CHARACTERISATION OF SOILS UNDER REED (*Ochlandra travancorica* Benth.) IN THE WESTERN GHATS

By

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THESIS

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DECLARATION

I hereby declare that the thesis entitled "Characterisation of soils under reed (*Ochlandra travancorica* Benth.) in the Western Ghats" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, fellowship, associateship or other similar title, of any other University or Society.

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INTRODUCTION

INTRODUCTION

The Western Ghats in peninsular India form an unbroken relief along the States of Maharashtra, Goa, Karnataka, Kerala and Tamil Nadu extending to about 1600 km from the mouth of the river Tapti (21° N) to the tip of South India (about 8°N) with a 30 km wide Palghat Gap in between. This region is a rich source of genetic diversity of flora and fauna in the country mainly due to the vast geographical area confining to different latitudes, varied topographies, climatic zones and biogeographic regions. According to Chandrasekharan (1962), the major vegetational types occurring in these regions, especially at the southern parts of the Ghats or otherwise confining to Kerala State include tropical wet evergreen forests, tropical moist deciduous forests, tropical dry deciduous forests, montane sub-tropical forests and montane temperate forests. Both moist bamboo (*Bambusa*) and wet bamboo (reed) brakes are classified under tropical wet evergreen forests as secondary types.

Bamboo, the giant tree grass, belongs to the sub-family *Bambusoideae* of family *Poaceae.* It has been put to innumerable uses since time immemorial as referred in Hindu epics Ramayana and Mahabharatha. Today, the multifarious uses of bamboo include building construction, fencing, furniture, handicraft articles, pickles etc. With the establishment of a bamboo based paper mill in 1919, the industrial demand for bamboo was channeled in this country. In addition to increasing demand in the paper, pulp and cottage industries, high calorific value of 4600 to 5400 kcal kg^{-1} makes bamboo a good source of energy (Thomas *et al.*, 1988). It plays a crucial role in combating soil erosion in steep highlands. It is considered important in landscaping, as wind breaks and hedges and in reforestation programmes (Kigomo, 1988). Bamboo growing on steep hill sides and along riverbanks can limit destruction during floods and land slides (Tewari, 1988).

India is endowed with about 136 species of bamboo comprising 21 genera and areas particularly rich in this are North Eastern India, Bastar region of Madhya Pradesh, Western Ghats and Andamans. Among these, the important genera found are *Arundinaria, Bambusa, Cephalostachyum, Dendrocalamus, Gigantochloa, Melocanna* and *Ochlandra* (Bahadur, 1979). But as per the latest taxonomic descriptions (Seethalakshmi and Kumar, 1998) there are 18 genera and 128 species in India which include 87 naturally occurring and 41 introduced cultivated species.

The genus *Ochlandra* occurring in Asia consists of 11 species (Bahadur, 1979). All the plants coming under the genus *Ochlandra* are commonly known as either reed or reed bamboo. From the Western Ghats of Kerala six species and one variety of *Ochlandra* have been reported and they include *Ochlandra beddomei, Ochlandra ebracteata, Ochlandra setigera, Ochlandra scriptoria, Ochlandra travancorica, Ochlandra tranvancorica* var. *hirsuta* and *Ochlandra wightii* among which *Ochlandra travancorica* is the most common and wide spread (Kumar, 1988). This erect tufted reed like gregarious bamboo (also called as elephant grass) occurs in association with the semi-evergreen and evergreen forests of the Western Ghats and also as pure reed brakes (Prasad, 1948). Reed occurs as primary and secondary formations and the growth is promoted by high rainfall and impeded drainage (Basha, 1994). Apart from providing diversified employment opportunities through paper and cottage industries, this long fibre yielding plant serves as better source of income through its multifarious uses. In addition to fire, grazing and gregarious flowering, over-exploitation also has depleted this natural resource to a large extent. This necessitates the proper management and large scale cultivation of this natural wealth of our country to ensure sustained supply of reed culms of good quality for which an understanding of soil supporting this species stands very important. In view of the above facts the present study was carried out with the following objectives.

1. To study the pedological / taxonomical characteristics of reed growing soils;
2. To find out the fertility status of soils supporting reed;
3. To analyse the growth performance of reed in relation to soil fertility, and
4. To study the leaf litter decomposition pattern and nutrient release from reed.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Systematically planned scientific studies on different aspects of soils on which reed flourishes are very few in the currently available literature. Hence related studies on other species of bamboo are also reviewed in this chapter.

1. Occurrence and distribution

Different species of bamboo are distributed over the tropical, subtropical and mild temperate regions of the world between the latitude 46° N to 47° S, from sea level to an altitude of more than 4000 m (Sodestrom and Calderon 1974 & 1979). They are distributed over Asia, Africa, North and South America, Australia, Malagasy and Pacific Islands.

1.1. Abroad

In Philippines bamboo forests are more or less confined to 15°-25° north latitude (Uchimura, 1978). Depending on the species, bamboo grows on areas from sea level to as high as 2800-3200 m. In Thailand, bamboo grows naturally in the mixed deciduous and tropical evergreen forests or semi-evergreen hill forest (Boontawee, 1988). Twenty two bamboo species have been reported to occur throughout Bangladesh (Gamble, 1896; Hooker. 1897; Prain, 1903 and Brandis, 1906).

1.2. In India

Van Rheede, the first writer on Indian bamboo identified two kinds of bamboo which are now identified as *Bambusa arundinaceae* and *Ochlandra rheedi* as important component of dry deciduous, moist deciduous and wet evergreen tropical forests. Bamboo forests of India are reported to occur in the dry and moist deciduous forests, and in mountain. subtropical, temperate and alpine forests (Gamble, 1896). Bahadur (1979) described the occurrence of bamboo as a rich belt of vegetation in well drained parts of the monsoon region at the foot of the Himalayas up to an altitude of 4000 m. Its distribution is quite dense in the Western Ghats, Bengal. Sikkim, Assam, Arunachal Pradesh and Andamans.

According to Thomas *et al.* (1988) India is the second richest country in bamboo genetic resources next to China. In India, tropical moist deciduous forests of north and south and the deciduous and semi-evergreen regions of north east are regions of bamboo diversity.

Kadambi (1949) focused on the ecology and silviculture of four species of bamboo in Mysore. According to him *Ochlandra travancorica* is confined to forests with heavy rainfall while *Dendrocalamus strictus* prefers well drained hill slopes within an elevation of 600-900 m. In Assam, reed is in plenty in the valley drained by the Brahmaputra river as well as in the island in the riverbed (Rajhowa, 1964). In Maharashtra, bamboo is found extensively in the dry and moist deciduous forests and also as an under-storey to the teak or miscellaneous forests (Desai and Subramanian, 1980).

1.3. In the Western Ghats

Iyppu (1964) reported the occurrence of *Ochlandra travancorica* from Kerala as an associate in the moist tropical evergreen forests, having an altitudinal distribution from 60 to over 900 m. Reports of Yegnaswami (1964) described the occurrence of *Ochlandra travancorica* as pure crop in Tirunalvely North Division over an area of 4402.8 ha and also in small patches in Coimbatore and Madurai Divisions. According to Kumar (1988), *Ochlandra travancorica* is the most important associate of the tropical evergreen forests and it attains maximum growth in the very wet type of evergreen forests. Paulose (1965) also indicated that *Bambusa arundinaceae* and *Ochlandra* sp. were most important bamboo species in Kerala.

2 Climate

2.1. Rainfall

Gamble (1896) found that distribution of bamboo followed distribution of rainfall. According to Boontawee (1988), bamboo forests in Thailand are confined to areas where annual rainfall is between 1000 and 2000 mm. But in India according to Koppar (1980) bamboo preferred regions of high rainfall ranging from about

1270 mm to 6350 mm or even more, though it also occurred in dry deciduous forests with as low rainfall as 750 mm.

In Assam, reed flourishes well where rainfall ranges from 200 cm to 450 cm (Rajkowa, 1964). Iyppu (1964) and Yegnaswami (1964) referred *Ochlandra travancorica* as a tropical species requiring hot and humid climate. Iyppu (1964) also emphasized the importance of rainfall along with soil and moisture in determining the distribution of this species. The optimum range of rainfall for *Ochlandra travancorica* varied between 3048 to 3810 mm.

2.2. Temperature

Hassan *et al.* (1988) noted that high temperature acted as a growth promoting factor for bamboo and big bamboo forests occurred in Bangladesh usually between 15-25°C. Koppar (1980) recorded a maximum temperature of 46.7° C and a minimum of 3.3°C from bamboo bearing localities in India.

In Kerala *Ochlandra travancorica* prefers an optimum temperature of 18.3-35° C (Iyppu, 1964) while in Assam reed flourishes well in areas where temperature varies between 7 and 37°C (Rajkowa, 1964).

3. Geology

In Philippines. bamboo thrives well on soils derived from river alluvium or from underlying rocks having a pH of about 5.0-6.5 (Uchimura, 1978). Growth of *Dendrocalamus strictus* is mainly restricted to Bengal or Dome gneiss and its detritus (Lyall, 1928) in Bihar and Orissa. In Mysore, *Dendrocalamus strictus* thrives well on soils developed from granite rock and moderately well on soils lying over hornblendes and does not seem to perform well on chlorite schists (Kadambi, 1949). Rajkowa (1964) reported that geology, rock and soil of bamboo tract were too varied and complex in Bihar. Koppar (1980) also reported that the bamboo thrived on soil derived from different parent rocks with its climatic habitat. The soil supporting *Ochlandra travancorica* in Kerala is reported to be of gneissic or lateritic in origin (Iyppu, 1964).

4. Site and soil characteristics

In India, bamboo is reported to occur both in hills and plains (Thomas *et al.*, 1988). *Dendrocalamus strictus* prefers well drained hill slopes while *Bambusa arundinaceae* demands moist localities (Kadambi, 1949). Even the direction of slope is found to play a significant role, the maximum density of *Dendrocalamus strictus* being on northern slopes and minimum on southern slopes (Joshi, 1984). Iyppu (1964) noted that in Kerala both *Bambusa arundinaceae* and *Ochlandra travancorica* were not influenced by aspect.

Troup (1921) indicated that different species of bamboo formed excellent soil indicators. According to Yegnaswami (1965) there is no clear-cut area or zone for each species and one replaces the other with even slight variations in edaphic conditions. Quershi *et al.* (1969) found that soils under different bamboo species showed wide variations in soil properties and recommended more systematic studies on the soil requirement of different species of bamboo.

4.1. Soil physical properties

In Bangladesh, bamboo flourishes well in loamy soils (Hassan, 1988) and in Philippines (Uchimura, 1978) it thrives best on well drained sandy loam to clay loam soils. According to Gamble (1896), a wide range of textural variation and soil depth do not interfere with the normal growth of bamboo. In Mysore, *Dendrocalamus* thrives best on porous gravelly and sandy loam soils and moderately well on ferruginous loam (Kadambi, 1949). Growth of *Dendrocalamus strictus* on loamy soils in Madhya Pradesh and Madras was not satisfactory (Anonymous, 1961). Kaul (1964) and Koppar (1980) reported that bamboo grew in light textured soil avoiding clay and waterlogging. In Kerala, according to Iyppu (1964) growth of *Ochlandra travancorica* is greatly influenced by the content of moisture in soil. Yegnaswami (1964) observed bamboo growing in clayey soil also. Preference to finer textured soils was again stressed by Yadav (1969). Some species of bamboo in Assam like *Teinostachyum dullooa* and *Oxytenanthera nigrociliata* are capable of growing satisfactorily even on coarse textured soils provided sufficient moisture is available, but the soils under

Bambusa tulda and *Dendrocalamus hamiltonii* generally contain higher amount of clay and silt (Quershi *et al.*, 1969). Thomas and Sujatha (1992) reported that reed was capable of improving soil physical properties and thus enhancing soil and water conservation.

4.2. Chemical characteristics of soil

4.2.1. Soil reaction

For bamboo in Bangladesh, the optimum soil pH reported is between 5.0 and 6.5 (Hassan 1988; Alam, 1992) but it can thrive even in soils with a pH of 3.5 (Alam, 1992). A comparison of bamboo growing soils in Japan and India (Anonymous, 1961) reveals that bamboo in Japan and India bamboo grows in acidic soils. Quershi *et al.* (1969) also reported that bamboo (*Bambusa arundinaceae*) growing soils were acidic. According to Koppar (1980), in India, bamboo is conspicuously absent on extremely acid, saline and alkaline soils and it prefers acidic to near neutral range of soil reaction.

4.2.2. Soil fertility

Lyall (1928) stated that geologically younger soils were more suitable for bamboo than the older soils, mainly because of the higher nutrient status of younger soils. Quershi *et al.* (1969) found that soil fertility status played significant role in governing the distribution of certain bamboo species in Assam. According to them, soil supporting *Bambusa tulda* contained by far the highest reserve of organic matter, nitrogen, calcium, potassium and phosphorus while the soil under *Teinostachyum dullooa* and *Oxytenanthera nigrociliata* had the lowest status of magnesium, potassium, phosphorus and nitrogen.

5. Growth of bamboo in relation to soil properties

In an attempt to improve bamboo plantations in India it was found (Anonymous 1961) that soils with high fertility status supported good bamboo growth and comparatively poor growth was observed on soils of low fertility. Yadav (1969) correlated the growth performance of bamboo with different soil properties in Bihar. and concluded that soils supporting good bamboo possessed

Binkley (1993) noted lignin : nitrogen ratio as the litter quality parameter most closely correlated with decomposition rates.

Gallardo and Merino (1993) reported that leaf toughness and the ratio toughness : phosphorus concentration were the best indicators of mass loss during leaching phase in both the ecosystems (Donana and La sauceda) studied and cutin: nitrogen or cutin : phosphorus ratios were best predictors of mass loss in the post-leaching phase, but only in the drier and more nutrient-poor ecosystem. When the two phases were combined, leaf toughness, toughness : nitrogen and/or cutin : nitrogen significantly explained mass loss in both ecosystems. Importance of leaf toughness in litter decomposition was again stressed by Cote and Fyles (1994). Gillon *et al.*, (1994) found that the rate at which labile and resistant components decreased during decomposition was related to the permeability of leaves for the former and to their thickness and mass per surface area for the latter. They also emphasised the prospects of near-infrared reflectance spectroscopy for providing new perspectives for characterising the capacity of litters to decompose.

6.1.2. Climate and site characteristics

It is reported that the climate as indicated by actual evapo-transpiration is more important as a predictor of decay rate than is litter quality (Meentemeyer, 1978). Singh and Joshi (1982) reported temperature and moisture as critical environmental factors for high rates of decomposition and the litter decomposition was maximum during rainy season. Munshi *et al.* (1987) also recorded maximum decomposition of leaf litter of *Shorea roubusta* in rainy season.

Kumar and Deepu (1992) observed rapid organic matter turn over in tropical moist deciduous species in comparison with published temperate forest litter.

Vitousek *et al.* (1994) examined the decomposition of common substrates for a range of sites and found that common substrates decomposed slowly on dry sites, but leaf litter produced on dry sites decomposed more than twice as rapidly as litter from wet sites when both were measured on same site. Mudrick *et al.*

(1994) reported that leaf litter of Appalachian forest on north facing slopes decomposed much faster than south facing slopes. They also added that leaves placed at the middle of the slope decomposed slower than those at lower or upper position.

It is reported that in Greek ecosystems timing of decomposition synchronised with climatic variations and higher rate of litter disappearance occurred in autumn and spring (Stamou *et al.*, 1994). Among the three main factors – climate, quality and nature of litter and abundance of decomposing organisms – climate is the dominant factor in areas subjected to unfavourable weather, whereas litter quality largely prevails as the regulator under unfavourable weather. Litter quality remains important until late decomposition stages through its effects on humus formation (Couteaux *et al.*, 1995). According to Gressel *et al.* (1995) salts of atmospheric origin mainly $CaSO_4$ accumulate on pine needles facilitating enhanced break down of the needles as compared to oak leaves.

6.1.3. Nature and abundance of decomposing organisms

Aranda *et al.* (1990) recorded a direct relationship between the rate of litter decomposition and the diversity of the edaphic mesofauna community. Wise and Schaefer (1994) showed the impact of meso and macro fauna on rates of leaf litter disappearance in beech forest. According to them macro-fauna had no significant impact on the rate of disappearance of fresh beech leaves, but accelerated the disappearance of aged beech.

In humid tropical conditions Tian *et al.* (1995) found that millipedes and earth worms contributed more to the break down of plant residues with low quality (high C:N ratio, lignin and polyphenol contents) than to the degradation of those with high quality. Pande and Sharma (1993) stressed the importance of macrofauna in decomposition processes especially in tropical climate.

6.2. Rate of decomposition

Litter of different plant species was found to vary in their decomposition rate subject to the changes in litter composition and climatic and other site characteristics (Satchell, 1974). However, rate constants evolved for different plants in India are reviewed hereunder. Needle litter decomposition of *Pinus kesiva* showed fast rates with rate constants (K) of -0.46 $year^{-1}$ for 1year and -0.78 $year^{-1}$ for 2 years (Das and Ramakrishnan, 1985). According to Munshi *et al.* (1987), turnover time (to decompose) for the litter of *Shorea robusta* was 144 days. Bahuguna *et al.* (1990) observed decomposition constants as 0.87 and 1.547 for sal and eucalypt respectively for a period of one year. Klemmedson (1992) reported that loss from pure oak was 60% higher than pure pine. Singh *et al.*, (1993) reported that rate of decomposition was highest in sal (2.01), followed by teak (1.26), poplar (1.05) and least in eucalypt (0.69). Pande and Sharma (1993) were also of the opinion that leaf litter decomposition followed the order sal (1.668) > teak (1.651) > pine (1.350) > eucalypt (1.350).

