
| 1 | * *A. officinalis* | 1.42 |
| 2 | * *A. marina* var. *acutissima* | 1.47 |
| 3 | * *A. marina* var. *resinifera* | 1.40 |
| 4 | *Avicennia* species (dwarf) | 1.92 |

Values are expressed in g/100 g of dry tissue.

* Values obtained from Sathe (1991).

Table - 19 : Proteins from Fruits of Avicennia dwarf species at different Stages

| Sr.No. | Stage | Protein |
|---|---|---|
| 1 | 1 | 2.86 |
| 2 | 2 | 2.64 |
| 3 | 3 | 2.38 |
| 4 | 4 | 2.95 |
| 5 | 5 | 1.75 |
| 6 | 6 | 0.94 |

Values are expressed in g/100 g of dry tissue.

Table 18 represents protein content in leaves of Avicennia species. According to athe (1991) the protein values differ in different plants.

From table it is seen that the protein values ranges from 1.40 g/ 100 g to 1.92 g/100 g for A. marina var. resinifera and Avicennia dwarf species respectively. There is no significant difference in protein values of three Avicennia species i.e. A. officinalis, A. marina var. acutissima and A. marina var. resinifera. Though the species differ metabolically in other process protein content remain same that means all are equally important as a fodder.

Table 19 represents proteins from fruits of Avicennia dwarf species at six different stages. The protein value ranges from 0.94 g/100 g to 2.95 g/100 g at 6th and 4th stages respectively. Protein values start increasing from 1st to 4th stage, it is highest at 4th stage and later on the level decreases upto 6th stage. Proteins in the fruits are higher than other parts of plants.

d. Elements

Mangrove grow in an environment which is rich in sodium and chloride ions. The elements like sodium, potassium, calculum and chlorides play significant role in mangrove metabolism. Inspite of these soil and water conditions, mangroves have successfully adapted themselves to the saline environment through their morphological, ecological and physiological modifications and established themselves as a distinct type of vegetation by itself.

