Physiology and Ecology of Mangroves

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Mangrove forest grows in the inter tidal zones along the coastline in most tropical and subtropical countries. Mangroves contribute in a wide variety of direct and indirect ways to the society and economy of these countries. These contributions can be divided into forest products, fishery products and nursery function, physical functioning, biodiversity and genetic resources.

With regard to fishery products and nursery function, the local people living along the coastline or inside the mangrove forest can harvest fishery products directly from mangrove areas. However, in the present situation, the destruction of mangrove forests in many parts of the world has resulted, in a net decrease of total fish catch.

Regarding physical functioning values, the mangrove forests play a very important role in coastal protection, land stabilisation, sedimentation and as an accretion nutrient sink and organic matter source. Mangroves, and the sediments associated with them, can assimilate substantial quantities of nutrients such as nitrogen and phosphorus. Mangroves can serve as nutrient sink or source. The mangrove forest is physiologically unique among trees with respect to its tolerance for and capacity to grow in brackish or saline water conditions, and this may prove to have particular genetic value as a salt-resistant or halophilic plants. Mangrove plants are very important for CO_2 fixation through photosynthesis.

1. INTRODUCTION

Environmental destruction is occurring globally, and one example of this destruction is deforestation. Mangroves are distributed over an area of 18 million ha in the coastal and estuarine areas of the tropical and sub-tropical regions of the world [1]. The largest distribution area is Southeast Asia, which accounts for a share of 42%. Although mangroves constitute only 1% of the world's forests, the biological productivity in mangrove areas is twenty one times higher as compared that in that in the oceanic areas. Accordingly, a region with abundant mangrove forests is a treasury of a variety of life- forms including fish, and this region also plays a very important role in protecting the natural environment. Moreover, since mangroves have the ability to absorb carbon dioxide through photosynthesis, the conservation of mangroves has become the focus of attention in recent years.

Mangrove is generic term for plant community distribution affected by seawater on the coast or at the mouth of a river in tropical and subtropical regions. The most important characteristic of many mangrove plants is that they can grow very well within wide ranges of salinity, which can reach a maximum of approximately 3% NaCl or more.

2. DISTRIBUTION OF MANGROVE FORESTS AND SPECIES OF MANGROVE PLANTS

Mangrove forests are one of the most important coastal resources, mainly distributed in the tropical region. In Southeast Asia mangroves account for the largest proportion of the worlds total mangrove area. The total area of the world mangrove forest is

Table 1. Estimates of mangrove areas and global totals

Region	Mangrove area (km^2) ISME (1997)* estimate		Mangrove area (km2) IUCN (1983) estimate	
South and Southeast Asia	75,173	(41.5%)	51,766	(30.7%)
Australia	18,789	(10.4%)	16,980	(10.0%)
The Americas	49,096	(27.1%)	67,446	(40.0%)
West Africa	27,995	(15.51/6)	27,110	(16.0%)
East Africa and the Middle East	10,024	(5.5%)	5,508	(3.3%)
Total area	181,077	(100%)	168,810	(100%)

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approximately 18 million ha.[1]. Estimates of global mangrove areas are shown in Table 1.

Approximately 120 species are listed are mangrove plants. Very few of which grow in tropical rain forest, due to their living environment. A mangrove forest extends from coast to inland. Hence, plants in the coastal zone are not easily distinguishable from those in the inland zone. Constituent species of mangroves, are largely divided into three groups, namely strict mangrove, sub mangrove and minor mangrove species. Strict mangrove species are the mainstay of mangrove forests, with their own characteristic shape and physiological features for growth under high salinity condition. They constitute the front line of the mangrove forest directly affected by seawater or tidal rivers. Strict mangrove species are eight families and 50 species [2,3].

3. FEATURES OF MANGROVE

The large environmental difference between mangrove habitat and that of land plants is that unlike the latter former is distributed in areas subject to tidal or regular flows of sea water. Distribution of many mangrove species of plants in sea or brackish water shows a unique zonation. The zonation indicates that mangrove species can grow only in particular environmental condition [4].

Macnae noted three conditions of zonation: (1) frequency of immersion of the mangrove area due to tidal ebb and flow, (2) mangrove's resistance to salt content of sea water (salinity), and (3) erosion of internal and peripheral waterways of the mangrove distribution area and the mangrove coast. Chapman also noted ecological factors in the mangrove development [3].

4. OSMOTIC REGULATION OF MANGROVE PLANTS

Halophyte cells must have lower water potentials inside than outside the plasmalemma to retain cellular water. The necessary osmotic adjustment in dicotyledons is largely achieved by Na^+ and Cl^- ions. In many halophytes, K+ ion and sugars appear to supplement this mechanism. The use of organic compounds as vacuolar solutes in succulent halophytes seem to be precluded on energetic grounds. In succulent halophytes, vacuolar concentrations of Na^+ and $C1^-$ ions generally exceed the external concentrations [5]. This appears to reflect a constitutive ability of halophytes to accumulate high ion concentrations. However, it is very difficult to make any general conclusions concerning the regulation of these ion concentrations due to lack of information on plant water potential, turgor and ion fluxes [6]. Nevertheless, inorganic ions, especially Na^+ and $C1^-$ ions, seem to be responsible for osmoregulation in the vacuole cells of mangrove plants and other halophytes. Osmotic adjustment in the cytoplasm appears to be maintained by accumulation of the amino acid (proline), organic acid and the quarternary ammonium compounds (choline and betaine). A positive correlation between substrate salinity and the levels of choline and betaines in the leaves of some mangrove plants were also found.