6.3. Nutrient dynamics

Most of the energy fixed autotrophically of the ecosystem find its way in the form of dead organic matter releasing different nutrients back to the soil by the action of biological and physical agencies (Swift *et al.*, 1979). Release of various elements at successive stages of decomposition varied with type of elements and rate of decomposition. A lot of investigations both under temperate and tropical conditions have been reported in different vegetational types. Upadhyay (1982) studied the nutrient release pattern in *Eucalyptus globulus* litter and found Na and K decreased most rapidly and had close correlation with the loss in total organic matter. Loss of these two elements occurred at all stages of decomposition, but it was more pronounced in July and September. Ca and P of litter were found to increase with the successive increase of decomposition and recorded maximum in July and September. According to Das and Ramakrishnan (1985) release of nutrient elements during decomposition of khasipine showed considerable variation with K showing rapid release followed by Ca, Mg, P and N.

In general, return of nutrients in different plantations of New Forest, Dehradun was in the order of Ca > N > K > Mg > P. Release followed the order Ca > K > N > Mg > P for pine and eucalypt while the order was Ca > N > K > Mg > P for teak and sal (Pande and Sharma, 1988). Stohlgren (1988) concluded that pattern of nutrient release was variable with content of lignin and N. It is reported that in the case of eucalypt, nutrient release efficiency was higher compared to sal (Bahuguna *et al.*, 1990). The elemental mobility of the nutrient from decomposing litter was observed in the order of Mg > K > P > Ca > N for sal and for eucalypt it followed the order of K > Mg > P > Ca > N for 12 months duration. The levels of P, K, Mg and B in decomposing leaf litter of some tree species decreased after 1 year period of decomposition and concentration of N, Ca, S, Zn, Mn, Fe, Cu and Al increased (Bockheim and Jepsen, 1991). Nutrient release patterns reported (Klemmedson, 1992) from mixtures of Gambel oak and pine leaf litter were similar for N, S and Ca with little or no loss over the study period. Nutrient release patterns for P, Mg and K were similar with marked release.

Along a decay continuum in a red spruce ecosystem, Rustard (1994) found a decrease of carbon concentration, increase of N, Fe and Al and all variable patterns of P, Ca, Mg and Mn concentration over time as fresh litter was transformed to soil organic matter. In the case of bamboo, Maoyi (1988) in China observed that leaf litter decomposition included three stages viz., leaching, accumulation and release. N, P and K had a long accumulation stage while Ca and Mg were released very early.

MATERIALS AND METHODS

MATERIALS AND METHODS

Reed resources of the State have considerably dwindled from the natural habitats due to over-exploitation, shifting cultivation, gregarious flowering and extensive forest fires. Sustained availability can be ensured only by raising reed plantations. Since development of plantation techniques rely on basic soil studies, the present study was formulated to find out the soil characteristics of reed pockets in the Western Ghats of Kerala. It consisted of following four parts. 1. Pedological / taxonomical features of reed growing soils. 2. Fertility status of soils supporting reed. 3. Growth performance of reed in relation to soil fertility. 4. Decomposition pattern and nutrient release from reed leaf litter.

1. Pedological / taxonomical characteristics of reed growing soils

This study was intended to characterise the reed growing soils with respect to pedological / taxonomical features. The variations in the depthwise distribution of soil properties due to changes in location, elevation and topography were looked into. Based on the informations derived from soil profiles, taxonomical positions of reed growing soils were found out.

1.1. Study area

Among the predominantly reed growing areas of the State, four regions viz., Vazhachal, Pooyamkutty, Adimali and Pamba were selected for this study (Fig. 1). In all these four locations selected, two elevations viz., 200-300 m (low) and 600-800 m (high) were located. At each elevation, two different types of topography (sloping and flat to undulating) were selected to dig representative soil profiles (Table 1). At certain elevations and topography, where pure reed brakes were not present, the reed growing as under growth in teak and moist deciduous trees was selected for collection of soil samples.

At Vazhachal, reed occurs mainly as undergrowth in teak and moist deciduous forests and also as pure patches. The pure patches were established mainly due to the removal of the plantations of *Albizzia falcataria*. Previously reed was growing as undergrowth in *Albizzia falcataria* and when these trees were removed, reed started to grow vigorously and formed dense patches. The sampling sites at lower elevation were selected in Charpa and Vazhachal ranges immediately

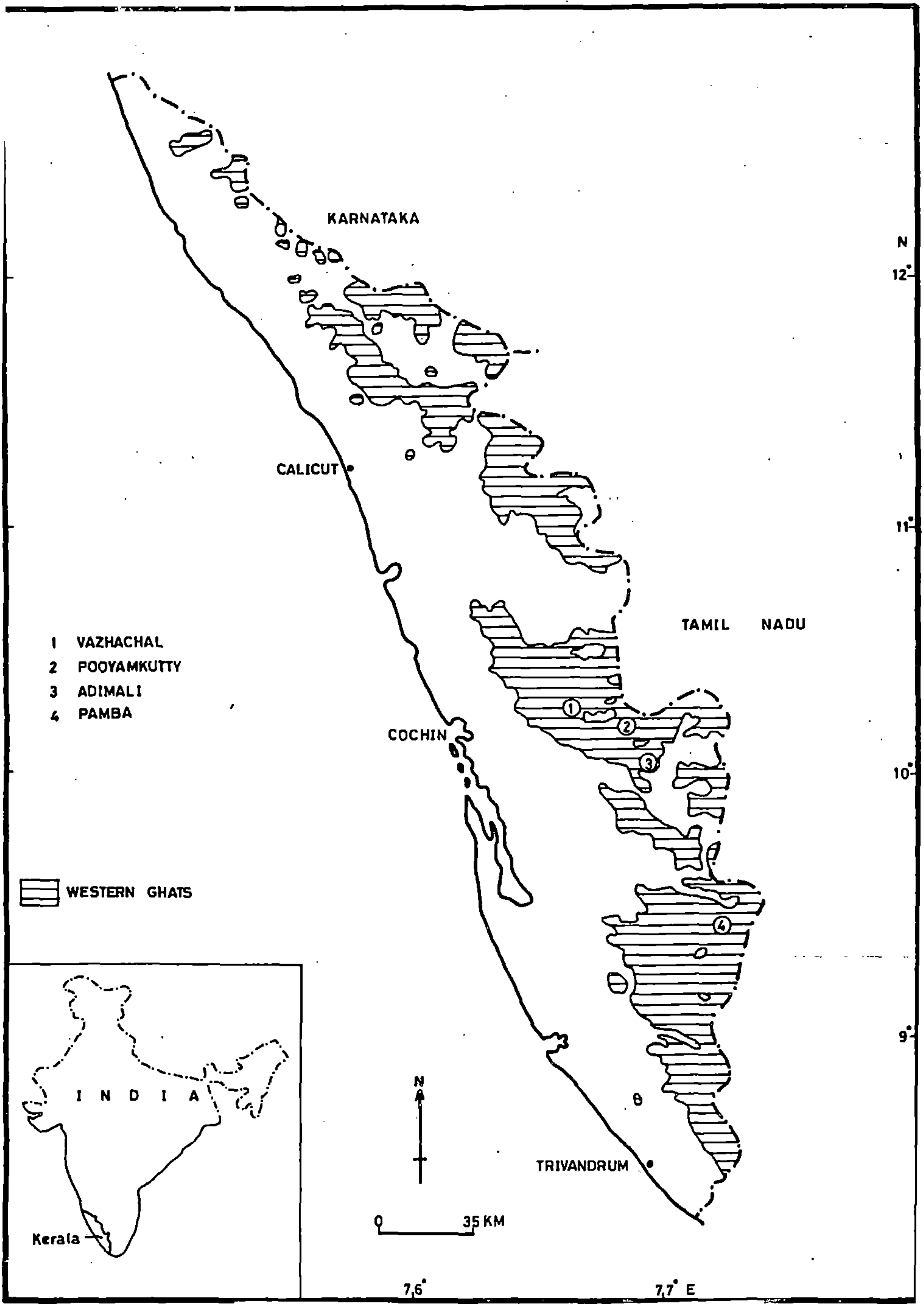


Fig .1. Location map showing study areas

Plate 1. A general view of natural reed patch

Plate 2. Reed growing naturally as undergrowth in teak

Plate 3. Reed inflorescence

Plate 4. Reed clumps - a closer view

after the Athirappilly water falls. Here, reed was growing mainly as undergrowth in teak along a water course. The sampling sites at higher elevation were located in Vazhachal and Kollathirumedu ranges. Dense patches of reed were found in this area in addition to the undergrowth in moist deciduous trees.

The reed growing tract of Pooyamkutty begins from 50 m above msl in Kuttampuzha range. The sites for soil sample collection at lower elevation were selected at Swamy's pocket, where reed was growing as undergrowth. For sampling at higher elevation, the site was selected at Pambarkayam of Mankulam range where reed was growing in dense patches.

At Adimali, the reed pockets at Averkutty were selected at lower elevation and the reed brakes at upper hills of Neriyamangalam were selected to represent higher elevation. In this area reed was growing mainly as dense patches.

At Pamba region, the sites for soil sample collection at low altitude was selected at Moozhiyar. Here reed was growing as under growth and the growth was poor. The reed tracts of Gudrikal range were selected to represent higher altitude and in this area most of the reed bamboo were mainly in dense patches.

The annual rainfall of the selected regions varied from 2500 mm in the south to about 5000 mm in the north and the morphology of the Ghats is attributed to be one of the major factors deciding the rainfall pattern.

1.2. Soil sampling

In all the four locations selected, two different elevations (200-300 m and 600-800 m) and at each elevation two different types of topography (sloping and flat to undulating) were located. Then representative soil profiles with 3 replications were struck at each site. Thus there were 12 profiles (2 x 2 x 3) examined in each location and a total of 48 profiles from four locations as shown in Table 1. The symbols HS, HF, LS and LF were used to denote the profiles at sloping land of higher elevation, flat to undulating land of higher elevation, sloping land of lower elevation and flat to undulating land of lower elevation respectively. Collection of samples from all locations was carried out during the period January 1994 to May 1994.

Table 1. Details of soil profiles taken from various sampling sites

Sl. No.	Location	Elevation	Topography
1.	Vazhachal	Low	Sloping
2.	Vazhachal	Low	Sloping
3.	Vazhachal	Low	Sloping
4.	Vazhachal	Low	Flat to undulating
5.	Vazhachal	Low	Flat to undulating
6.	Vazhachal	Low	Flat to undulating
7.	Vazhachal	High	Sloping
8.	Vazhachal	High	Sloping
9.	Vazhachal	High	Sloping
10.	Vazhachal	High	Flat to undulating
11.	Vazhachal	High	Flat to undulating
12.	Vazhachal	High	Flat to undulating
13.	Pooyamkutty	Low	Sloping
14.	Pooyamkutty	Low	Sloping
15.	Pooyamkutty	Low	Sloping
16.	Pooyamkutty	Low	Flat to undulating
17.	Pooyamkutty	Low	Flat to undulating
18.	Pooyamkutty	Low	Flat to undulating
19.	Pooyamkutty	High	Sloping
20.	Pooyamkutty	High	Sloping
21.	Pooyamkutty	High	Sloping
22.	Pooyamkutty	High	Flat to undulating
23.	Pooyamkutty	High	Flat to undulating
24.	Pooyamkutty	High	Flat to undulating
25.	Adimali	Low	Sloping
26.	Adimali	Low	Sloping
27.	Adimali	Low	Sloping
28.	Adimali	Low	Flat to undulating
29.	Adimali	Low	Flat to undulating
30.	Adimali	Low	Flat to undulating
31.	Adimali	High	Sloping
32.	Adimali	High	Sloping
33.	Adimali	High	Sloping
34.	Adimali	High	Flat to undulating
35.	Adimali	High	Flat to undulating
36.	Adimali	High	Flat to undulating
37.	Pamba	Low	Sloping
38.	Pamba	Low	Sloping
39.	Pamba	Low	Sloping
40.	Pamba	Low	Flat to undulating
41.	Pamba	Low	Flat to undulating
42.	Pamba	Low	Flat to undulating
43.	Pamba	High	Sloping
44.	Pamba	High	Sloping
45.	Pamba	High	Sloping
46.	Pamba	High	Sloping
47.	Pamba	High	Flat to undulating
48.	Pamba	High	Flat to undulating

1.3. Processing of soil samples

The soil samples brought directly from the field were air dried in the shade, sieved through 2 mm sieve and gravel content was accounted. The 2 mm sieved soil samples were used for various laboratory analyses. For estimation of organic carbon, these samples were again ground and sieved through 0.5 mm sieve and then subjected to analysis.

1.4. Analytical procedures

1.4.1. Physical properties

Important physical properties like texture (international pipette method), bulk density (core method), particle density (standard flask technique), maximum water holding capacity (by weighing 400 g soil before and after saturating with water and allowing to drain for 24 h) were estimated following the procedures described by Black *et al.* (1965).

1.4.2. Chemical properties

1.4.2.1. pH, organic carbon, available nutrients and exchange characteristics

The pH of soil water suspension (1:2.5) was determined using a digital type Elico pH meter.

Organic carbon content was estimated by sulphuric acid and potassium dichromate wet digestion (Walkley and Black, 1934) as described by Jackson (1958).

Available N was estimated by alkaline permanganate method (Subbiah and Asija, 1956). Available P was extracted by Bray No. 1 extractant (0.03 N NH_4F + 0.025 N HCl soil solution ratio 1:10; period of extraction 5 minutes) and the P content was determined colorimetrically by the ascorbic acid reduced molybdo phosphoric blue colour method in hydrochloric acid systems (Watanabe and Olsen, 1965).

Exchange acidity of the soil was estimated by titrating 1M KCl extract of soil (soil solution ratio 1:5; period of extraction 30 minutes) with standard NaOH using phenolphthalein as indicator (Yuan, 1959). Exchangeable K, Na, Ca and Mg were estimated from the neutral ammonium acetate extract of the soil. Five g of soil was extracted with neutral normal ammonium acetate (1:15) for 10 minutes, filtered and the filtrate was used to determine K and Na using a digital type Elico (CL-360) flame photometer (Jackson, 1958). The same filtrate was used to estimate Ca and Mg using complexometric EDTA titration (Hesse, 1971). Cation exchange capacity (CEC) was determined by neutral normal ammonium acetate method (Jackson, 1958). Base saturation was calculated by dividing the sum of exchangeable K, Na, Ca and Mg by CEC and expressed as percentage (Jackson, 1958).

1.4.2.2. Total nutrients

Total N was determined by kjeldahl digestion and distillation (Jackson, 1958). Total P and K were determined by nitric-perchloric acid digestion. For this 0.5 g of soil was digested with nitric perchloric acids (2:1) and made up to 100 ml (Hesse, 1971).

Total P was determined in an aliquot of this extract following vanadomolybdate yellow colour method in HNO_3 system (Jackson, 1958). Total K was determined by feeding a diluted aliquot of this extract in a digital type Elico (CL-360) flame photometer.

1.5. Statistical analysis

Correlation coefficients between various physico-chemical characteristics of soils were determined (Snedecor and Cochran, 1967).

2. Fertility status of soils supporting reed

This study was carried out to find the fertility status of reed growing soils. Moreover, the impacts of various factors like location, elevation and topography on various soil properties was also assessed.

2.1. Study area

The locations selected for pedological characteristics *viz.*, Vazhachal, Pooyamkutty, Adimali and Pamba were used to study the fertility status also. In all the four locations selected, two different elevations (200-300 m and 600-800 m) and at each elevation two different types of topography (sloping and flat to undulating) were located. Instead of selecting the surface soil of profile, eight surface soil samples embedding the profile sites were collected from one topography of each elevation and hence there were a total of 16 samples per elevation and 32 samples in each location. The symbols HS, HF, LS and LF were used to denote the soil samples at sloping land of higher elevation, flat to undulating land of higher elevation, sloping land of lower elevation and flat to undulating land of lower elevation respectively. Soil samples inclusive of core samples were collected and they were brought to laboratory. Collection of soil samples from all the locations was carried out during the period January 1994 to May 1994.

2.2. Processing of soil samples

The soil samples brought directly from the field were processed as described under 1.3.

2.3. Laboratory analyses

Important physical properties like texture, bulk density, particle density and maximum water holding capacity were estimated following the procedures described under 1.4.1.

Various chemical properties like pH, organic carbon, available nutrients, exchange characteristics and base saturation were estimated following procedures described under 1.4.2.1.

2.3.4. Statistical analysis

The analysis was carried out using the statistical package 'SPSS / PC+'. Significance between sites, elevations and topography with respect to various soil properties were tested statistically using student's t test. Correlation coefficients between various physico-chemical characteristics of soils were determined (Snedecor and Cochran, 1967).

3. Growth performance of reed in relation to soil fertility

3.1. Study area

This study was carried out at reed growing tracts in Vazhachal. At this location reed growing in dense patches were mostly observed above 500 m above msl. Different classes of reed stands viz., class I, class II and class III were selected within 520-550 m above mean sea level with minimum possible variation due to change in elevation. Data on various growth parameters viz., number of culms/clump, number of culms/ha, spacing between clumps, maximum height of each clump and maximum girth at first node were collected (15 replications) from these three classes of vegetations.

3.2. Sample collection

3.2.1. Soil sample

A total of 15 soil samples (0-15 cm) were collected at random from top, middle and lower parts of the hill in each class of vegetation.

3.2.2. Plant samples

For collecting plant samples, reed clumps growing very near to the sites selected for soil sampling were used. In each clump, two year old culm was then identified. Various plant parts viz. leaves, culms, roots and rhizome, were collected separately. From each culm. recently matured green leaf was collected. There were a total of 15 samples in each class of vegetation to represent 15 soil samples.