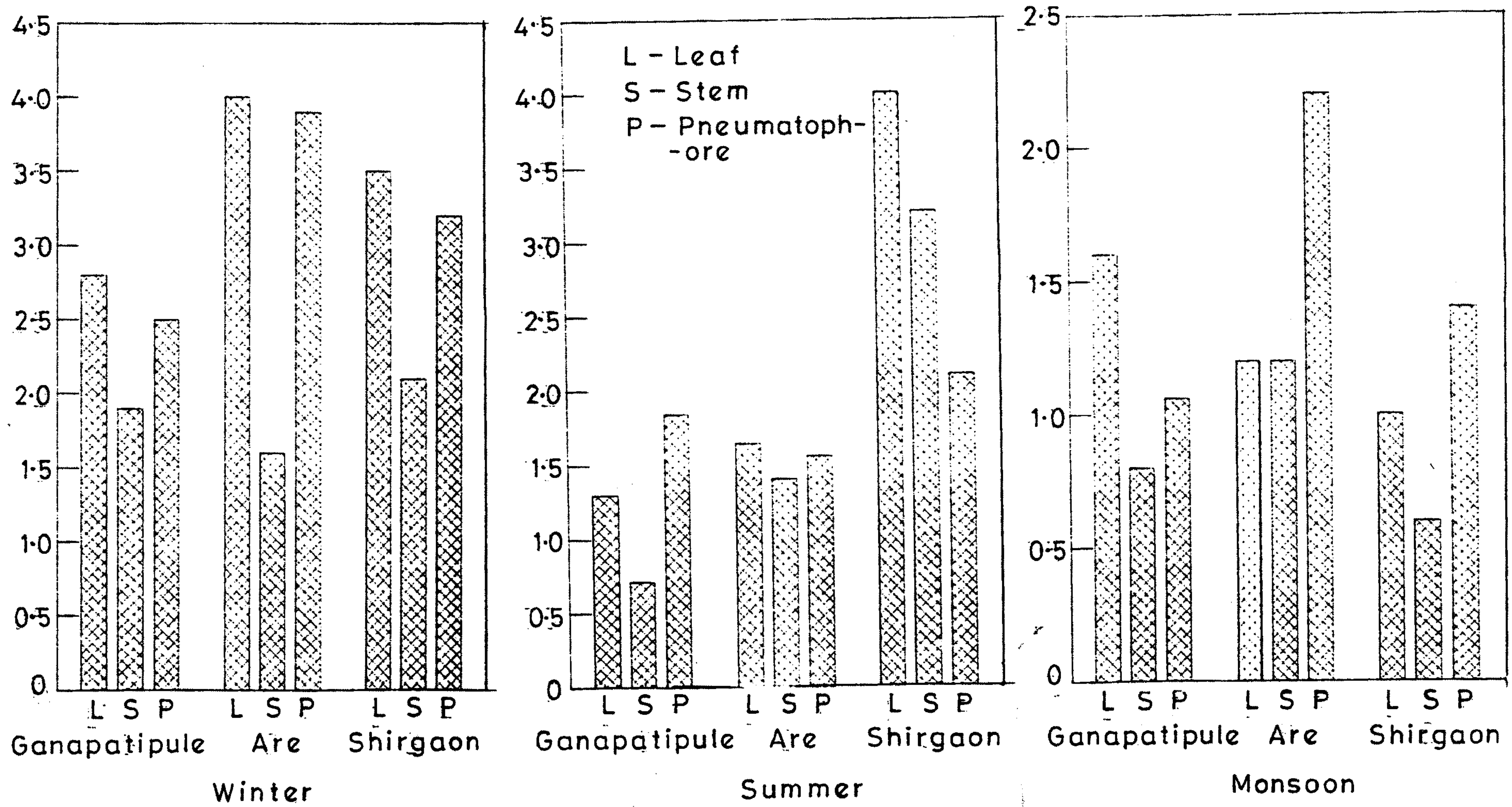
Several investigators (Miller, 1938; Navalkar and Bharucha, 1942; Pradhan, 1957; Warick, 1960; Stout, 1961 and Oser, 1965) have tried to determine the inorganic constituents of different parts of the mangrove plants. Bhosale (1974) determined the seasonal variation in mineral element of many mangrove plants.

The Avicennia species are salt excreting type of mangroves and keep the balance in endogenous salt levels (Joshi et al, 1975; Bhosale et al 1983).

The accumulation of ions in the leaves of various mangroves in the field has been studied by several workers (Atkinson et al, 1967; Joshi et al, 1975; Popp, 1983a) and the general conclusion is that for the leaves of most mangroves the $Na^+$ and $Cl^-$ concentrations expressed on a plant water basis are close to sea water. The reported values vary between 400 and 600 mol $m^{-3}$ (plant water). However, Popp (1983a) noted that leaf age did not appear to effect $Na^+$ and $Cl^-$ storage much but concentrations of $SO_4^{2-}$ and $Mg^{2+}$ increased in old leaves of salt secreting species as well as in the members of Rhizophoraceae. This suggests removal mechanisms in the leaves for $Na^+$ and $Cl^-$ in both salt secreting and non-salt secreting species of mangroves. Another interesting point is that the reported values for $Na^+/K^+$ ratio are in the range from 2-14 for the leaves of a wide variety of mangroves depending on species and age. The results clearly indicate the machanism of potassium uptake by mangroves (Joshi et al, 1975; Popp, 1983a).

In the present investigation seasonal variation in minerals like sodium, potassium, calcium and chlorides are estimated.

Fig. 21 – Distribution of Na in *Avicennia* dwarf species at different sites.



**<u>Sodium</u>**

Epstein (1972) noted that halophytes not only tolerate high concentration of Na but actually require it for their full requirement. Figure 21 depicts seasonal variation in sodium from leaf, stem and pneumatophore from different estuaries.