5. ROOT SYSTEM OF MANGROVE PLANTS

Various physiological strategies are apparent to control uptake and concentration of these ions in metabolic tissues. The physiological mechanism is yet to be fully ascertained. Many scientists and researchers have suggested that mangroves can regulate salt (NaCl) by mainly three mechanisms; exclusion, extrusion and accumulation. Mangroves are also classified into salt-secretors and salt-excluders [9,10]

(a) **Salt glands**

Excessively absorbed Na^+ and Cl^- ions are gradually accumulated in leaves or discharged as salt (NaCl) from salt glands distributed over the surface of the leaf such as *Avicennia spp*. It has salt glands distributed over the surface of the leaf [11]. *A. marina* was cultivated in a cultivation liquid solution with salt concentration of 0 to 3.5%. It was found that salt was discharged from the salt glands as the salt concentration of cultivation liquid increased and analysis of the discharged salt indicated that it was almost entirely composed of NaCl [12].

(b) **Salt accumulation**

Many mangrove species without salt glands (salt-secreting glands) can adjust osmotic pressure to avoid physiological disorders by diluting the cell by sap with enlarging the vacuole or by neutralising cations with organic adds in response to various ions excessively absorbed or taken into the leaves. Leaf succulence of mangrove plants is associated with the enlargement of cells in the leaf, mainly in the hypodermal and mesophyll tissues. Mangrove leaves distinctively contain high levels of sodium chloride (NaCl), most of which is located in vacuole of cell. Osmotic potentials of sap extracted from crushed mangrove leaves are reported to
have yielding value ranging from -2.5 to -6.0 Mpa [13].

6. PHOTOSYNTHESIS OF MANGROVE FOREST

The rate of photosynthesis and transpiration in the rainy season were measured in Thailand [14]. The rate of photosynthesis in mangrove forests reached 100 mg $CO_2/dm^2/h$ at an exposure to sunshine of 1.5 cal/cm/min. in the rainy season. This value is about twice as high as the maximum of 40 to 50 mg $CO_2/dm^2/h$ for tropical rain forests in Malaysia (leaf area index was 8) and tropical dry evergreen forests in Thailand measured in the rainy season. The rate of photosynthesis was found to be markedly lower in the dry season than in the rainy season. This effect is also found in tropical evergreen forests. This phenomenon is attributed to water stress on plants in dry season following a decrease in the water content of soil and the drop in atmospheric humidity.

7. PHOTOSYNTHESIS OF PNEUMATOPHORES

A layer containing chlorophyll was observed under the epidermis of the straight pneumatophore *of Avicennia spp*. and *Sonneratia* spp. This indicates that pneumatophores fix CO_2 (carbon dioxide) and produce O_2 (oxygen) in the photosynthesis process. It is assumed that O_2 resulting from photosynthesis through pneumatophores, diffused into roots during daytime in the mud through the ventilating tissue. In turn, roots absorb O_2. Photosynthesis of *A. manna*, *S. alba and R. mucronata* were simultaneously measured [7,8].

At light intensity of 0.45 $cal/cm^2/min.$, the net rates of photosynthesis of pneumatophores of *A. marina and S alba* were 2.1 mg $CO_2/dm^2/h$ and 6.4 mg $CO_2/dm^2/h$, respectively. The overall rates of photosynthesis of *A marina* and *S alba* were 2.8 mg $CO_2/dm^2/h$ and 11.3 mg $CO_2/dm^2/h$, respectively.

8. WATER RELATIONS OF MANGROVE PLANTS

The water potential was determined by the osmotic potential of the cell sap and tugor pressure of the cytoplasmic membranes against the cell wall. A plant rooted in seawater has to generate an additional hydrostatic pressure. Mangroves also raise water against a hydrostatic gradient to heights of up to 30 m [15]. Pioneer species of mangrove plants grow directly in areas affected by seawater. The osmotic potential of seawater is about -2.9 MPa. Most species of mangroves seem to grow best in the salinity conditions between that of fresh water and seawater. In order to maintain a positive water balance, the mangrove plants must have tissue water potential lower than the osmotic potential of the substrate.

The hydrostatic pressure potential in xylem of a number of mangrove plant were measured. [16] The potential value range was from -2.7 to -5.7 MPa. All potentials of saps of three mangrove species showed daily changes, which was low at daytime and high at night-time. In particular, the potential of *R stylosa* was as low as -4.5 MPa around noon.

Some mangrove species were cultivated under artificial conditions and organic acids were analysed as osmosis control substances. The main organic acids in the plants were found to be oxalic acid and malic acid [17]

9. MANGROVE PLANTS AND ECOSYSTEMS OF EARTH

Creating a new ecosystem of mangrove forests or rehabilitating degraded mangrove forests will contribute to a better quality of life and more stability for the people living there. It would also contribute to the recovery of the natural mangrove ecosystem. Rehabilitation of mangrove forests along the coastline has a potential, to fix C02 and may contribute to an increase in food production. The amount of CO_2 actually absorbed by forests and the release of oxygen will depend on the tree species, tree age, soil, climate conditions etc. For example, thirty tons of timber in 1 ha of forest will annually consume 144 tons of CO_2, from air, and discharge 108 tons of oxygen. Trees themselves will absorb 72 tons of oxygen required to survive and discharge 96 tons of CO_2. It is finally calculated that they could absorb 48 tons Of CO_2 from air, and discharge 36 tons of oxygen [18].

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