3.3. Processing of samples

3.3.1. Soil sample

The soil samples brought directly from the field were processed as described under 1.3.

3.3.2. Plant sample

The various parts of plant (leaf, clum, rhizome and root) collected from the field were dried in the oven at 70°C for 24 h, powdered and used for laboratory analysis.

3.4. Laboratory analysis

3.4.1. Soil samples

pH, organic carbon, available N, available P and available K were determined as described under 1.4.2.1.

3.4.2. Plant samples

Nitrogen content was determined using microkjeldahl method. Powdered plant sample was digested in a triacid mixture of HNO_3 H_2SO_4 and $HClO_4$ (volume ratio of 9:2:1) and made up to 100 ml. Phosphorus was determined in an aliquot of this extract following vanado molybdate yellow colour method in HNO_3 system (Jackson, 1958). Total K was estimated by feeding an aliquot of this extract in a digital type Elico (CL-360) flame photometer.

3.5. Statistical analysis

The estimates of variability in soil fertility status, content and uptake of nutrients in various parts of plants between different growth classes of reed stands were evaluated using F test. Multiple comparisons between pairs of means were done by using critical difference. Correlation coefficients between growth parameters, soil fertility characteristics and nutrient uptake in plants were worked out (Snedecor and Cochran, 1967).

A response function relating number of culms to different soil properties viz., soil pH, organic carbon, N, P and K was fitted using step wise regression technique (Montgomery, 1991). The complete function was a second order equation in five variables as shown below.

$$Y=\beta_o + \sum_{i=1}^{5} \beta_i x_i + \sum_{i=1}^{5} \beta_{ii} x_1^2 + \sum_{i}^{5} \sum_{\substack{j \\ i<j}}^{5} \beta_{ij} x_i x_j$$

Similarly the response functions relating the biomass (culms and leaves) to the uptake of N, P and K were also worked out.

4. Leaf litter decomposition and nutrient release

This study was to find out the pattern of leaf litter decomposition of reed leaf litter over a period of one year. Monthly changes in the loss of organic matter and release of nutrients viz., N, P, K, Ca and Mg were examined.

4.1. Study area

In situ reed leaf litter decomposition was studied at two selected reed growing sites in Vazhachal located at 500 m above msl. The first site selected was a pure reed patch while in the other reed was growing as under growth in teak. The topography of both the sites was sloping, the first one facing towards north and the other towards west.

The total rainfall received during the study period was 4337.7 mm with maximum recorded during June (1138.5 mm). The rainfall received during March and December was negligible. The absolute maximum temperature was recorded during March (39° C) and absolute minimum during December (15° C).

4.2. Method

This study was carried out by adopting litter bag technique (Bock and Gilbert, 1957). For this freshly fallen reed leaf litter was collected from the two selected reed growing sites at Vazhachal during December, 1993. These litter were brought to laboratory, air dried and made free of adhering materials. A known weight (25 g) of these litter was packed in nylon bag of size 25 x 25 cm and mesh size 5 mm. These bags were placed at the two selected reed growing sites on January 4, 1994. At each site, 12 bags were placed on soil surface around a reed bamboo clump in three replications selected at random and covered with reed leaf litter to avoid disturbance from man and wild animals. Thus, there were 36 bags (3 x 12) in one site and a total of 72 bags in two sites. Three samples @ one sample from one replication in each site were drawn on 4th day of every month starting from February, 1994 for a period of one year. Soil samples (0-15 cm) for moisture determination were also collected from these sites in triplicate during the monthly withdrawal of litter bags. So there were nine soil samples per site for moisture determination. After removing the adhering soil particles these bags were taken to laboratory, made free of foreign materials, oven dried at 70° C for constant weight, powered and used for nutrient analysis.

4.3. Laboratory analysis

4.3.1. Soil sample

The soil samples collected in stainless steel boxes from the field for moisture determination were weighed for initial wet weight in the laboratory. They were oven dried for constant weight and the loss in weight was used to determine the moisture percentage.

4.3.2. Litter sample

The plant nutrients viz. N, P and K in the litter samples were determined as described under 3.4.2. Ca and Mg were determined by following EDTA titrimetry (Hesse, 1971).

4.4. Statistical analysis

To find out the best model to work out the decomposition rate constant, the data were subjected to curve fit. Among the 25 models tried, based on the value of R^2, the best fitting curve was selected. Thus the decomposition rate constant was worked out using the equation $x/x_o = e^{-kt}$, where x is the weight remaining at time t, x_o is the original weight, e is the base of natural logarithm, k is the decay rate coefficient and t is time (Olson, 1963). The same model was used to compute the time required for 50% and 95% decomposition. The significance of difference between decay rates in the two study sites was assessed by comparing regression coefficients using `t' test. Correlation between various parameters related to litter decomposition was also worked out (Snedecor and Cochran, 1967).

RESULTS AND DISCUSSION

RESULTS AND DISCUSSION

The present study was undertaken to investigate the pedological/ taxonomical characteristics and fertility status of reed growing soils of Kerala as influenced by variation in location, elevation and topography. It also aimed to assess the growth performance of reed in relation to soil fertility and pattern of decomposition and nutrient release from reed leaf litter. The salient results of this study are summarised below in four separate parts.

PART I . PEDOLOGICAL / TAXONOMICAL CHARACTERISTICS

In order to examine the pedological / taxonomical characteristics of reed growing soils, four major locations namely Vazhachal, Pooyamkutty, Adimali and Pamba were selected (Fig. 1). Under each major location low and high elevations were identified and from each group of elevations two different types of topography (sloping and flat to undulating) were located. Three profiles were taken from each topography and thus there were 12 profiles examined from a major location (Table 1), details of which are already furnished under Materials and Methods.

1. General soil characteristics

Forests are normally characterised by diversified flora and fauna flourishing in it. Drastic disturbance to these forests sometimes results in the proliferation and dominance of a particular type of vegetation. Most of the extensive reed patches in the State have been established through this transition. Usually the nature and amount of organic matter produced after decomposition of the fallen litter depends on the dominating vegetation present and this regulates the properties of soil supporting it. In the present study various morphological and physico-chemical characteristics of soils in reed growing tracts are presented and discussed.

1.1. Morphological properties

The profile-wise morphological features of the soils are highlighted in Table 2. Various studies so far conducted on soils of natural forests and forest plantations in Kerala (Thomas and Brito-Mutunayagam, 1965, Yadav *et al.*, 1970, Sankar *et al.*, 1987 and Alexander, 1987) reveal an accumulation of litter on soil surface.

These litter on decomposition give rise to organic rich dark coloured surface horizon. The thickness of this horizon depends on the rate of litter fall and consequent decomposition.

The soils of reed growing tracts also carried litter on its surface which was under varying degree of decomposition. The colour of surface soils was mostly in the hue of 7.5 YR, the colour ranging from brown to dark brown, imparted mainly by the decaying organic residues. The subsurface layers were characterised mainly by the decrease in dark colour with simultaneous dominance of either red or yellow with hue 5YR or 10YR. This is attributed to the depletion of organic matter at lower depth coupled with fluctuation in the dehydration of sesquioxides.

According to Webster (1965) the intense red colour of soils has been associated with free iron oxide content. Compared to other forest vegetations, reed is characterised by fine fibrous root system which ramifies vertically downwards and horizontally. The major portion of these fine roots occupies the surface layer and functions like a thick mat. This peculiar flooring binds the soil particles together resulting in granular and crumb structure and helps to lessen the soil erosion to a great extent. The good structural development may also be due to the binding action of the products of microbes, sesquioxides and good drainage conditions. The soils of subsurface layers were generally structureless especially in pure reed tracts. In other cases development of weak subangular blocks was observed. The cementing action exerted by the fine fibrous roots of reed is concentrated mainly at surface layers. This together with very low content of fine soil separates causes poor development of structure at subsurface layers.

Table 2. Profile morphology of soils in reed growing tracts

Eln/ tpy	Profile No.	Site features	Horizon	Depth (cm)	Colour	Texture	Structure	Consistence	Special features
				Vazhachal					
LS	1	Lower middle of a hill, reed undergrowth in teak, medium growth, southern aspect, plenty of litter and exposed rocks	A	0-13	10 YR 3/3	gsl	cr	ml, wpo	Abundant roots, plenty of rock fragments
			Bt1	13-43	10 YR 4/3	gsl	gr	mfr, wpo	Abundant roots
			Bt2	43-150+	10 YR 4/6	gscl	m1sbk	mfr, wp	Few roots, presence of clay skins
	2	Upper middle of a hill, reed undergrowth in teak, medium growth, southern aspect, plenty of litter and exposed rocks	A	0-10	7.5 YR 3/4	gsl	cr	ml, wpo	Abundant roots, plenty of rock fragments
			Bt1	10-56	10 YR 4/3	sl	gr	mfr, wpo	Plenty of roots and rock fragments
			Bt2	56-150+	5 YR 4/6	scl	m1sbk	mfr, wp	Few roots, presence of clay skin and plenty of stones
	3	Middle of a hill, reed undergrowth in teak, southern aspect, reed growth medium, near to water course	A	0-9	7.5 YR 3/4	gsl	cr	ml, wpo	Abundant roots and stones
			Bt1	9-41	5 YR 3/4	gscl	gr	ml, wp	Abundant roots and stones
			Bt2	41-77	5 YR 4/6	gscl	m1sbk	mfi,wvp	Abundant roots and stones, presence of clay skin
			C	77+	Weathered rock				
LF	4	Valley of a hill, reed undergrowth in teak, medium to dense growth, plenty of exposed rocks	A	0-21	7.5 YR 3/4	gsl	cr to gr	ml, wpo	Abundant roots, few stones
			Bt1	21-33	5 YR 3/3	scl	gr	ml, wp	Abundant roots, few stones
			Bt2	33-69	5 YR 3/3	scl	m1sbk	ml, wp	Few roots and stones
			Bt3	69-150+	5 YR 4/6	scl	m1sbk	ml, wop	No roots, presence of clay skin
	5	Valley of a hill, reed undergrowth in teak, medium to dense growth, near to water course, plenty of exposed rocks	A	0-20	7.5 YR 3/4	gsl	cr to gr	ml, wpo	Abundant roots, few rock fragments
			Bt1	20-33	5 YR 3/3	gscl	gr to m	ml, wp	Abundant roots, few stones
			Bt2	33-72	5 YR 3/3	scl	m1sbk	ml, wp	No roots, few stones. presence of clay skin
			Bt3	72-112	5 YR 3/3	scl	m1sbk	ml, wp	Presence of lateritic gravels
			C	112+	Weathered rock				
	6	Valley of a hill, reed undergrowth in teak, medium to dense growth, near to water course, plenty of exposed rocks	A	0-20	7.5 YR 3/4	gsl	cr to gr	ml, wpo	Abundant roots, few stones
			Bt1	20-33	5 YR 3/3	gscl	m1sbk	ml, wp	Abundant roots, few stones
			Bt2	33-73	5 YR 3/3	scl	m1sbk	mfi, wop	No roots, few stones and presence of clay skin
			Bt3	70-150+	5 YR 3/3	scl	m1sbk	mfi, wop	Few lateritic gravels
	7	Middle of a hill, northern aspect, pure reed patch, closed canopy, no undergrowth, abundant litter	A1	0-6	7.5 YR 3/4	sl	cr to gr	ml, wpo	Abundant roots, presence of partly decomposed litter
			A2	6-62	7.5 YR 5/4	sl	cr to gr	mfr,wpo	Abundant roots, presence of big stones and lateritic gravels
			Bw1	62-80	5 YR 4/3	gscl	m	ml, wpo	Plenty of roots presence of lateritic gravels
			Bw2	80-108	5 YR 4/3	scl	m	ml, wpo	No roots, presence of lateritic gravels
			Bw3	108-126	5 YR 4/3	sl	m	ml, wpo	Presence of lateritic gravels
			C	126+	Weathered rock				

Plate 5. Reed clumps - rhizomes and roots exposed

Plate 6. Closed canopy of a natural reed patch

Plate 7. Litter cover in natural reed patch

Plate 8. Root ramification of reed on soil surface

Table 2 (continued)

Eln/ tpy	Profile No.	Site features	Horizon	Depth (cm)	Colour	Texute	StrUcture	Consistence	Special features
HS	8	Lower middle of a hill pure reed patch, closed canopy, no undergrowth, abundant litter	A1	0-4	7.5 YR 3/4	gsl	cr	ml, wpo	Abundant roots, presence of partly decomposed litter
			A2	4-28	7.5 YR 5/4	sl	cr to gr	mfi, wpo	Plenty of roots
			Bw1	28-54	5 YR 4/3	sl	m	ml, wpo	Presence of stony layer and plenty of roots
			Bw2	54-88	5 YR 4/3	sl	m	ml, wpo	Few roots and no stones
			Bw3	88-115+	5 YR 4/3	gsl	m	ml, wpo	Presence of lateritic gravels
	9	Lower middle of a hill, southern aspect, pure reed patch, closed canopy, no undergrowth, abundant litter	A1	0-4	10 YR 3/3	sl	cr	ml, wpo	Abundant roots, presence of partly decomposed litter
			A2	4-26	10 YR 6/3	sl	cr to gr	ml, wpo	Abundant roots, few stones
			Bw1	26-46	10 YR 5/4	sl	m	ml, wpo	Few roots, red concretions, presence of charcoal layer
			Bw2	46-108+	10 YR 5/4	sl	m	mfr, wpo	Few roots, plenty of stones
HF	10	Pure reed patch, dense growth, near to water course, closed canopy, no undergrowth, litter abundant	A1	0-2	7.5 YR 5/4	sl	cr	ml, wpo	Abundant roots, presence of partly decomposed litter
			A2	2-25	7.5 YR 6/4	sl	cr to gr	ml, wpo	Abundant roots, presence of rock fragments
			Bt	25-70	5 YR 5/3	gscl	m1sbk	ml, wp	Plenty of roots,presence of lateritic gravels
			C	70+	Weathered rock				
	11	Valley of a hill, reed under growth in moist deciduous trees, very near to water course, abundant litter	A	0-4	7.5 YR 5/4	sl	cr	ml, wpo	Abundant roots, plenty of partly decomposed litter
			Bw	4-63	5 YR 4/6	gsl	gr	ml, wpo	Abundant roots
			C	63+	Weathered rock				
	12	Valley of a hill, reed under growth in moist deciduous trees, medium to dense growth, abundant litter	A1	0-4	7.5 YR 3/4	sl	cr	ml, wpo	Abundant roots, presence of partly decomposed litter and macropores
			A2	4-20	7.5 YR 4/6	gsl	cr to gr	mfr, wpo	Abundant roots, few stones
			Bw	20-100+	5 YR 4/3	gsl	m	mfr, wpo	Presence of rock fragments
					Poovamkutty				
LS	13	Upper middle of a hill, northern aspect, poor reed growth, few undergrowth, few litter	A	0-14	7.5 YR 3/2	sl	cr to gr	ml, wpo	Abundant roots
			Bt1	14-40	5 YR 4/4	scl	m1sbk	ml, wpo	Few roots, presence of rock fragments and clay skin
			Bt2	40-140	10 YR 5/4	scl	m1sbk	mfr, wop	Few roots, presence of rock fragments
			C	140+	Weathered rock				
	14	Middle of a hill, northern aspect, medium reed growth, few undergrowth, plenty of litter	A	0-12	7.5YR 3/2	sl	cr	ml, wpo	Abundant roots
			Bt1	12-39	5 YR 6/4	scl	gr to m	ml, wpo	Abundant roots
			Bt2	39-100	2.5 YR 3/6	gscl	m1sbk	mfr, wop	Plenty of roots, presence of clay skin
			Bt3	100-150+	2.5 YR 4/8	gscl	m1sbk	mfi, wop	Few roots and lateritic gravels
	15	Lower part of a hill, northern aspect, medium reed growth, few to plenty of litter	A	0-8	7.5 YR 3/2	sl	cr	ml, wpo	Abundant roots
			Bt1	8-42	5 YR 4/4	scl	gr to m	ml, wpo	Abundant roots, few stones
			Bt2	42-125	5 YR 4/3	gscl	m1sbk	ml, wop	Few roots, plenty of rock fragments, presence of clay skin
			C	125+	Weathered rock				

Table 2 (continued)