From figure it is clear that values of sodium are low in mansoon. For sodium the maximum value obtained is 4.0 g/100 g in leaf which is recorded at Shirgaon site during summer while the minimum value is 0.6 g/100 g recorded in stem at Shirgaon site during monsoon. The values of sodium are higher at Shirgaon estuary. When salinity of soil decreases, all the mangroves reduce sodium and chloride accumulation and increase Ca and K uptake. Sathe (1991) recorded mineral elements from four <u>Avicennia</u> species.

Potassium is a vital mineral element. Bukovac and Wittwer (1957) have reported that K can be readily absorbed and is a highly mobile element. Joshi and Mishra (1970) have reported that K is withdrawn from old and mature leaves and supplied to young and growing leaves. Figure 22 depicts seaonal variation in potassium from different estuaries. From figure it is clear that the values for K are more during monsoon. The maximum value obtained is 3.92 g/100 g in leaf which is recorded at Shirgaon site during summer while the minimum one is 0.83 g/100 g in leaf recorded at Ganapatipule during summer. Joshi and Bhosale (1982) reported higher potassium values like 1.63 g/100 g of dry tissue for <u>A. officinalis</u> and 1.65 g/100 g of dry tissue for <u>A. alba</u>. The values of sodium and potassium are similar but the values of calcium are very low. The chloride values are higher than sodium, potassium and calcium.

Fig. 22 - Levels of K from *Avicennia* dwarf species at different sites.