Eln/ tpy	Prof-ile No.	Site features	Hori-zon	Depth (cm)	Colour	Tex-ture	Str-uct-ure	Consis-tence	Special features
LF	16	Top of a hill, medium reed growth, few to plenty litter	A	0-16	7.5 YR 4/4	sl	cr to gr	ml, wpo	Abundant roots
			Bt1	16-74	5 YR 4/6	scl	m1sbk	mfi, wp	Abundant roots
			Bt2	74-150+	5 YR 5/8	gscl	m1sbk	mfi, wop	No roots, presence of big stones and clay skin
	17	Bottom of a hill and top of another hill, pure reed patch, plenty of exposed rocks, few to plenty litter	A	0-16	7.5 YR 4/4	sl	cr to gr	ml, wpo	Abundant roots
			Bt	16-82	7.5 YR 6/4	scl	m1sbk	mfi, wp	Abundant roots, presence of clay skin
			C	82+	Weathered rock				
	18	Bottom of a hill, pure reed patch, few to plenty of litter, plenty of exposed rocks	A	0-18	7.5 YR 4/4	scl	cr to gr	ml, wp	Abundant roots
			Bw1	18-50	7.5 YR 6/4	sl	gr	mfr,wpo	Abundant roots
			Bw2	50-115+	5 YR 6/8	gsl	m	mfr,wpo	Few roots
HS	19	Middle of a hill, northern aspect, medium reed growth, plenty of exposed rocks, abundant litter	A1	0-8	7.5 YR 4/4	sl	cr	ml, wpo	Abundant roots, presence of partly decomposed litter and macropores
			A2	8-45	7.5 YR 5/2	ls	cr to gr	ml, wpo	Abundant roots, presence rock fragments
			Bt1	45-102	5 YR 6/6	scl	m1sbk	mfr, wpo	Few roots, presence of big stones
			Bt2	102-129	7.5 YR 5/4	scl	m1sbk	mfr, wop	Few roots
			Bt3	129-147	10 YR 5/8	scl	m1sbk	ml, wop	Few roots, presence of clay skin
			C	147+	Weathered rock				
	20	Upper middle of a hill, northern aspect, medium to dense reed growth, very few under growth, presence of big boulders, abundant litter	A1	0-4	7.5 YR 3/4	sl	cr	ml, wpo	Abundant roots, presence of partly decomposed litter
			A2	4-64	7.5 YR 3/4	sl	cr	ml, wpo	Abundant roots
			Bw1	64-75	7.5 YR 3/4	sl	m	ml, wpo	Presence of rock fragments
			Bw2	75-125+	10 YR 5/8	sl	m	ml, wpo	No roots
	21	Upper middle of a hill, northern aspect, medium dense reed growth, no under growth, abundant litter	A	0-4	7.5 YR 4/4	sl	cr	ml, wpo	Abundant roots, presence of partly decomposed litter
			Bw	4-102	7.5 YR 4/4	sl	cr to gr	ml, wpo	Abundant roots, presence of rock fragments
			C	102+	Weathered rock				
HF	22	Valley of a hill, thick reed patch, no undergrowth, abundant litter	A1	0-6	7.5 YR 4/2	sl	cr	ml, wpo	Abundant roots, partly decomposed litter
			A2	6-48	7.5 YR 3/4	sl	cr to gr	ml, wpo	Abundant roots, presence of big boulders
			Bw	48-115	10 YR 4/6	sl	m	ml, wpo	Few roots
			C	115+	Weathered rock				
	23	Valley of a hill, dense reed growth, no undergrowth, abundant litter, near to water course, plenty of exposed rocks	A1	0-3	7.5 YR 4/2	sl	sg	ml, wpo	Abundant roots, presence of partly decomposed litter
			A2	3-48	7.5 YR 3/4	sl	sg	ml, wpo	Abundant roots
			Bw	48-122	10 YR 4/6	sl	m	mfr, wpo	Presence of big stones
			C	112+	Weathered rock				

Table 2 (continued)

Eln/ tpy	Profile No.	Site features	Horizon	Depth (cm)	Colour	Texture	Structure	Consistence	Special features
	24	Top of a hill, dense reed growth, no under growth, abundant litter, near to water course, plenty of exposed rocks	A1	0-15	7.5 YR 2/4	sl	sg	ml, wpo	Abundant roots, presence of partly decomposed litter
			A2	15-46	7.5 YR 2/4	sl	m	ml, wpo	Abundant roots, presence of and rock fragments
			Bw	46-95	10 YR 5/4	sl	m	mfr, wpo	Presence of rock fragments
			C	95+	Weathered rock				
				Adimali					
LS	25	Lower middle of a hill, northern aspect, pure reed patch, closed canopy, no under growth, near to water course, abundant litter, plenty of exposed rocks	A	0-15	7.5 YR 2/4	sl	cr to gr	ml, wpo	Abundant roots
			Bt1	15-48	7.5 YR 3/2	sl	m1sbk	ml, wpo	Plenty of roots
			Bt2	48-76	7.5 YR 5/2	gsl	m1sbk	mfr, wpo	Few rock fragments
			Bt3	76-115	5 YR 4/4	scl	m1sbk	mfi, wp	Few roots, plenty of rock fragments, presence of clay skin
			C	115+	Weathered rock				
	26	Upper middle of a hill, western aspect, pure reed patch, no under growth, closed canopy, abundant litter	A	0-20	7.5 YR 3/2	sl	cr to gr	ml, wpo	Abundant roots
			Bt1	20-60	7.5 YR 5/2	sl	m1sbk	mfr, wpo	Abundant roots
			Bt2	60-150+	7.5 YR 3/2	scl	m1sbk	mfi, wp	Plenty of rock fragments, presence of clay skin
	27	Lower middle of a hill, northern aspect, pure reed patch, no under growth, closed canopy, abundant litter, plenty of exposed rocks	A	0-12	7.5 YR 2/4	sl	cr to gr	ml, wpo	Abundant roots
			Bt1	12-42	7.5 YR 3/2	scl	m1sbk	ml, wpo	Plenty of roots
			Bt2	42-126	7.5 YR 3/2	scl	m1sbk	ml, wp	Few roots and rock fragments, presence of clay skin
			C	126+	Weathered rock				
LF	28	Bottom of a hill, pure reed patch, no under growth, closed canopy, abundant litter, few exposed rocks	A1	0-2	7.5 YR ¾	ls	cr	ml, wpo	Abundant roots
			A2	2-39	7.5 YR 5/2	sl	cr to gr	mfi, wp	Abundant roots, presence of rock fragments, moutles and termatarium
			Bw	39-120+	5 YR 4/3	sl	m	mfi, wp	Few roots, plenty of rock fragments
	29	Bottom of a hill, pure reed patch, no under growth, closed canopy, abundant litter, few exposed rocks	A	0-59	7.5 YR 2/4	ls	cr to gr	ml, wpo	Abundant roots
			AB	59-78	7.5 YR 5/2	sl	m1sbk	mfi, wp	Few roots
			Bt	78-150+	5 YR 4/3	sl	m1sbk	mfri, wp	Very few roots, presence of clay skin
	30	Bottom of a hill, pure reed patch, no under growth, closed canopy, abundant litter, few exposed rocks	A1	0-2	7.5 YR 2/4	sl	Cr	ml, wpo	Abundant roots
			A2	2-48	7.5 YR 5/2	sl	cr to gr	mfr, wp	Few roots
			Bt	48-154+	5 YR 4/3	sl	m1sbk	mfr, wp	Few roots, presence of clay skin
	31	Middle of a hill, western aspect, pure reed patch, no under growth, closed canopy, abundant litter, exposed rocks plenty	A	0-7	7.5 YR 2/4	sl	Cr	ml, wpo	Abundant roots, presence of partly decomposed litter
			Bw	7-85	7.5 YR 2/4	ls	cr to gr	ml, wpo	Plenty of roots and rock fragments
			C	85+	Weathered rock				

Table 2 (continued)

Eln/ tpy	Prof- ile No.	Site features	Hor- izon	Depth (cm)	Colour	Text- ure	Strcture	Cons- istence	Special features
HS	32	Middle of a hill, southern aspect, pure reed patch, no undergrowth, closed canopy, abundant litter	A1	0-3	7.5 YR 2/4	sl	cr	ml, wpo	Abundant roots, presence of partly decomposed litter
			A2	3-22	7.5 YR 5/2	sl	cr to gr	ml, wpo	Abundant roots
			AB	22-60	7.5 YR 5/2	sl	m	ml, wpo	Few roots,
			Bw	60-128	5 YR 4/3	sl	m	ml, wpo	No roots, presence of big boulders
			C	128+	Weathered rock				
	33	Upper middle of a hill, northern aspect, pure reed patch, closed canopy, no under growth, abundant litter, plenty of exposed rocks	A	0-4	7.5 YR 2/4	sl	cr	ml, wpo	Abundant roots, presence of partly decomposed litter
			Bw	4-90	7.5 YR 2/4	sl	cr to gr	ml, wpo	Abundant roots
			C	90+	Weathered rock				
	34	Valley of a hill, pure reed patch, closed canopy, no under growth, very near to water course, abundant litter, plenty of exposed rocks	A	0-3	7.5 YR 2/4	scl	cr	ml, wpo	Abundant roots, presence of partly decomposed litter
			Bw	3-48	7.5 YR 5/3	sl	cr to gr	ml, wpo	Abundant roots
			C	48+	Weathered rock				
HF	35	Valley of a hill, pure reed patch, closed canopy, no under-growth, abundant litter, plenty of exposed rocks	A1	0-15	7.5 YR2/4	sl	cr	ml, wpo	Abundant roots, presence of partly decomposed litter
			A2	15-46	7.5 YR 3/4	sl	cr to gr	ml, wpo	Abundant roots, plenty of rock fragments
			Bw	46-95	10 YR 5/4	scl	m	ml, wpo	Abundant rock fragments
			C	95+	Weathered rock				
	36	Valley of a hill, pure reed patch, closed canopy, no under-growth, near to water course, abundant litter	A	0-4	7.5 YR 3/4	gsl	cr	ml, wpo	Abundant roots, presence of partly decomposed litter
			Bw	4-115	7.5 YR 5/2	sl	m	mfr, wp	Plenty of roots, presence of mottles
			C	115+	Weathered rock				
Pamba									
LS	37	Lower middle of a hill northern aspect, reed undergrowth in moist deciduous forests few exposed rocks, plenty of litter	A	0-8	7.5 YR ¾	scl	cr	ml, wpo	Abundant roots
			AB	8-68	7.5 YR 5/2	gscl	cr to gr	mfi, wp	Abundant roots, presence of mottles, big stones and lateritic gravels
			Bt	68-150+	5 YR 4/3	scl	m2sbk	mfi, wp	Few roots. presence of clay skin and lateritic gravels
	38	Lower middle of a hill, northern aspect, reed under growth in moist deciduous forests, few exposed rocks, plenty of litter	A	0-8	7.5 YR 3/4	scl	cr	ml, wpo	Abundant roots
			AB	8-54	7.5 YR 5/2	gscl	cr to gr	mfi, wop	Abundant roots, presence of clay skin. big stones and lateritic gravels
			Bt	54-150+	5 YR 4/3	gscl	m1sbk	mfi, wop	Few roots. presence of clay skin and lateritic gravels

Table 2 (continued)

Eln/ tpy	Prof-ile No.	Site features	Hor-izon	Depth (cm)	Colour	Tex-ture	Strct-ure	Cons-istence	Special features
	39	Lower middle of a hill, southern aspect, reed undergrowth in moist deciduous forest, few exposed rocks, plenty of litter	A	0-6	7.5 YR 3/4	gscl	cr	ml, wpo	Abundant roots
			AB	6-70	7.5 YR 5/2	gscl	cr to gr	mfi, wop	Plenty of few roots, presence of big stones and lateritic gravels
			Bt	70-128	5 YR 4/3	gscl	m1sbk	mfi, wop	Few roots, presence of lateritic gravels
			C	128+	Weathered rock				
LF	40	Valley of a hill, reed undergrowth in semi evergreen forest, near to water course, plenty of litter	A	0-15	7.5 YR 3/2	scl	cr to gr	mfr, wp	Abundant roots
			Bw	15-105	5 YR 4/3	scl	m	mfr, wpo	Plenty of roots
			C	105	Weathered rock				
	41	Valley of a hill, reed under growth in semi evergreen forest, near to water course, plenty of litter	A	0-17	7.5 YR 3/2	scl	cr to gr	mfr, wp	Abundant roots
			Bw	17-88	5 YR 4/3	scl	m	mfr, wp	Plenty of roots
			C	88+	Rocky layer				
	42	Valley of a hill, reed undergrowth in semi evergreen forests, near to water course, plenty of litter	A	0-24	7.5 YR 3/2	scl	cr to gr	mfr, wp	Abundant roots, presence of partly decomposed litter
			Bw	24-105	5 RY 4/3	scl	m	mfr, wp	Plenty to few roots
			C	105+	Weathered rock				
HS	43	Lower middle of a hill, northern aspect, pure reed patch, no undergrowth, closed canopy, abundant litter	A1	0-4	7.5 YR3/2	sl	cr	ml, wpo	Abundant roots, presence of partly decomposed litter
			A2	4-20	7.5 YR 4/4	gsl	cr to gr	ml, wpo	Abundant roots, presence of clay skin and lateritic gravels
			Bt1	20-54	5 YR 5/6	scl	m1sbk	mfi, wp	Plenty to few roots, presence of clay skin and lateritic gravels
			Bt2	54-150+	5 YR 5/8	gscl	m2sbk	mfi, wop	No roots. presence of lateritic gravels
	44	Upper middle of a hill, southern aspect, pure reed patch, no under growth, closed canopy, abundant litter	A1	0-4	7.5 YR 2/2	scl	cr	ml, wpo	Abundant roots, presence of partly decomposed litter
			A2	4-28	7.5 YR 4/4	scl	cr to m	mfr, wp	Plenty of roots
			Bt1	28-46	10 YR 4/6	gscl	m1sbk	mfi, wp	Few roots
			Bt2	46-140	5 YR 4/3	gscl	m2sbk	mfi, wop	No roots. presence lateritic gravesl
			C	140+	Weathered rock				
	45	Lower middle of a hill, pure reed patch, no under growth, plenty of litter	A	0-3	7.5 YR 2/2	sl	cr	ml, wpo	Abundant roots, presence of partly decomposed litter
			Bw	3-32	7.5 YR 4/4	sl	gr	mfi, wp	Abundant roots, presence of big stones
			C	32+	Weathered rock				

Table 2 (continued)

Eln/ tpy	Profile No.	Site features	Horizon	Depth (cm)	Colour	Texture	Strcture	Consistence	Special features
HF	46	Valley of a hill, medium to dense reed growth, abundant litte	A1	0-3	10 YR 2/2	sl	cr	ml, wpo	Abundant roots, presence of partly decomposed litter
			A2	3-11	7.5 YR 4/6	sl	gr	ml, wpo	Abundant roots
			Bw	11-105+	5 YR 4/4	sl	gr to sbk	mfi, wp	Plenty of roots
	47	Valley of a hill, dense reed growth, closed canopy, no under-growth, abundant litter	A1	0-3	7.5 YR /2	sl	cr	ml, wpo	Abundant roots, presence of partly decomposed litter
			A2	3-10	7.5 YR 3/4	sl	gr	ml, wpo	Abundant roots
			Bt1	10-13	7.5 YR 4/6	scl	gr	mfr, wp	Abundant roots
			Bt2	13-96	10 YR 4/6	gscl	m1sbk	mfi, wp	Presence of clay skin and lateritic gravels
			C	96+	Weathered rock				
	48	Valley of a hill, pure reed patch, no under-growth, closed canopy, abundant litter	A1	0-5	7.5 YR 3/4	sl	cr	ml, wpo	Abundant roots
			A2	5-15	7.5 YR 4/4	sl	gr	ml, wpo	Abundant roots
			Bt1	15-40	5 YR 6/3	scl	gr	mfr, wp	Plenty of roots
			Bt2	40-78	5 YR 6/3	gscl	m1sbk	mfi, wop	Presence of clay skins and big stones
			C	78+	Weathered rock				

Eln=Elevation; tpy = topography; LS = Sloping land at low elevation; LF = Flat to undulating land at low elevation; HS = Sloping land at high elevation; HF = Flat to undulating land at high elevation

Texture: gravel (g); sand (s); sandy loam (sl); clay loam (cl)
Structure: granular (gr); fine (f); medium (m); crumb (cr); sub angular blocky (sbk)

Consistence:	Wet soil	Moist soil
	non plastic (wpo)	loose (ml)
	fairly plastic (wp)	friable (mfr)
	very plastic (wvp)	firm (mfi)
		very firm (mvfi)

Reeds flourished on both shallow and deep soils. In deep soils B horizon was comparatively thicker than shallow soils. In majority of the profiles the parent material constituted gneissic materials.

It was also observed that in pure reed brakes where upper canopy was closed the undergrowth was completely absent. This is thought to be due to the prevention of sunlight by the closed canopy and inhibition of regeneration of undergrowth by the root mat of reed.

1.2. Physical characteristics

Table 3 gives a clear picture of depth-wise distribution of various soil physical properties in reed growing tracts. The properties studied include texture, bulk density, particle density, porosity and maximum water holding capacity.

Texture

The forest soils of Kerala generally show wide variation in the content of gravel (4-79 per cent) and this is attributed to the variation in the degree of disturbance to natural forests (Thomas and Brito-Mutunayagam, 1965; Sankar *et al.*, 1987; Alexander, 1987 and Elsy, 1989). Reed growing soils also showed wide variation in the content of gravel and it was found dominated by rock fragments rather than secondary lateritic gravels. In general it was comparatively lower in soils supporting pure reed patches than reed undergrowth in teak and moist deciduous trees. In pure reed patches due to the closed canopy and thick litter cover, the soil is not supposed to be exposed to the direct actions of rain and sun and this explains the relatively low content of secondary gravels observed in these soils. In pure reed areas, surface soils were observed to contain less content of gravel than subsurface layers.

Forest soils of Kerala texturally are sandy, sandy loam or sandy clay loam (Thomas and Brito-Mutunayagam, 1965; Sankar *et al.*, 1987; Alexander, 1987 and Elsy 1989). In the case of reed also sand fraction dominated (53.8 - 81.8 per cent) in the textural make up and this facilitated free movement of air and water through *the soil. But no definite pattern was observed with increase in depth of soil profiles.* The profiles struck near permanent water courses recorded relatively higher content of sand. In the case of silt also no general pattern was observed in its distribution towards lower depths of the profiles. The variation in the content of silt ranged from 3.1 to 15.2 per cent and the content of clay varied between 12.3 to 38.0 per cent from profile to profile in the reed growing tracts. Compared to surface layer an increase of clay was observed in the subsurface layers of most of the profiles which could be the illuvial clay from the upper horizon through micropores. As revealed in certain profiles reed was also found to grow on soils where surface layer carried

Plate 9. Reed growing on rocky terrain

Plate 10. Soil profile (No: 6) of reed growing tracts in Vazhachal

Plate 10. Soil profile (No. 6) of reed growing tracts in Vazhachal

Plate 11. Soil profile (No. 34) of reed growing tracts in Pooyamkutty

more clay than subsurface. This can be either due to the alluvial or colluvial deposit of finer particles before the establishment of reed.

The vertical distribution of sand, silt and clay in reed growing soils in general conveyed the fact that the texture of these soils turned from sandy loam to sandy clay loam from surface to subsurface layers of the profiles caused by the illuviation of the clay from the surface. In cases where the content of gravel was found more than 15 per cent, the texture was prefixed by the term gravelly.

Bulk density

Bulk density of a soil is greatly influenced by the content of organic matter plant roots and micro and macro fauna. Higher content of organic matter increases granulation and this encourages a fluffy and porous condition resulting in low bulk density. Similarly plant exudates, gums and resins produced by micro organisms bind the primary soil partricles, increase granulation and thus reduce bulk density. So low values of bulk density are naturally expected in forest soils and the values reported in the forest soils of Kerala ranged from 0.90 to 1.48 g cm^{-3} (Thomas and Brito- Mutunayagam, 1965, Jose and Koshy, 1972 and Elsy, 1989). Reed growing soils also showed low values of bulk density (0.54 to 1.39 g cm^{-3}) especially at upper surface. As expected a highly significant and negative correlation ($r=-0.7126^{**}$) of bulk density with organic carbon was also observed. In addition to the relatively high accumulation of organic matter, the fibrous roots matting the soil surface were also found to have a special role in reducing the values of bulk density in these soils.

Results also reveal a distinct tendency for the bulk density to rise with profile depth (Fig. 2). This apparently results from a lower content of organic matter, less aggregation and root penetration and a compaction caused by the weight of the over lying layers.

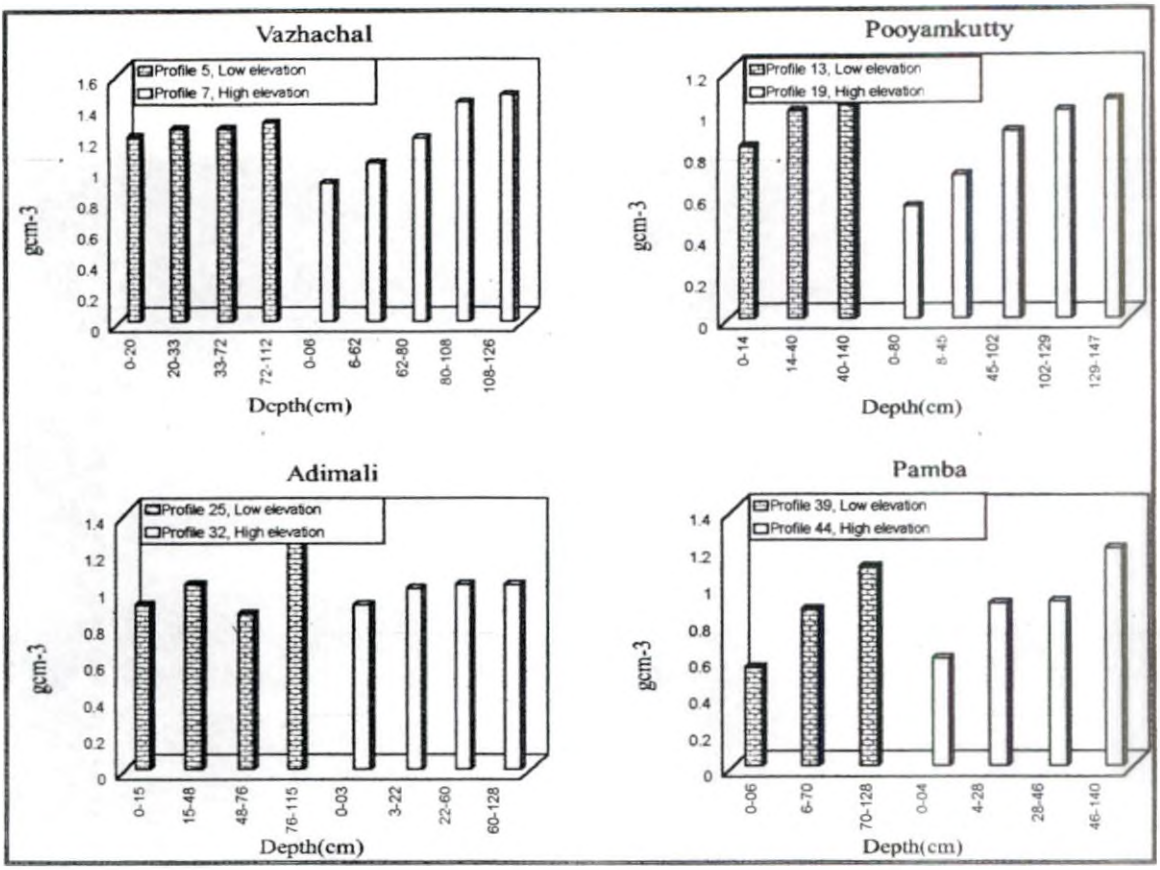


Fig. 2. Depth wise variation of bulk density in reed growing soils

Particle density

The values of particle density in forest soils of Kerala generally varied from 1.73 - 2.52 g cm^{-3} (Thomas and Brito-Mutunayagam, 1965, Jose and Koshy, 1972 and Elsy, 1989) and in the present study it ranged from 1.47-2.88 g cm^{-3}. The wide variation between the minimum and maximum values indicates heterogeneity in the composition of parent material. More over particle density is greatly influenced by the content of organic matter. Considerable variations in the organic matter status of soils under study might have reflected in the values of particle density. Role of fine fibrous roots ramifying through the soil is also important in this context. Variations in textural classes (sandy loam to sandy clay loam) observed in this study also result in conspicuous variation in the values of particle density. But no definite trend was observed with increase in depth of soil profiles.

Table 3. Physical characteristics of soil profiles in reed growing tracts

Eln / tpy	Prof-ile No.	Depth (cm)	Hori-zon	Gravel %	Sand %	Silt %	Clay %	BD g cm^{-3}	PD g cm^{-3}	Porosity %	MWHC %
Vazhachal											
LS	1	0-13	A	30.2	74.1	11.4	14.5	1.08	2.48	56.50	39.02
		13-43	Bt_1	28.1	69.2	12.0	18.8	1.12	2.62	57.30	34.47
		43-150+	Bt_2	31.3	66.8	9.0	24.2	1.22	2.55	52.20	31.79
	2	0-10	A	41.0	68.8	12.9	18.3	1.01	2.46	58.90	36.91
		10-56	Bt1	17.1	67.1	11.2	21.7	1.16	2.37	51.10	35.61
		56-150+	Bt2	8.7	62.5	12.0	25.5	1.32	2.34	43.60	35.56
	3	0-9	A	24.8	69.8	12.2	18.0	0.98	2.37	58.60	36.55
		9-41	Bt1	37.8	59.3	12.2	28.5	1.11	2.54	56.30	36.02
		41-77	Bt2	29.3	57.2	11.0	31.8	1.30	2.54	52.80	36.47
		77+	Weathered rock								
LF	4	0-21	A	30.0	72.9	13.4	13.7	1.01	2.47	59.10	38.01
		21-33	Bt1	39.5	60.3	12.1	27.6	1.09	2.56	57.20	36.00
		33-69	Bt2	19.6	59.0	12.5	28.5	1.18	2.49	52.60	32.60
		69-150+	Bt3	17.4	60.5	11.0	34.2	1.19	2.54	48.50	30.22
	5	0-20	A	31.9	76.7	11.0	12.3	1.19	2.58	53.90	37.62
		20-33	Bt1	32.7	64.4	11.0	24.6	1.24	2.51	50.60	35.12
		33-72	Bt2	18.4	60.9	10.4	28.7	1.24	2.42	48.80	31.56
		72-112	Bt3	25.9	61.3	10.2	28.5	1.28	2.44	47.54	31.40
		112+	Weathered rock								
	6	0-20	A	32.4	70.9	13.6	15.5	1.12	2.48	54.80	37.08
		20-33	Bt1	34.5	61.9	12.6	25.5	1.14	2.55	55.30	34.98
		33-70	Bt2	18.8	54.4	11.4	34.2	1.25	2.42	48.30	31.60
		70-150+	Bt3	18.0	54.4	11.4	34.2	1.28	2.42	47.10	29.60
HS	7	0-6	A1	9.3	70.9	9.1	20.0	0.89	2.26	60.60	36.75
		6-62	A2	10.9	67.3	13.2	19.5	1.02	2.30	55.60	35.86
		62-80	Bw1	21.2	67.0	12.0	21.0	1.18	2.44	51.60	34.38
		80-108	Bw2	15.5	67.7	11.0	21.3	1.41	2.91	52.40	35.40
		108-126	Bw3	3.0	71.0	11.0	18.0	1.46	2.39	38.90	27.75
		126+	Weathered rock								
	8	0-4	A1	25.5	74.8	9.0	16.2	0.85	2.60	68.00	36.99
		4-28	A2	15.2	73.7	8.3	18.0	1.04	1.97	47.20	37.81
		28-54	Bw1	8.2	69.5	12.0	18.5	1.20	2.60	53.80	36.75
		54-88	Bw2	8.2	68.9	12.8	18.3	1.32	2.58	58.50	32.61
		88-115+	Bw3	22.7	68.3	12.1	19.6	1.35	2.52	45.70	30.99
	9	0-4	A1	12.0	70.0	11.0	19.0	0.94	2.40	60.80	36.27
		4-26	A2	13.8	72.1	8.2	19.7	1.00	2.35	57.50	35.82
		26-46	Bw1	9.6	70.2	13.1	16.7	1.24	2.70	54.60	34.26
		46-108+	Bw2	14.9	68.6	13.1	18.3	1.37	2.88	52.40	35.40
HF	10	0-2	A1	12.0	70.0	16.0	14.0	0.92	2.38	61.30	39.39
		2-25	A2	22.1	65.8	15.0	19.2	1.26	2.71	53.50	41.18
		25-70	Bt	72.0	58.5	11.0	30.5	1.37	2.46	30.40	38.76
		70+	Weathered rock								

Table 3. (continued)

Eln / tpy	Profile No.	Depth (cm)	Horizon	Gravel %	Sand %	Silt %	Clay %	BD g cm^{-3}	PD g cm^{-3}	Porosity %	MWHC %
	11	0-4	A	14.7	78.5	7.5	14.5	1.18	2.58	50.60	35.44
		4-63	Bw	31.0	81.0	5.0	14.0	1.32	2.42	42.40	31.60
		63+	Weathered rock								
	12	0-4	A1	13.8	73.3	10.0	16.7	1.08	2.42	55.70	38.65
		4-20	A2	32.0	73.1	11.1	15.8	1.35	2.51	46.90	36.43
		20-100+	BW	31.3	74.4	10.0	15.6	1.49	2.78	41.10	35.48
Pooyamkutty											
LS	13	0-14	A	8.3	70.7	13.1	16.2	0.83	2.09	60.30	39.76
		14-40	Bt1	13.5	64.2	13.0	22.8	1.00	2.57	61.10	34.70
		40-140	Bt2	16.5	62.8	15.2	32.0	1.03	2.46	58.10	31.90
		140+	Weathered rock								
	14	0-12	A	8.0	77.4	7.4	15.2	0.95	2.81	66.20	37.40
		12-39	Bt1	11.4	65.6	12.5	21.9	1.08	2.39	54.20	35.33
		39-100	Bt2	26.2	56.9	15.1	38.0	1.05	2.49	57.80	32.02
		100-150+	Bt3	22.8	57.0	15.0	38.0	1.16	2.54	54.33	29.20
	15	0-8	A	9.0	71.5	11.8	16.7	0.99	2.12	53.30	38.50
		8-42	Bt1	12.6	67.2	11.6	21.2	1.08	2.40	55.00	36.00
		42-125	Bt2	22.0	63.3	8.5	28.2	1.09	2.49	56.00	32.80
		125+	Weathered rock								
LF	16	0-16	A	7.7	68.5	12.0	19.5	0.93	2.40	61.30	35.80
		16-74	Bt1	11.0	68.6	10.2	21.2	1.03	2.42	57.40	32.20
		74-150+	Bt2	24.8	60.9	10.8	28.3	1.10	2.46	55.20	30.30
	17	0-16	A	6.1	75.5	8.0	16.5	0.73	2.39	69.50	33.60
		16-82+	Bt	10.0	62.3	9.0	28.7	0.98	2.42	59.50	32.90
		82-	Weathered rock								
	18	0-18	A	8.0	64.1	10.4	25.5	0.70	2.39	70.70	33.20
		18-50	Bw1	10.7	69.5	10.8	19.7	1.01	2.42	58.30	30.10
		50-115+	Bw2	24.0	71.5	12.0	16.5	1.20	2.48	51.60	29.00
HS	19	0-8	A1	3.2	80.0	5.0	15.0	0.54	2.82	80.90	36.90
		8-45	A2	12.9	81.8	6.2	12.0	0.69	2.56	73.00	34.00
		45-102	Bt1	12.7	72.1	9.4	18.5	0.90	2.46	66.40	30.10
		102-129	Bt2	13.6	62.2	8.6	29.2	1.00	2.46	59.30	29.60
		129-147	Bt3	11.8	60.0	8.6	31.4	1.05	2.49	59.40	34.70
		147+	Weathered rock								
	20	0-4	A1	3.4	76.9	9.0	14.1	0.68	2.50	72.80	28.80
		4-64	A2	12.5	78.1	7.4	14.5	0.79	2.39	66.90	34.30
		64-75	Bw1	10.8	77.5	9.0	13.5	1.00	2.87	65.20	31.70
		75-125+	Bw2	12.8	79.6	5.4	15.0	1.04	2.27	54.20	28.20
	21	0-4	A	2.9	76.6	6.8	16.6	0.69	2.50	72.40	37.10
		4-102	Bw	13.2	73.9	7.4	18.7	0.75	2.42	69.00	34.00
		102-	Weathered rock								

Table 3. (continued)

Eln / tpy	Prof-ile No.	Depth (cm)	Horizon	Gravel %	Sand %	Silt %	Clay %	BD g cm^{-3}	PD g cm^{-3}	Porosity %	MWHC %
HF	22	0-6	A1	7.4	75.9	8.1	16.0	0.82	2.44	66.40	35.48
		6-48	A2	16.8	75.6	7.0	17.4	0.94	2.54	63.00	31.30
		48-115	Bw	9.2	72.4	9.2	18.4	1.15	2.54	54.70	30.50
		115+	Weathered rock								
	23	0-3	A1	4.1	81.5	4.0	14.5	0.72	2.50	71.20	37.10
		3-48	A2	12.9	80.2	4.0	15.8	0.83	2.39	65.30	34.20
		48-122	Bw	10.0	76.5	7.0	16.5	1.08	2.54	57.50	30.20
		122+	Weathered rock								
	24	0-15	A1	5.8	80.5	4.0	15.5	0.80	2.40	66.70	37.70
		15-46	A2	14.9	77.6	5.5	16.9	0.85	2.50	66.00	34.80
		46-95	Bw	10.4	73.3	9.5	17.2	1.16	2.54	54.30	29.20
		95+	Weathered rock								
Adimali											
LS	25	0-15	A	8.5	77.0	8.0	15.0	0.90	2.21	59.30	36.12
		15-48	Bt1	12.6	72.4	9.6	18.0	1.01	2.16	53.20	34.40
		48-76	Bt2	27.6	72.5	9.5	18.0	0.85	2.35	63.80	32.00
		76-115	Bt3	13.4	64.0	7.0	29.0	1.25	2.38	47.50	31.20
		115+	Weathered rock								
	26	0-20	A	8.0	77.5	7.5	15.0	0.93	2.50	71.80	36.20
		20-60	Bt1	12.0	72.2	8.3	19.5	1.01	2.57	60.70	35.10
		60-105	Bt2	10.6	58.9	11.1	30.0	1.02	2.83	63.60	32.00
	27	0-12	A	9.3	74.8	7.0	18.2	0.90	2.20	59.10	38.50
		12-42	Bt1	13.1	71.0	6.5	22.5	1.05	2.14	50.90	35.80
		42-126	Bt2	15.8	62.2	10.0	27.8	1.02	2.35	56.60	33.10
		126+	Weathered rock								
LF	28	0-2	A1	2.0	81.9	3.9	14.2	0.65	2.84	77.10	36.70
		2-39	A2	8.2	76.2	8.2	15.6	0.79	2.64	70.10	32.30
		39-120+	Bw	10.9	66.3	8.2	15.0	1.24	2.49	50.20	28.10
	29	0-59	A	5.9	81.7	5.1	13.2	0.63	2.12	70.30	35.19
		59-78	AB	6.0	79.8	3.9	16.3	0.80	2.15	62.80	33.20
		78-150+	Bt	14.6	64.2	9.8	26.0	1.02	2.02	49.50	32.20
	30	0-2	A1	6.0	80.7	5.3	14.0	0.59	2.08	71.60	36.70
		2-48	A2	14.0	79.1	3.3	17.6	0.82	2.21	62.90	33.20
		48-154+	Bt	12.0	63.0	8.1	28.9	1.14	2.15	47.00	31.00
HS	31	0-7	A	11.1	76.8	9.5	13.7	0.56	2.08	73.10	37.90
		7-85	Bw	7.5	79.4	8.5	12.4	0.70	2.07	66.20	41.80
		85+	Weathered rock								
	32	0-3	A1	12.0	80.6	3.1	16.3	0.90	2.82	68.09	37.70
		3-22	A2	6.8	73.0	8.4	18.6	0.99	2.54	61.02	35.40
		22-60	AB	6.1	72.5	8.6	18.9	1.01	2.82	75.20	35.20
		60-128	Bw	6.0	73.0	9.0	18.0	1.01	2.49	59.40	34.70
		128+	Weathered rock								

Table 3. (continued)

Eln / tpy	Profile No.	Depth (cm)	Horizon	Gravel %	Sand %	Silt %	Clay %	BD g cm^{-3}	PD g cm^{-3}	Porosity, %	MWHC, %
	45	0-3	A	6.2	71.8	9.8	18.4	0.68	2.15	68.40	39.20
		3-32	Bw	12.0	68.6	12.6	18.8	1.00	2.12	52.80	35.10
		32+	Weathered rock								
HF	46	0-3	A1	8.0	73.5	9.8	16.7	0.49	1.43	65.70	42.20
		3-11	A2	6.9	73.0	9.9	17.1	0.79	2.11	62.60	36.20
		11-105+	Bw	11.9	77.7	6.8	15.5	0.96	2.34	59.00	33.00
	47	0-3	A1	18.9	80.3	7.1	12.6	0.58	2.17	73.30	40.40
		3-10	A2	11.7	77.4	6.4	16.2	0.90	2.28	60.50	35.10
		10-43	Bt1	13.7	67.0	6.4	26.6	1.15	2.41	52.30	32.30
		43-96	Bt2	35.1	62.5	8.0	29.5	1.08	2.17	50.20	29.15
		96+	Weathered rock								
	48	0-5	A1	3.6	81.1	5.4	13.5	0.69	2.18	68.30	40.80
		5-15	A2	9.8	73.7	9.6	16.7	0.94	2.26	58.80	36.70
		15-40	Bt1	12.0	63.7	10.5	25.8	1.02	2.75	62.90	33.30
		40-78	Bt2	38.7	61.5	6.4	32.1	1.13	2.70	58.10	29.26
		78+	Weathered rock								

Eln = Elevation; tpy = topography; BD = bulk density; PD = particle density; MWHC = maximum water holding capacity; LS = sloping land at low elevation; LF = flat to undulating land at low elevation; HS = sloping land at high elevation at high elevetaion; HF = flat to undulating land at high elevation

Porosity

Normally the porosity of a sandy surface soil is in the range 35-50 per cent and in the forest soils of Kerala it ranges from 42.6-55.76 per cent (Thomas and Brito-Mutunayagam, 1965, Jose and Koshy, 1972 and Elsy, 1989). Results of the present study indicated that porosity of reed growing soils varied from 41.10 to 80.9 per cent. Porosity was found to be related to bulk density as evidenced by a significant and negative correlation (r=-0.5268**) between them. According to the report of improvement in bamboo plantation in India (Anonymous, 1961) the soils under *Bambusa arundinaceae* in Hasanar area of Madras State was extra ordinarily light and loose down to 50 cm depth. High content of organic carbon together with the ramifying roots is expected to improve aeration in these soils.