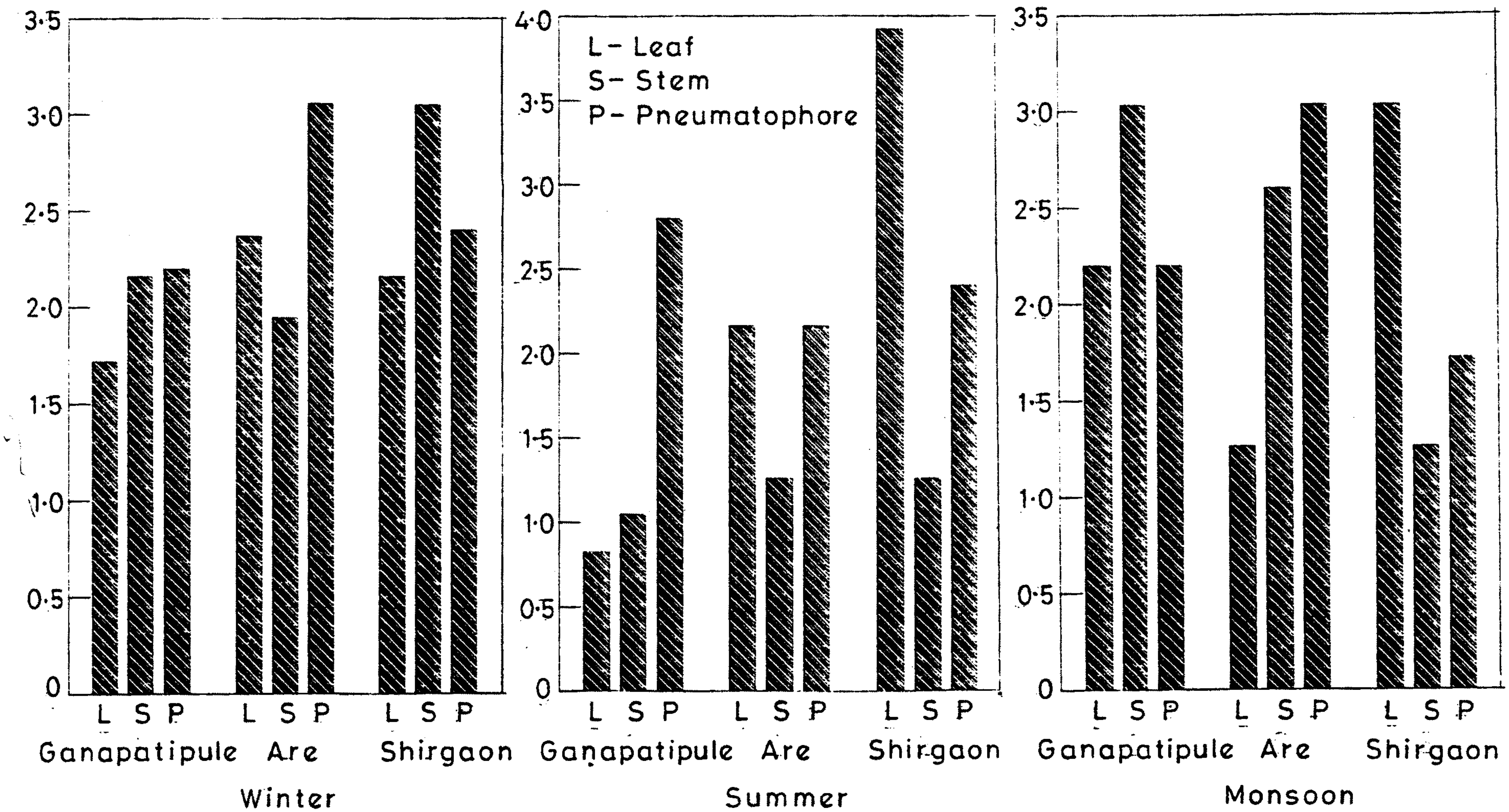