Maximum water holding capacity

The maximum water holding capacity down the profiles varied from 27.75 to 42.2 per cent in the reed growing soils. Forest soils of Kerala in general were observed to have 28.1 - 63.2 per cent water holding capacity (Thomas and Brito

Mutunayagam, 1965; Yadav *et al.*, 1970; Jose and Koshy, 1972). Within each profile, the maximum water holding capacity decreased towards lower depths, mainly due to the depletion of organic matter. Owing to the dominance of sand fraction in these soils, the water holding capacity was supposed to be mainly a function of organic matter. This is supported by a significant and positive correlation (r=0.5185**) of water holding capacity and organic carbon content.

1.3. Chemical characteristics

The soil analytical results of various chemical properties down the profiles at reed growing tracts are listed in Tables 4 and 5. Table 4 exhibits the characters related to soil reaction, organic carbon and exchange characteristics and Table 5 indicates the nutrient status of reed growing soils.

Soil reaction (pH)

Various studies conducted so far in the forest soils of Kerala (Thomas and Brito-Mutunayagam, 1965; Yadav *et al.*, 1970; Jose and Koshy, 1972; Sankar, 1987 and Elsy, 1989) indicate that these soils are generally acidic in reaction. But the degree of acidity was found to vary with the dominant vegetation it carried. According to Thomas (1991) the soils under moist deciduous forests of Wynad Forest Division in Kerala were less acidic than soils under evergreen and semi evergreen forests. The soils of reed growing tracts are strongly to moderately acid in reaction with pH variation between 4.40-5.81 in different layers of soil profiles. In areas where reed grew as an undergrowth in teak and moist deciduous forests, the soils were relatively less acidic than pure reed soils. The higher acidity of soils of pure reed areas may be due to a relatively higher accumulation of organic matter at varying stages of decomposition which can release large amounts of organic acids during the process of decomposition. Another possible reason for the higher acidity of soil under reed as compared to that of undergrowth in teak and other moist deciduous trees is the relatively basic or less acidic nature of litter from these trees. This is supported by the study of Hase and Foelster (1983) in which they found that the nutrient accumulation in the biomass / ha. of 38 years old teak plantation was in the order of 973 kg of Ca, 370 kg of N, 331 kg of K, 128 kg of Mg and 108 kg of P and the content of Ca in the teak leaf litter was 2.60 per cent. It is further strengthened by the study of Thomas (1991) in which he reported that exchangeable base status in moist deciduous forests was significantly higher than the evergreen and semi- evergreen forests of Wynad Forest Division in Kerala. The results of the present study also conveyed that in pure reed areas surface soils were more acidic than subsurface soils and in areas where reed grew as undergrowth in teak and moist deciduous forests, the surface soils were less acidic than subsurface soils. This clearly demonstrate the dominance of companion vegetation in deciding the surface soil pH of reed growing soils. Thomas and Sujatha (1992) also reported an increase of pH with depth in pure reed growing soils of Ranny Forest Division in Kerala.

Exchangeable bases

(Elsy, 1989) reported that the exchangeable base status (by summation) in moist deciduous and evergreen forests of Kerala in general ranged from 0.71 to 8.33 cmol (+) kg. In the present study it varied from 0.33 to 9.14 cmol (+) kg^{-1} of soil. In Kerala, under conditions of heavy rainfall, the bases present on soil surface are removed to bottom layers through percolating water. But in forest ecosystem, the litter on the forest floor causes the accumulation of bases on soil surface by its continuous supply through decomposition. A gradual decrease of these bases was noted with increase in depth of the profiles. But Elsy (1989) could observe accumulation of bases at lower layers of the profiles, which was thought to be due to the removal of bases from the soil surface by the high precipitation. The results of the present study, in general, indicate the accumulation of bases in the soil surface and their decrease with increase in depth of the profiles and this highlights the influence of organic residues of reed in enriching the soil surface with bases. This is further supported by a significant and positive correlation ($r=0.5697^{**}$) between exchangeable bases and organic carbon. Moreover, the closed canopy of reed and its fast uptake of bases may not be permitting the rapid leaching of bases down the profiles. The extensive ramification of fibrous roots of reed spread over the soil surface is also thought to have a great role in reducing the loss of bases through gravitational flow of water especially in thickly populated reed stands.

Among the exchangeable bases, Ca dominated and was seen concentrated in the surface soil in most of the profiles studied. In general, its content was found to decrease with increasing depth of the profiles except in a few cases. The reed litter is thought to be the main source of Ca in these soils and an added effect of teak and other moist deciduous trees was observed in areas where reed grew as an undergrowth.

Next to Ca and Mg, K dominated in the magnitude of exchangeable bases. Distribution of exchangeable K showed a diminishing trend from top to bottom of all the profiles. A similar trend was also observed in the depth wise distribution of exchangeable Mg except in a few profiles. The data also revealed that the contribution of Na in deciding the exchangeable base status of these soils was not remarkable as that is the case with acid soils in general. Since the soils under study are acidic and enjoy high precipitation, the chance of occurrence of Na in larger quantities is very meagre. Various studies conducted in the forest soils of Kerala also did not report any appreciable quantity of this element. In general, the percentage base saturation was low (14.1-67.6) in these soils and it was higher in the surface layers than subsurface layers.

Exchange acidity

The depth-wise distribution of exchange acidity in the forest soils of Kerala was reported to be in the range of 1.9 to 7.7 cmol (+) kg^{-1} (Sankar *et al.*, 1987; Alexander, 1987 and Thomas, 1991). But in the present study it ranged from 1.1 to 5.8 cmol (+) kg^{-1} and a decreasing tendency was observed from surface to the bottom of the profiles. The higher values obtained in the surface horizons can be attributed to the dominating influence of organic acids released during the decomposition of reed leaf litter. This is supported by a highly significant and positive correlation of exchange acidity with organic carbon (r=0.5167**) Nasre *et al.* (1998) reported that the surface soils in ferrugiuous soils of Western Ghats of Kerala generally had lower Al^{3+} saturation which increased with depth, for which they explained the

Table 4. Soil reaction and exchange characteristics of soil profiles in reed growing tracts

Eln./tpy	Profile No	Depth (cm)	Horizon	pH	OC' %	Exchangeable cations cmol (+) kg^{-1}				Exch. Bases	Exch. Acidity	CEC	CEC/kg clay	PBS (Amm. Acetate)
						K	Na	Ca	Mg	Cmol (+) kg^{-1}				
						Vazhachal								
LS	1	0-13	A	5.25	1.58	0.35	0.06	2.60	1.10	4.11	2.10	8.8	60.7	46.7
		13-43	Bt1	5.15	1.11	0.08	0.06	1.90	0.70	2.74	1.70	6.4	34.0	42.8
		43-150+	Bt2	5.29	0.18	0.05	0.08	1.10	0.30	1.53	1.00	3.6	14.9	42.5
	2	0-10	A	5.35	1.61	0.83	0.06	3.30	0.90	5.09	2.20	8.3	45.4	61.3
		10-56	Bt1	5.10	1.29	0.37	0.05	1.20	0.40	2.02	2.00	5.0	23.0	40.4
		56-150+	Bt2	5.08	0.16	0.19	0.06	1.00	0.20	1.45	0.10	3.8	14.9	38.2
	3	0-9	A	5.31	1.72	0.37	0.06	1.80	1.16	2.83	1.70	8.6	47.8	32.9
		9-41	Bt1	5.15	1.34	0.35	0.08	1.50	0.50	2.43	2.00	6.8	23.9	35.7
		41-77	Bt2	5.27	1.08	0.26	0.08	1.00	0.20	1.54	1.20	5.2	16.4	29.6
		77+	Weathered rock											
LF	4	0-21	A	5.11	1.43	0.30	0.09	2.20	0.30	2.89	2.20	8.1	59.1	35.7
		21-33	Bt1	5.08	1.32	0.17	0.09	1.50	0.30	2.06	2.00	6.7	24.3	30.7
		33-69	Bt2	5.14	0.70	0.18	0.09	1.00	0.20	1.47	1.40	5.2	18.2	28.3
		69-150+	Bt3	5.15	0.61	0.06	0.09	0.40	0.10	0.65	1.10	4.4	12.9	14.8
	5	0-20	A	5.40	1.67	0.43	0.09	4.30	0.10	4.92	2.20	8.4	68.3	58.6
		20-33	Bt1	5.45	1.12	0.50	0.08	2.90	0.80	4.28	2.80	8.0	32.5	53.5
		33-72	Bt2	5.07	0.79	0.59	0.13	3.10	1.40	3.22	1.40	6.2	21.6	51.9
		72-112	Bt3	5.07	0.64	0.12	0.13	2.00	0.50	1.75	1.10	4.8	16.8	36.5
		112+	Weathered rock											
	6	0-20	A	4.87	1.87	0.34	0.06	2.30	0.70	3.45	3.30	8.8	56.8	39.2
		20-33	Bt1	4.77	0.91	0.35	0.06	2.00	0.30	2.71	3.00	5.4	21.2	50.2
		33-70	Bt2	4.99	0.73	0.19	0.05	1.50	0.30	2.14	2.70	4.2	12.3	51.0
		70-150+	Bt3	5.05	0.79	0.18	0.05	1.40	0.20	1.83	0.80	4.2	12.3	43.6
HS	7	0-6	A1	4.40	2.98	0.32	0.10	1.40	1.70	3.52	3.10	10.3	51.5	34.2
		6-62	A2	4.51	1.38	0.13	0.09	1.30	0.90	2.42	2.60	7.0	35.9	34.6
		62-80	Bw1	4.85	0.72	0.04	0.08	1.40	0.90	2.42	2.40	6.4	30.5	37.8
		80-108	Bw2	5.05	0.52	0.04	0.09	1.90	0.40	2.43	1.00	6.0	28.2	40.5
		108-126	Bw3	5.18	0.30	0.03	0.08	1.10	0.80	1.29	1.50	3.6	20.0	35.8
	8	0-4	A1	4.90	2.57	0.33	0.06	2.10	1.40	3.89	3.20	9.6	59.3	40.5
		4-28	A2	4.81	2.10	0.10	0.04	0.90	1.60	2.64	2.80	8.4	46.7	31.4
		28-51	Bw1	4.81	1.57	0.07	0.04	1.20	0.30	1.61	3.50	8.0	43.2	20.1
		51-88	Bw2	4.89	1.99	0.05	0.05	0.20	0.50	1.70	1.60	8.0	43.7	21.2
		88-115	Bw3	5.11	0.52	0.02	0.04	1.20	0.60	0.86	1.40	4.1	20.9	21.4
	9	0-4	A1	4.96	2.11	0.32	0.04	1.40	0.90	2.66	3.30	8.4	44.2	31.7
		4-26	A2	4.89	1.67	0.12	0.06	0.80	0.50	1.48	3.00	7.6	38.6	19.5
		26-46	Bw1	4.82	0.73	0.06	0.04	1.20	0.20	1.50	1.50	4.8	28.7	31.3
		46-108+	Bw2	4.84	0.64	0.02	0.04	1.00	0.20	1.26	0.90	4.4	24.0	28.6
	10	0-2	A1	4.50	2.08	0.53	0.06	1.80	0.20	2.59	5.80	8.5	60.7	30.5
		2-25	A2	4.64	1.93	0.20	0.05	1.10	traces	1.35	4.70	8.3	43.2	16.3
		25-70	Bt	4.97	0.73	0.12	0.04	1.10	traces	1.26	1.00	4.0	13.1	31.5
		70+	Weathered rock											

Table 4. (continued)

Eln/ tpy	Prof-ile No	Depth (cm)	Hori-zon	pH	OC %	Exchangeable cations cmol (+) kg^{-1}				Exch bases	Exch acidity	CEC	CEC/ kg clay	PBS (Amm. Acet-ate)
						K	Na	Ca	Mg	cmol (+) kg^{-1}				
HF	11	0-4	A	5.20	2.50	0.17	0.05	1.80	traces	2.02	3.20	7.3	50.3	27.7
		4-63	Bw	5.35	1.11	0.10	0.04	1.10	0.20	1.44	2.60	3.2	22.9	34.7
		63+	Weathered rocks											
	12	0-4	A1	4.95	1.99	0.45	0.05	1.60	0.90	3.00	4.60	7.9	7.3	38.0
		4-20	A2	4.90	1.40	0.33	0.06	1.40	traces	1.79	0.80	6.4	40.5	28.0
		20-100	Bw	4.92	0.85	0.21	0.05	1.30	0.60	2.16	2.40	4.6	29.5	50.0
Pooyamkutty														
LS	13	0-14	A	5.05	2.73	1.18	0.04	3.50	0.90	5.62	3.70	9.8	60.5	57.3
		14-40	Bt1	4.50	1.56	0.26	0.03	0.60	0.20	1.09	3.40	7.2	31.6	15.1
		40-140	Bt2	4.81	0.42	0.18	0.04	0.60	0.20	1.02	0.80	3.2	10.0	31.9
		140+	Weathered rock											
	14	0-12	A	4.70	2.91	0.50	0.04	1.40	0.10	2.04	5.20	10.2	67.1	20.0
		12-39	Bt1	4.60	1.83	0.20	0.06	0.60	0.10	0.96	3.00	6.4	29.2	15.0
		39-100	Bt2	4.80	1.48	0.07	0.04	0.50	0.10	0.71	0.80	5.7	15.0	12.5
		100-150+	Bt3	4.68	0.99	0.05	0.04	0.40	traces	0.61	0.10	3.2	8.4	19.1
	15	0-8	A	4.50	2.11	0.27	0.10	2.00	0.10	2.47	5.10	7.4	44.3	33.6
		8-42	Bt1	4.82	0.91	0.16	0.10	1.40	0.10	1.76	1.10	4.6	21.7	38.3
		42-125	Bt2	4.95	0.70	0.09	0.09	0.20	traces	0.38	0.50	2.2	7.8	17.3
		125+	Weathered rock											
LF	16	0-16	A	4.55	2.25	0.51	0.05	0.88	0.80	2.24	5.30	7.2	36.9	31.1
		16-74	Bt1	4.60	1.12	0.45	0.04	0.50	0.30	1.29	1.00	4.8	22.6	26.9
		74-150+	Bt2	4.67	0.99	0.17	0.04	0.33	0.30	0.81	1.00	2.6	9.2	31.2
	17	0-16	A	4.70	2.15	0.70	0.05	1.10	0.60	2.45	5.10	7.6	46.1	32.0
		16-82	Bt	4.85	1.59	0.40	0.07	0.50	0.20	1.17	3.70	3.9	13.6	30.0
		82+	Weathered rock											
	18	0-18	A	4.52	2.04	0.59	0.05	0.62	0.18	1.44	5.20	8.2	32.2	17.6
		18-50	Bw1	4.66	1.42	0.22	0.04	0.54	0.10	0.90	3.80	4.1	20.8	22.0
		50-115+	Bw2	4.69	0.83	0.18	0.04	0.28	0.10	0.60	1.20	2.8	16.9	21.4
HS	19	0-8	A1	4.69	3.33	0.73	0.04	2.50	1.10	4.37	2.40	11.3	68.7	42.4
		8-45	A2	4.79	2.20	0.54	0.04	2.80	0.70	4.08	2.80	7.6	63.3	53.7
		45-102	Bt1	4.74	0.90	0.30	0.04	0.50	0.10	0.94	2.00	4.8	25.9	19.0
		102-129	Bt2	4.80	0.82	0.18	0.04	0.50	0.10	0.82	1.50	3.6	12.3	22.8
		129-147	Bt3	4.87	0.78	0.10	0.02	0.40	0.10	0.62	0.80	2.2	7.0	28.2
		147+	Weathered rock											
	20	0-4	A1	4.91	2.91	0.26	0.06	1.40	0.20	1.92	5.10	9.2	65.2	20.9
		4-64	A2	5.11	2.61	0.15	0.06	0.60	0.20	1.01	0.70	8.0	55.2	12.6
		64--75	Bw1	5.10	1.17	0.08	0.05	0.70	0.20	1.03	1.30	4.2	31.1	24.5
		75-125+	Bw2	4.99	0.50	0.05	0.05	0.50	0.10	0.70	1.00	2.2	14.7	31.8
	21	0-4	A	4.75	3.20	0.45	0.04	2.20	0.80	3.49	2.96	9.2	55.4	37.9
		4-102	Bw	4.82	2.67	0.26	0.02	0.60	0.20	1.08	1.20	7.1	38.0	15.2
		102+	Weathered rock											
HF	22	0-6	A1	4.86	2.35	1.30	0.07	1.90	0.70	3.97	3.80	7.8	48.8	50.9
		6-48	A2	5.05	1.20	0.79	0.04	0.60	0.70	2.13	2.40	6.0	34.5	35.5
		48-115	BW	4.85	0.57	0.46	0.05	0.50	0.10	1.11	0.70	3.4	18.5	32.6
		115+	Weathered rock											