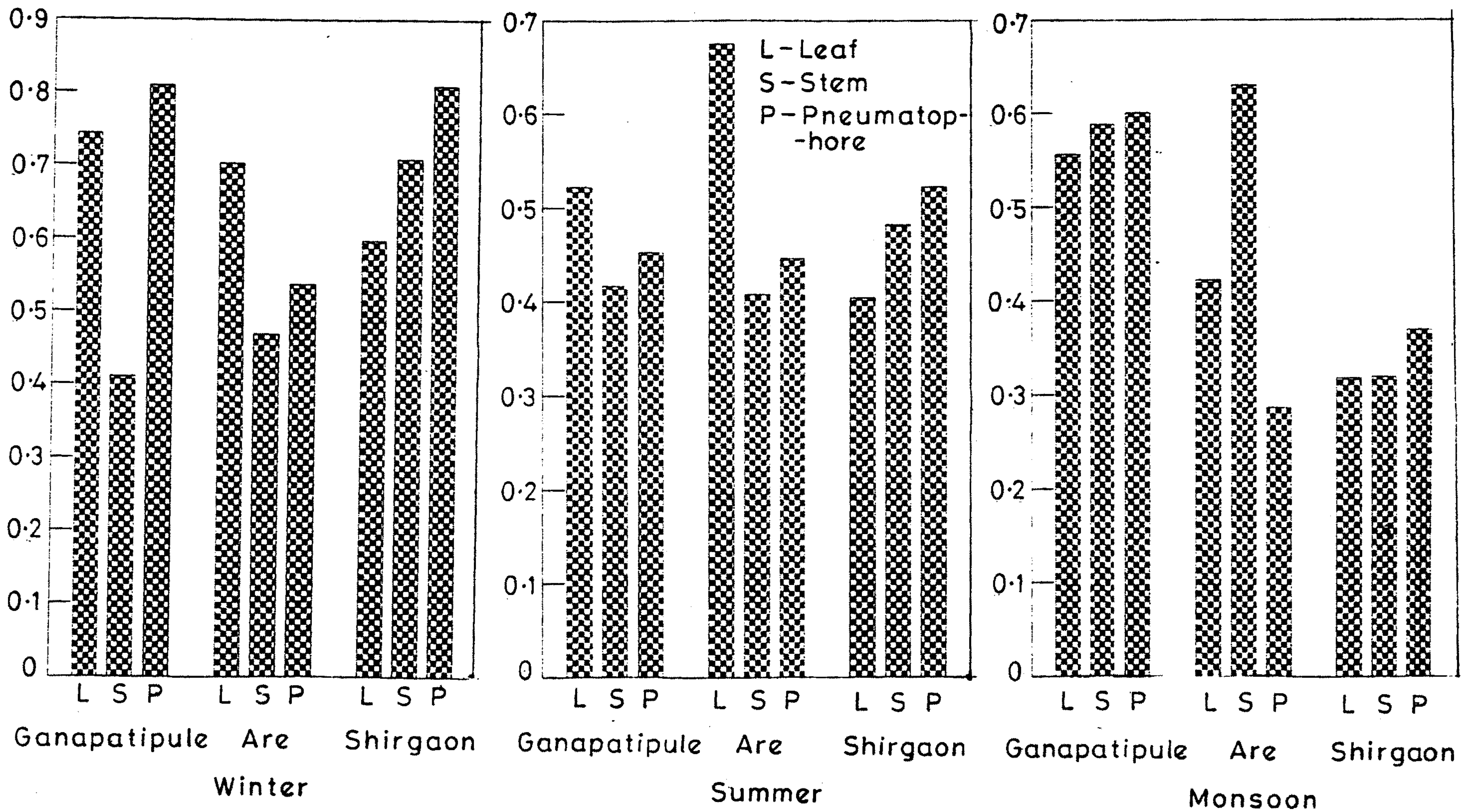


Fig. 23 – Distribution of Ca in *Avicennia* dwarf species at different sites.



Calcium is another element which is associated with the problem of adaptation of mangroves. Eventhough the mangrove soil is rich in calcium, its absorption is difficult due to predominance of Na in the rooting environment. Excess sodium interefers with calcium uptake. Under less salinity, the mangroves absorb more calcium. Figure 23 depicts the seasonal variation in clacium values from different estuaries. It is clear that, there is no much variation in calcium values during three seasons. The maximum calcium value recorded is 0.809 g/100 g obtained in pnumatophore at Shirgaon estuary during winter whereas the minimum one is 0.236 g/100 g in pneumatophore at Sakhartar estuary during summer. Joshi et al (1975) reported 0.48 calcium in A. officinalis from west coast of India. Sathe et al (1986) reported that mangrove species occur in a definite set of environmental conditions where internal salt contents differ, depending upon locality, in case of A. officinalis.

Beadle et al (1957) have stated that among the anions chloride is always dominant in salt rich plant. Extensive work on chlorides in halophytes has been carried out by a number of investigators (Adriani, 1934; Chapman, 1936, 1938; Cooper and Pasha, 1935; Bharucha and Navalkar, 1942; Warick, 1960; Chirputkar, 1969; Joshi and Bhosale, 1982). Figure 24 depicts the seasonal variation in chloride content from different plant parts from different estuaries.

From observations it is clear that the chloride content is less during monsoon and the higher chloride content is observed in summer. The maximum chloride value obtained is 4.95 g/100 g in stem at Shirgaon estuary during summer while the minimum is 2.66 g/100 g in pneumatophore at Ganapatipule estuaryduring monsoon. The values of chlorides are

Fig. 24 – Chloride contents from *Avicennia* dwarf species at different sites.