Table 4. (continued)

Eln/ tpy	Prof-ile No	Depth (cm)	Hori-zon	pH	OC %	Exchangeable cations cmol (+) kg^{-1}				Exch bases	Exch acidity	CEC	CEC/ kg clay	PBS (Amm. Acet-ate)
						K	Na	Ca	Mg	cmol (+) kg^{-1}				
		0-3	A1	5.09	2.59	0.27	0.06	1.80	0.60	2.73	6.40	8.0	55.2	34.1
	23	3-48	A2	5.14	1.85	0.10	0.05	0.40	0.50	1.05	5.30	6.4	40.5	16.4
		48-122	Bw	4.68	0.88	0.05	0.02	0.20	0.10	0.37	5.20	3.8	23.0	9.7
		122+	Weathered rock											
		0-15	A1	4.98	2.82	0.54	0.08	1.80	0.50	2.92	6.40	8.0	51.6	36.5
	24	15-46	A2	5.00	1.57	0.40	0.08	0.40	0.50	1.38	5.30	6.2	36.7	22.3
		46-95	Bw	4.94	1.40	0.09	0.04	0.20	traces	0.33	5.20	4.0	23.3	8.3
		95+	Weathered rock											
Adimali														
		0-15	A	4.5	2.50	0.36	0.09	1.80	0.70	2.95	8.10	8.8	58.7	33.5
	25	15-48	Bt1	4.9	1.44	0.27	0.06	0.60	0.30	1.23	7.22	6.8	37.8	18.1
		48-76	Bt2	4.65	0.86	0.19	0.08	0.40	traces	0.67	6.40	4.2	23.3	16.0
		76-115	Bt3	4.55	0.50	0.14	0.06	0.40	0.10	0.70	5.30	3.2	11.0	21.7
		115+	Weathered rock											
LS		0-20	A	4.68	2.39	0.28	0.06	1.00	0.70	2.04	7.20	6.5	43.3	31.3
	26	20-60	Bt1	4.72	1.52	0.18	0.05	0.40	0.10	0.73	6.50	3.0	15.4	24.3
		60-105+	Bt2	4.60	1.03	0.11	0.05	0.70	0.10	0.96	5.20	2.8	9.3	34.3
		0-12	A	4.88	2.20	0.40	0.07	1.30	0.60	2.37	7.20	7.4	40.7	32.0
	27	12-42	Bt1	4.98	1.40	0.32	0.08	0.50	0.20	1.10	5.80	4.4	19.6	25.0
		42-126	Bt2	4.88	1.00	0.14	0.08	0.50	0.20	0.92	5.60	2.5	9.0	36.0
		126+	Weathered rock											
		0-2	A1	4.75	2.17	0.84	0.10	2.00	0.70	3.84	7.00	6.6	46.5	58.2
	28	2-39	A2	5.06	1.33	0.19	0.10	0.50	0.30	1.09	6.10	4.3	27.6	25.3
		39-120+	Bw	4.75	0.68	0.05	0.04	0.40	traces	0.49	5.80	2.8	18.7	17.5
		0-59	A	4.85	3.60	0.52	0.09	3.80	0.70	5.11	8.10	10.2	77.3	50.1
LF	29	59-78	AB	4.91	2.21	0.29	0.09	1.80	traces	2.18	8.60	8.0	49.1	27.3
		78-150+	Bt	5.0	1.34	0.19	0.06	1.50	0.10	1.85	6.90	4.6	17.7	40.2
		0-2	A1	4.89	2.82	0.53	0.06	2.20	0.60	3.39	7.90	8.6	61.4	39.4
	30	2-48	A2	5.04	2.13	0.22	0.08	0.70	0.10	1.10	6.10	7.6	43.2	14.5
		48-154+	Bt	4.87	1.95	0.07	0.08	0.20	0.10	0.45	5.80	5.4	18.7	5.9
HS	31	0-7	A	4.82	5.62	0.23	0.05	1.40	0.40	2.08	9.20	12.1	88.3	18.7
		7-85	Bw	4.95	4.61	0.07	0.05	0.80	0.40	1.90	5.90	10.6	85.5	17.9
		85+	Weathered rock											
		0-3	A1	4.69	3.33	0.73	0.04	2.50	1.10	4.37	10.50	9.6	58.9	48.9
	32	3-22	A2	4.71	2.29	0.15	0.06	1.30	0.30	1.81	10.50	8.4	45.2	21.5
		22-60	Bw	4.69	1.48	0.09	0.04	0.40	0.30	0.83	9.00	5.9	31.2	14.1
		60-128	Bw2	4.87	0.78	0.10	0.05	0.70	0.10	0.95	6.60	3.8	21.1	25.0
		128+	Weathered rock											
	33	0-4	A	4.68	3.35	0.70	0.05	1.40	0.80	2.95	7.90	7.8	43.3	37.8
		4-90	Bw	4.70	2.13	0.22	0.04	0.70	0.30	1.26	5.90	5.1	34.0	24.7
		90+	Weathered rock											
HF	34	0-3	A	5.14	2.59	0.27	0.04	1.80	0.60	2.71	8.40	8.2	36.4	33.0
		3-48	Bw	5.04	1.85	0.10	0.04	0.40	0.50	1.04	7.20	4.1	21.4	25.4
		48+	Weathered rock											

Table 4. (continued)

Eln/ tpy	Prof- ile No	Depth (cm)	Hori- zon	pH	OC %	Exchangeable cations cmol (+) kg^{-1}				Exch. bases	Exch. acidity	CEC	CEC/ kg clay	PBS (Amm. Acet- ate)
						K	Na	Ca	Mg	cmol(+) kg^{-1}				
	35	0-15	A1	5.25	5.07	0.55	0.05	3.40	2.70	6.70	2.10	12.1	64.7	60.4
		15-46	A2	4.97	4.01	0.14	0.05	0.50	traces	0.69	1.80	11.2	59.6	26.5
		46-95	Bw	4.68	3.96	0.06	0.05	0.40	2.10	2.61	0.60	9.8	48.0	26.6
		95+	Weathered rock											
	36	0-4	A	5.14	3.85	0.52	0.04	2.20	1.80	4.56	1.80	9.9	53.5	46.1
		4-115	Bw	5.08	2.40	0.18	0.04	0.60	0.40	1.22	1.00	7.6	39.6	16.1
		115+	Weathered rock											
Pamba														
LS	37	0-8	A	5.45	2.83	1.14	0.05	4.80	0.70	6.69	2.80	9.6	42.7	69.7
		8-68	AB	4.75	1.42	0.03	0.05	0.80	0.30	1.15	3.50	7.4	27.2	15.5
		68-150+	Bt	4.77	0.83	0.15	0.04	1.40	0.30	1.89	2.50	4.0	13.3	47.2
	38	0-8	A	5.16	2.62	1.24	0.05	2.10	1.40	4.79	4.00	9.7	37.7	49.4
		8-54	AB	5.10	1.90	1.18	0.05	3.10	1.70	5.03	2.00	7.9	26.7	63.4
		54-150+	Bt	5.29	1.30	0.34	0.06	0.50	1.10	2.00	2.80	4.5	12.8	44.4
	39	0-6	A	5.65	3.43	1.90	0.05	3.3	2.00	7.25	1.50	10.2	42.1	59.4
		6-70	AB	5.22	2.52	1.37	0.04	2.00	0.70	4.11	1.50	7.7	25.0	42.4
		70-128	Bt	5.25	1.57	0.33	0.04	0.90	0.70	1.97	1.00	5.6	10.0	34.7
		128+	Weathered rock											
LF	40	0-15	A	4.75	1.06	0.34	0.06	1.70	0.10	2.20	2.60	7.2	22.9	31.4
		15-105	Bw	4.78	0.88	0.33	0.06	1.30	0.50	2.19	2.50	5.3	25.2	41.3
		105+	Weathered rock											
	41	0-47	A	4.80	1.57	0.40	0.06	2.20	0.60	3.26	1.80	7.2	24.0	45.2
		47-88	Bw	4.76	0.42	0.10	0.05	1.40	0.10	1.65	0.60	3.8	17.9	55.0
		88+	Weathered rock											
	42	0-24	A	4.82	1.40	0.33	0.05	1.70	0.60	2.68	2.40	6.0	19.5	44.7
		24-105	Bw	4.75	0.61	0.12	0.05	1.00	0.20	1.37	1.40	3.8	16.3	36.1
		105+	Weathered rock											
HS	43	0-4	A1	4.65	5.17	1.24	0.05	2.10	0.90	4.29	9.80	12.2	73.1	38.3
		4-20	A2	4.80	3.85	0.90	0.06	1.70	0.40	3.06	6.80	8.2	47.7	37.3
		20-54	Bt1	4.78	1.40	0.15	0.06	1.40	traces	1.61	4.60	5.4	19.1	29.8
		54-150+	Bt2	4.88	0.99	0.23	0.08	0.50	0.40	1.21	2.20	4.0	11.0	30.3
	44	0-4	A1	4.71	4.95	1.24	0.05	2.40	0.70	4.39	3.10	11.1	45.9	43.5
		4-28	A2	4.80	3.78	0.10	0.05	0.60	0.10	0.85	1.50	8.2	26.6	10.4
		28-46	Bt1	4.86	1.03	0.07	0.06	0.90	traces	1.03	1.50	3.3	12.8	31.2
		46-140	Bt2	4.96	0.33	0.04	0.05	0.40	0.10	0.59	0.40	2.4	6.6	24.6
		140+	Weathered rock											
	45	0-3	A	4.70	4.20	1.17	0.05	2.80	0.40	4.42	2.20	8.2	44.6	53.9
		3-32	Bw	4.75	2.82	0.28	0.07	1.40	0.10	1.85	0.60	4.8	25.5	38.5
		32+	Weathered rock											
	46	0-3	A1	4.63	5.98	0.52	0.07	4.90	1.20	6.69	8.30	13.2	79.0	58.7
		3-11	A2	5.07	3.29	0.23	0.06	2.20	1.00	3.49	2.90	8.7	50.9	42.6
		11-105	Bw	4.70	0.88	0.10	0.05	0.70	0.10	0.95	1.50	3.8	24.5	25.0

Table 4. (continued)

Eln/ tpy	Prof-ile No	Depth (cm)	Hori-zon	pH	OC%	Exchangeable cations cmol (+) kg^{-1}				Exch. bases	Exch. acidity	CEC	CEC/ kg clay	PBS (Amm. Acetate)
						K	Na	Ca	Mg	cmol(+) kg^{-1}				
HF	47	0-3	A1	4.69	4.58	0.54	0.06	5.70	0.40	6.70	7.10	10.5	83.3	58.3
		3-10	A2	4.75	3.95	0.35	0.06	3.50	0.20	4.11	5.90	9.6	59.3	42.8
		10-43	Bt1	4.80	2.0	0.20	0.06	1.60	0.10	1.96	4.70	5.6	21.1	35.0
		43-96	Bt2	4.75	1.2	0.42	0.05	0.70	traces	1.17	1.50	3.2	10.8	36.6
		96+	Weathered rock											
	48	0-5	A1	4.85	4.73	1.44	0.10	6.20	1.40	9.14	1.50	10.9	80.7	65.8
		5-15	A2	5.81	2.04	1.38	0.10	5.30	1.20	7.98	2.00	9.8	58.7	67.6
		15-40	Bt1	5.47	1.67	0.92	0.10	1.60	1.20	3.82	7.80	6.5	25.2	58.8
		40-78	Bt2	5.42	0.83	0.44	0.08	0.90	0.20	1.62	3.00	3.8	11.8	42.6
		78+	Weathered rock											

Eln= Elevation; Tpy = topography; LS = sloping land at low elevation; LF = flat to undulating land at low elevation; HS = sloping land at high elevation; HF= flat to undulating land at high elevation; CEC = cation exchange capcity; PBS = Percentage base saturation

formation of metallic complexes of Al^{3+} with organic substances. This observation could be applicable for soils under the present study since the geographical area covered under this study is almost the same as that related to the above reference though the vegetation differed. In the surface soils of reed growing areas the exchange acidity may be mainly due to the influence of organic acids released during decomposition while at lower layers it may be also due to the dominance of Al^{3+}.

Cation exchange capacity

The cation exchange capacity of forest soils of Kerala in general varied from 1.1 to 17.5 cmol (+) kg^{-1} (Thomas and Brito-Mutunayagam, 1965; Yadav *et al.*, 1970 and Elsy, 1989) and almost similar values (2.2 to 13.2 cmol (+) kg^{-1} were observed in reed growing soils also. The values were found decreasing with increasing depth of the profiles, the bottom layer recording the lowest values. Since the distribution of organic matter also followed a similar trend from surface to bottom of all the profiles, CEC may be mainly a function of organic matter in these soils. This is again supported by a significant and positive correlation (r=0.3778**) between cation exchange capacity and organic carbon. The coarse textured nature of these soils with comparatively low content of clay also supports the above statement. Since the soils under study are primarily kaolinitic in nature, a low value of cation exchange capacity in subsoil which is relatively poor in organic matter content is quite expected. Similar observations have also been made by Thomas and Brito-Mutunayagam (1965) in forest soils of Kerala.

Organic carbon

The organic carbon content of forest soils of Kerala, in general ranged from 0.14 to 5.56 per cent and the content of organic carbon is usually decided by the rate of litter fall and its consequent decomposition (Thomas and Brito-Mutunayagam, 1965; Yadav *et al.*, 1970; Sankar, 1987 and Elsy, 1989). The organic carbon content of reed growing soils was in the range 0.13 - 5.98 per cent and heavy accumulation was restricted to surface layers. Compared to other forest plantations viz., teak (Balagopalan, 1991) and acacia (Sankaran *et al.*, 1992) the total accumulation of organic matter in reed growing soils is very high probably due to the relatively high rate of leaf fall observed in these tracts. Unlike in other forest vegetations, addition of organic matter through an extensively ramified root system also contributes to the total pool of soil organic matter. This is further supported by the study of Nye and Greenland (1960) in bamboo which revealed that about 10-20 per cent of above ground litter and 20-50 per cent of root litter were converted into soil organic matter and the rest was released as carbon dioxide. The data on the depth-wise distribution of organic carbon reveals a progressive decrease towards lower layers (Fig. 3). The extraordinary accumulation in a few profiles is suspected due to the entrapping of organic rich surface horizon in the subsurface layers by the action of landslides or similar physical calamities. Sanalkumar *et al.* (1998) had recorded a high diversity of soil faunal groups in reed growing soils of Vazhachal and majority of them was found to help in the degradation of reed leaf litter.

Nutrient status

Total and available N

Forest soils of Kerala were found to vary considerably in the content of total N. The content of total N as reported by Thomas and Brito-Mutunayagam (1965), Elsy (1989) and Sujatha (1997) were in the range from 0.01-0.56 per cent. Data presented in Table 5 indicated that the content of total N in reed growing soils ranged from 0.052-0.632 per cent. The higher content of N especially on soil surface is attributed to the higher content of organic matter contributed by the abundant litter cover occurring on soil surface. This is further supported by a highly significant and positive correlation (r=0.6611**) between total N and organic carbon. As expected, a decreasing tendency was observed with increase in depth of soil profiles. The status of available N in these soils varied from 0.04 - 0.078 per cent. Lowering of available N with increase in depth of the profiles was noticed in all the reed growing tracts and this can be related to the surface enrichment through litter decomposition and its immediate uptake by fast growing reed plant.