L – Leaf, S – Stem, P – Pneumatophore

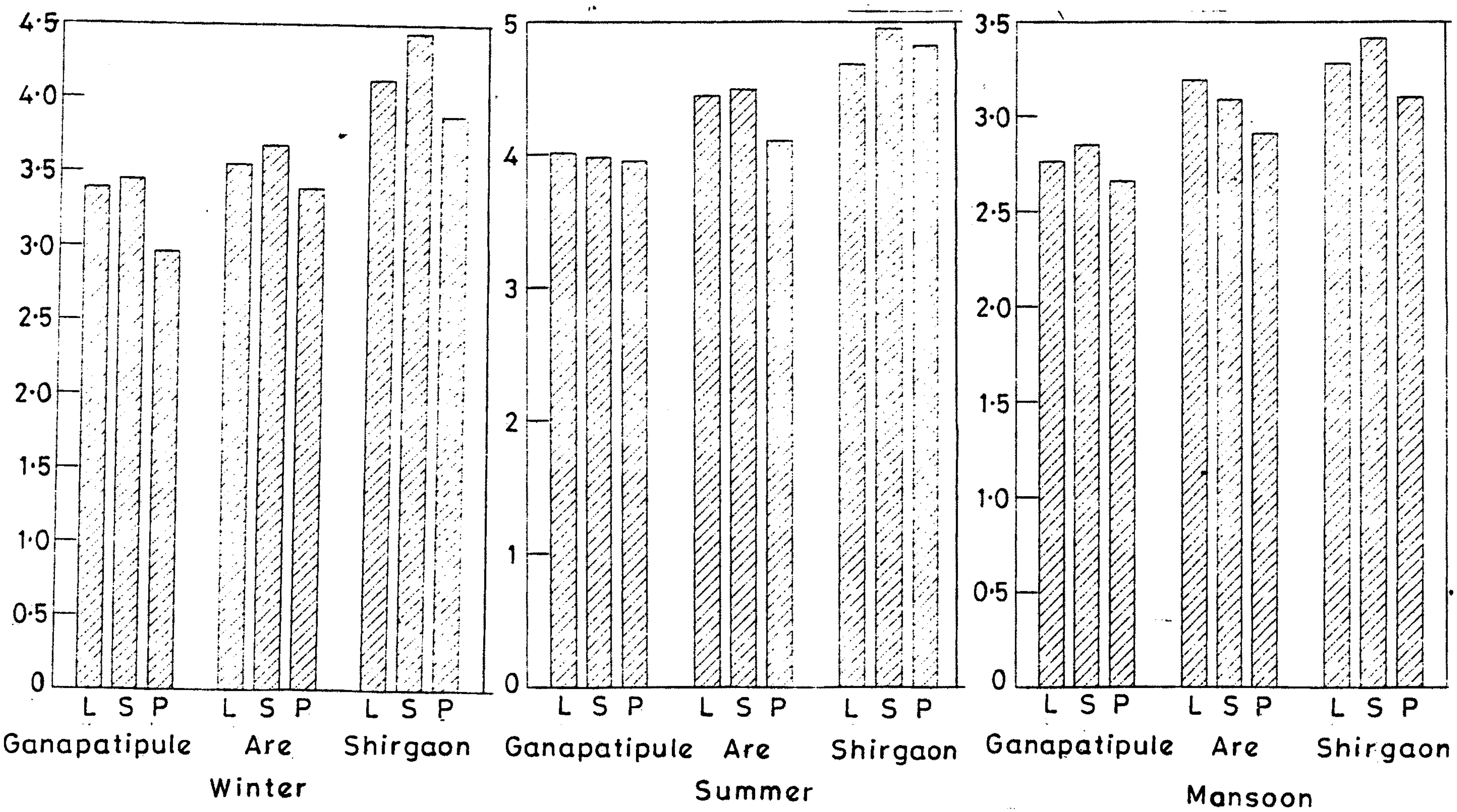
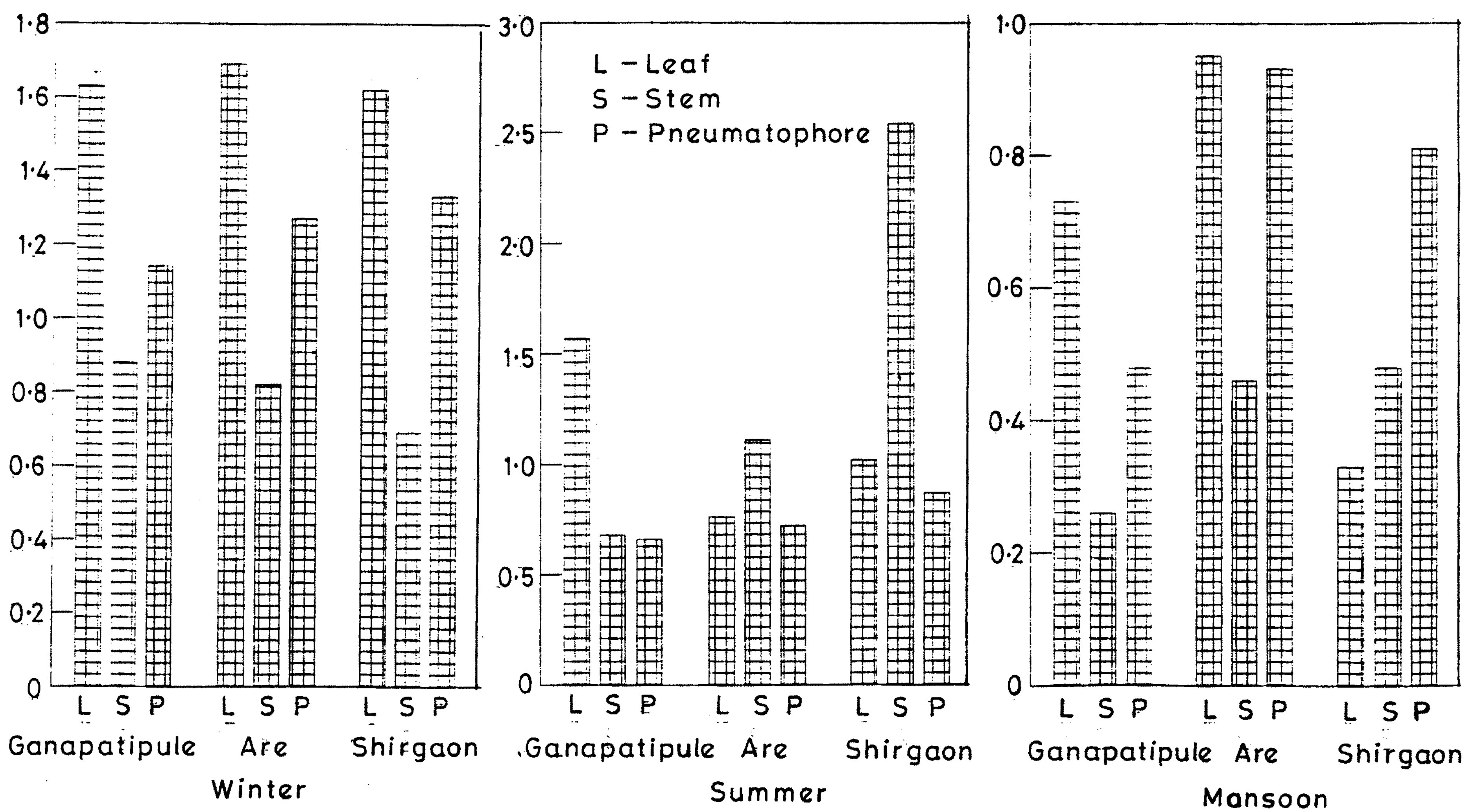


Fig. 25 – Seasonal variation in Na/K ratio in *Avicennia* dwarf species.



higher at Shirgaon estuary than Ganapatipule and Are. It is seen that the stem contain high chloride levels than leaf and pneumatophore. High levels of chloride in the leaf and stem tissue of S. portulacastrum has been recorded by Shinde (1981). With the help of $^{36}Cl$ it has been shown that chlorides are taken up by the stem and are translocated to the leaves and to the seedlings.

It is seen from the analysis of mineral elements from different parts that sodium percentage is higher in leaves than pneumatophores and stem. Pneumatophores contain more sodium than stem.

Figure 25 shows Na/K ratio during different seasons at different sites. In leaf the Na/K ratio is 0.33 and 1.69 during monsoon and winter respectively. In stem the range is 0.26 - 2.54 during monsoon and summer respectively. In pneumatophores the range is 0.48 - 1.43 during monsoon.

e. Energy Content

The mangrove plants are extensively used as a fuel along the coast. People directly cut (fell) the plants for fuel. To test potential of the wood as a firewood source, energy content (calorific value) is found out.

The energy content of Avicennia species is determined by testing its calorific value. As the mangrove shows variation in their physiology from place to place, the wood properties may also vary.

Brown and Fischer (1918) reported that in Phillippines the wood from mangroves was sold in the market for fuel purpose. They stated that Rhizophora species, A. officinalis and Bruguiera parviflora are in great demand for their wood as a fuel.

Table - 20 : Energy Content of Avicennia dwarf species and its Comparison with other Avicennia species.

| Energy content / Species | Leaf | Wood |
|---|---|---|
| * Avicennia officinalis | 3668.69 | 5922.12 |
| * A. marina var. acutissima | 3396.64 | 4901.05 |
| * A. marina var. resinifera | 3347.15 | 5309.47 |
| Avicennia sp. (dwarf) | 2242.50 | 3380.02 |

Values are expressed as cal $g^{-1}$ of dry wt.

* Values obtained from Sathe (1991).

Table 20 represents the calorific values of different species of Avicennia. Calorific values of the different species differ greatly. Calorific value is calculated from the leaf and stem of four Avicennia species. The calorific values are 2242.50 cal/g and 3668.69 cal/g for the leaves of A. dwarf species and A. officinalis respectively. For the stem the values are 3380.02 cal/g and 5922.12 cal/g for Avicennia dwarf species and A. officinalis respectively. The calorific value for pneumatophore of Avicennia species is 3943.33 cal/g which is higher than leaf and stem.

Rodger (1984) reported that in Burma people prefer wood of Hiretiera spp. which is an excellent source of fuel in the delta. Sathe (1991) reported the calorific values of different species of mangroves. According to him Sonneratia alba shows lowest value, the highesdt being in A. officinalis.

Gaykar and Bhosale (1989) have reported calorific values of some mangrove leaves from Ratnagiri district. Untawale et al (1978) reported seasonal variation in major metabolites of mangrove foliage. Seasonal variations are studied from the leaves of mangroves from Goa coast.

Calorific value of leavesd indicate the energy source available for detritus based food chain; whereas that of stem indicate energy content available for heating.

There is a lot of confusion regarding species of Avicennia in the world in general and in Maharashtra in particular. The species A. alba has been reported in the literature upto 1976 (Jamale, 1976). Later on it was found that the species referred to as A. alba was A. marina var. accutissima (Kotmira and Bhosale, 1979, 1980). However, it remains

**PLATE - 10**

Seedling of *Avicennia* dwarf species
under laboratory condition

Plate - 10

unclear whether there was A. alba present in the past in Maharashtra. A. alba is not reported from Maharashtra coast during 15 years. There are confusing reports under this name. Sathe (1991) used this name for the dwarf ecotype which has been considered in the present group of species. The heteromorphic leaves of the dwarf individuals show resembalance weith A. marina in most of the cases. Apart from heteromorphic dwarf, there is another dwarf found at Ganapatipule only which is still different.

The present investigation concludes that the heteromorphic dwarfs are ecotypes whereas the dwarf at Ganapatipule is a genotype. Therefore, it is identified as a distinct species/variety as compared to A. marina (both varieties) and A. officinalis. The results of cytological work are awaited which will help identifying it either as variety, species or hybrid. This dwarf has been recognised as a genotype on the basis of transplantation experiments.