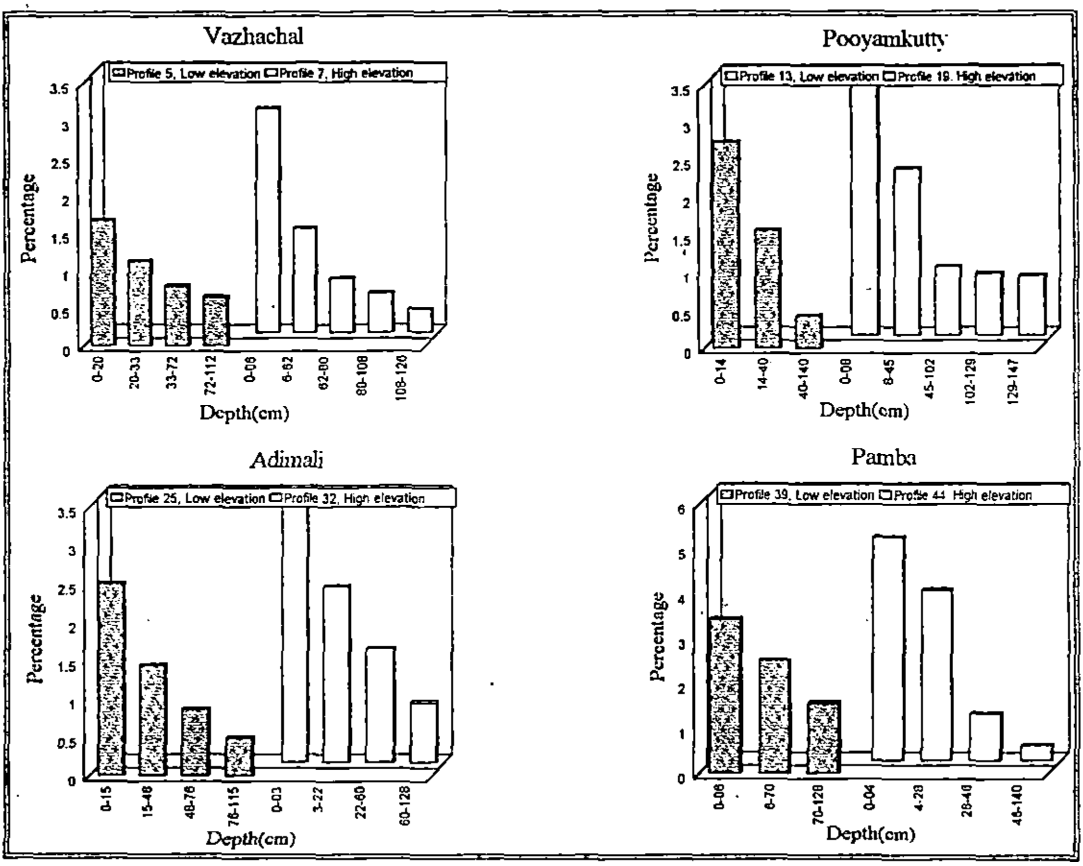


Fig. 3. Depthwise variation of organic carbon in reed growing soils

Table 5. Nutrient status of soil profiles in reed growing tracts.

Eln / tpy	Profile No	Depth (cm)	Horizon	Nitrogen, %		Phosphorus, ppm		Potassium, %	
				Total	Available	Total	Available	Total	Available
Vazhachal									
LS	1	0-13	A	0.189	0.085	440	1.2	0.19	0.014
		13-43	Bt1	0.143	0.050	420	traces	0.22	0.003
		43-150+	Bt2	0.085	0.036	420	traces	0.24	0.002
	2	0-10	A	0.196	0.065	600	4.6	0.31	0.032
		10-56	Bt1	0.143	0.065	360	traces	0.32	0.015
		56-150	Bt2	0.111	0.054	440	traces	0.24	0.008
	3	0-9	A	0.209	0.063	420	2.8	0.26	0.014
		9-41	Bt1	0.365	0.065	340	0.1	0.15	0.014
		41-77	Bt2	0.104	0.061	360	traces	0.21	0.010
		77+	Weathered rock						
LF	4	0-21	A	0.209	0.083	460	1.2	0.26	0.012
		21-33	Bt1	0.157	0.058	370	traces	0.23	0.007
		33-69	Bt2	0.104	0.067	350	traces	0.44	0.007
		69-150+	Bt3	0.095	0.054	250	traces	0.50	0.004
	5	0-20	A	0.202	0.074	410	2.6	0.37	0.017
		20-33	Bt1	0.157	0.062	370	0.4	0.39	0.020
		33-72	Bt2	0.104	0.067	280	traces	0.69	0.023
		72-112	Bt3	0.091	0.061	250	traces	0.27	0.003
		112+	Weathered rock						
	6	0-20	A	0.228	0.072	620	10.2	0.38	0.013
		20-33	Bt1	0.254	0.069	610	6.4	0.40	0.014
		33-70	Bt2	0.209	0.081	430	9.4	0.43	0.008
		70-150+	Bt3	0.104	0.071	440	7.6	0.46	0.007
HS	7	0-6	A1	0.306	0.062	1230	4.8	0.38	0.012
		6-62	A2	0.235	0.038	520	3.6	0.42	0.005
		62-80	Bw1	0.196	0.029	150	4.4	0.48	0.002
		80-108	Bw2	0.117	0.021	150	2.8	0.58	0.002
		108-126	Bw3	0.095	0.021	120	3.0	0.61	0.001
		126+	Weathered rock						
	8	0-4	A1	0.287	0.084	310	6.5	0.61	0.013
		4-28	A2	0.218	0.053	410	4.2	0.50	0.004
		28-51	Bw1	0.183	0.041	210	3.0	0.75	0.003
		51-88	Bw2	0.183	0.038	440	traces	0.76	0.002
		88-115	Bw3	0.085	0.024	250	traces	0.70	traces
	9	0-4	A1	0.282	0.078	420	4.8	0.58	0.013
		4-26	A2	0.207	0.052	450	2.8	0.50	0.010
		26-46	Bw1	0.015	0.040	380	1.2	0.41	0.002
		46-108+	Bw2	0.062	0.025	250	traces	0.23	0.001
HF	10	0-2	A1	0.300	0.086	380	4.8	0.20	0.021
		2-25	A2	0.235	0.085	590	3.4	0.15	0.008
		25-70	Bt	0.143	0.090	480	2.4	0.18	0.005
		70+	Weathered rock						
	11	0-4	A	0.300	0.092	1120	3.0	0.58	0.007
		4-63	Bw	0.189	0.072	1000	1.6	0.53	0.004
		63+	Weathered rock						

Table 5. (continued)

Eln / Tpy	Profile No.	Depth, (cm)	Horizon	Nitrogen, %		Phosphorus, ppm		Potassium, %	
				Total	Available	Total	Available	Total	Available
	12	0-4	A1	0.222	0.086	480	4.6	0.29	0.018
		4-20	A2	0.157	0.040	460	traces	0.33	0.013
		20-100+	Bw	0.130	0.067	380	traces	0.27	0.008
Pooyamkutty									
LS	13	0-14	A	0.287	0.066	370	9.6	0.60	0.046
		14-40	Bt1	0.209	0.053	410	3.0	0.76	0.010
		40-140	Bt2	0.052	0.025	440	2.8	0.96	0.003
		140+	Weathered rock						
	14	0-12	A	0.306	0.068	420	3.4	0.36	0.023
		12-39	Bt1	0.183	0.050	290	3.0	0.34	0.008
		39-100	Bt2	0.117	0.040	300	2.4	0.90	0.004
		100-150+	Bt3	0.098	0.032	250	traces	0.39	0.002
	15	0-8	A	0.352	0.086	600	7.0	0.43	0.010
		8-42	Bt1	0.196	0.072	560	6.6	0.41	0.006
		42-125	Bt2	0.117	0.040	540	2.4	0.43	0.004
		125+	Weathered rock						
LF	16	0-16	A	0.267	0.080	580	3.8	0.76	0.020
		16-74	Bt1	0.178	0.066	560	1.2	0.65	0.008
		74-150+	Bt2	0.137	0.045	640	0.4	0.60	0.007
	17	0-16	A	0.248	0.061	350	4.8	0.37	0.028
		16-82	Bt	0.163	0.048	290	3.2	0.47	0.004
		82+	Weathered rock						
	18	0-18	A	0.235	0.072	350	4.6	0.62	0.028
		18-50	Bw1	0.172	0.058	300	3.2	0.50	0.006
		50-115+	Bw2	0.117	0.025	270	0.2	0.28	0.003
HS	19	0-8	A1	0.352	0.080	380	9.6	0.49	0.029
		8-45	A2	0.228	0.061	310	5.0	0.45	0.021
		45-102	Bt1	0.143	0.066	300	1.2	0.45	0.014
		102-129	Bt2	0.089	0.049	310	1.2	0.72	0.010
		129-147	Bt3	0.080	0.043	270	1.2	0.76	0.004
		147+	Weathered rock						
	20	0-4	A1	0.248	0.033	350	9.9	0.53	0.010
		4-64	A2	0.274	0.066	280	3.6	0.32	0.006
		64-75	Bw1	0.124	0.035	210	2.4	0.52	0.003
		75-125+	Bw2	0.091	0.028	290	2.0	0.45	0.002
	21	0-4	A	0.336	0.086	350	9.6	0.53	0.027
		4-102	Bw	0.281	0.052	210	4.2	0.42	0.018
		102+	Weathered rock						
HF	22	0-6	A1	0.316	0.061	280	15.4	0.52	0.051
		6-48	A2	0.182	0.049	3600	4.2	0.64	0.031
		48-115	Bw	0.156	0.034	310	5.2	0.51	0.038
		115+	Weathered rock						
	23	0-3	A1	0.265	0.055	290	25.2	0.41	0.011
		3-48	A2	0.202	0.055	270	16.8	0.36	0.004
		48-122	Bw	0.117	0.025	170	4.0	0.22	0.002
		122+	Weathered rock						

Table 5. (continued)

Eln / tpy	Pro-file No	Depth (cm)	Hori-zon	Nitrogen, %		Phosphorus, ppm		Potassium, %	
				Total	Avai-lable	Total	Avai-Lable	Total	Avai-lable
	24	0-15	A1	0.316	0.062	300	14.2	0.45	0.011
		15-46	A2	0.182	0.050	280	8.6	0.48	0.004
		46-95	Bw	0.156	0.025	200	2.0	0.25	0.003
		95+	Weathered rock						
Adimali									
LS	25	0-15	A	0.255	0.061	420	12.5	0.68	0.011
		15-48	Bt1	0.162	0.045	390	10.2	0.61	0.010
		48-76	Bt2	0.108	0.035	360	3.6	0.58	0.007
		76-115	Bt3	0.091	0.028	280	2.2	0.57	0.006
		115+	Weathered rock						
	26	0-20	A	0.243	0.068	330	8.4	0.55	0.011
		20-60	Bt1	0.156	0.038	260	5.1	0.60	0.005
		60-105	Bt2	0.117	0.030	200	3.2	0.76	0.004
	27	0-12	A	0.232	0.059	290	6.8	0.55	0.011
		12-42	Bt1	0.156	0.042	220	2.8	0.52	0.005
		42-126	Bt2	0.105	0.029	170	traces	0.57	0.003
		126+	Weathered rock						
LF	28	0-2	A1	0.232	0.058	270	16.8	0.40	0.033
		2-39	A2	0.148	0.040	290	4.4	0.50	0.007
		39-120+	Bw	0.068	0.028	260	2.8	0.58	0.002
	29	0-59	A	0.412	0.074	420	10.4	0.48	0.020
		59-78	AB	0.256	0.050	430	5.8	0.60	0.002
		78-150+	Bt	0.152	0.029	290	3.6	0.66	0.002
	30	0-2	A1	0.316	0.060	450	10.4	0.40	0.022
		2-48	A2	0.222	0.051	340	5.5	0.52	0.018
		48-154+	Bt	0.208	0.045	250	2.9	0.59	0.002
HS	31	0-7	A	0.602	0.056	250	5.4	0.32	0.003
		7-85	Bw	0.552	0.094	400	6.0	0.30	0.009
		85+	Weathered rock						
	32	0-3	A1	0.400	0.066	380	19.6	0.49	0.029
		3-22	A2	0.242	0.053	480	13.6	0.66	0.006
		22-60	Bw1	0.151	0.043	410	4.2	0.68	0.003
		60-128	Bw2	0.102	0.043	360	2.4	0.76	0.004
		128+							
	33	0-4	A	0.408	0.059	420	6.9	0.36	0.026
		4-90	AB	0.230	0.043	310	5.2	0.36	0.009
		90+	Weathered rock						
HF	34	0-3	A	0.286	0.055	380	12.5	0.41	0.011
		3-48	Bw	0.200	0.055	270	6.8	0.36	0.004
		48+	Weathered rock						
	35	0-15	A1	0.582	0.108	250	8.4	0.24	0.021
		15-46	A2	0.438	0.063	200	9.2	0.19	0.006
		46-95	Bw	0.402	0.025	170	4.0	0.22	0.002
		95+	Weathered rock rock						

Table 5. (continued)

Eln / tpy	Profile No	Depth (cm)	Horizon	Nitrogen, %		Phosphorus, ppm		Potassium, %	
				Total	Available	Total	Available	Total	Available
	36	0-4	A	0.412	0.068	280	8.8	0.32	0.021
		4-115	Bw	0.261	0.049	280	6.5	0.26	0.004
		115+	Weathered rock						
Pamba									
LS	37	0-8	A	0.284	0.071	440	5.8	0.60	0.045
		8-68	AB	0.158	0.043	320	1.9	0.63	0.012
		68-150+	Bt	0.180	0.045	410	1.8	0.62	0.006
	38	0-8	A	0.297	0.083	520	7.0	0.62	0.048
		8-54	AB	0.205	0.071	310	5.3	1.12	0.046
		54-150+	Bt	0.152	0.111	350	2.3	1.03	0.013
	39	0-6	A	0.375	0.098	380	8.2	0.68	0.038
		6-70	AB	0.329	0.050	380	7.3	0.98	0.013
		70-128	Bt	0.170	0.061	310	1.9	1.05	0.008
		128+	Weathered rock						
LF	40	0-15	A	1.167	0.053	360	2.1	0.73	0.013
		15-105	Bw	1.140	0.048	440	2.1	0.73	0.013
		105+	Weathered rock						
	41	0-47	A	0.182	0.053	320	3.6	0.85	0.011
		47-88	Bw	0.088	0.042	200	1.8	1.06	0.007
		88+	Weathered rock						
	42	0-24	A	0.158	0.058	280	3.1	0.78	0.013
		24-105	Bw	0.111	0.052	220	1.8	0.89	0.007
		105+	Weathered rock						
HS	43	0-4	A1	0.531	0.106	360	8.0	0.90	0.048
		4-20	A2	0.400	0.098	420	3.0	1.39	0.035
		20-54	Bt1	0.207	0.055	240	9.2	1.02	0.006
		54-150+	Bt2	0.153	0.040	180	1.2	1.11	0.009
	44	0-4	A1	0.568	0.112	480	9.6	0.80	0.030
		4-28	A2	0.412	0.043	340	1.2	0.98	0.011
		28-46	Bt1	0.382	0.035	240	1.2	0.45	0.003
		46-140	Bt2	0.135	0.023	420	1.2	0.56	0.003
		140+	Weathered rock						
	45	0-3	A	0.530	0.106	420	8.2	0.80	0.029
		3-32	Bw	0.408	0.862	280	10.5	1.05	0.001
		32+	Weathered rock						
HF	46	0-3	A1	0.632	0.028	330	6.3	0.54	0.031
		3-11	A2	0.351	0.159	350	2.8	0.60	0.014
		11-105+	Bw	0.122	0.096	340	1.9	1.29	0.008
	47	0-3	A1	0.554	0.126	480	18.0	0.54	0.021
		3-10	A2	0.455	0.103	370	8.2	0.58	0.014
		10-43	Bt1	0.257	0.083	430	4.2	0.71	0.015
		43-96	Bt2	0.140	0.038	470	3.8	0.98	0.004
		96+	Weathered rock						

Table 5. (continued)

Eln / tpy	Profile No	Depth (cm)	Horizon	Nitrogen, %		Phosphorus, ppm		Potassium, %	
				Total	Available	Total	Available	Total	Available
	48	0-5	A1	0.568	0.055	700	20.0	0.55	0.054
		5-15	A2	0.235	0.050	440	6.5	0.97	0.051
		15-40	Bt1	0.175	0.066	270	3.4	1.18	0.075
		40-78	Bt2	0.098	0.061	240	1.9	1.25	0.056
		78+	Weathered rock						

Eln= Elevation; tpy = topograpahy; LS = sloping land at low elevation; LF = flat to undulating land at low elevation; HS = sloping land at high elevation; HF= flat to undulating land at high elevation

Total and available phosphorus

The total phosphorus content of reed growing soils (Table 5) exhibited moderately high values (0.017 to 0.112 per cent) compared to its general status (0.01 - 0.08 per cent) in forest soils of Kerala (Thomas and Brito-Mutunayagam (1965) and Sujatha (1997). In majority of the profiles the maximum content was concentrated in the surface layers and the data in the subsequent layers indicate its downward mobilisation. The status of available P which is of much important from the point of view of plant growth was very low and most of the values were lying below 10 ppm except in a few profiles. Most of the values were less than 5 per cent of total P. The available P has to be released by the mineralisation of accumulated organic carbon in the surface where the ramification of the roots is extremely intense. This could cause heavy absorption of available P released by the mineralisation of organic matter. Even if a fraction of soluble P is left unabsorbed, it can immediately react with iron and aluminium of the soil which is highly acidic due to the presence of organic acids released from decomposing organic matter thus converting the water soluble P to insoluble Fe and Al phosphates. The extra-ordinary content of available P noted in certain top most layers is due to the thinness of layer as compared to the layer thickness of other soils since the topmost part of the profile always carried the maximum content of organic matter and consequently the P released by the mineralisation. When it moves down; it can undergo fixation resulting in decreased availability. In most of the profiles the bottom layer retained only traces of available P.

Total and available K

The total content of K (Table 5) in reed growing tracts ranged from 0.19 to 1.18 per cent and it is comparatively higher than the general status (0.04 - 0.16 per cent) of forest soils of Kerala (Thomas and Brito-Mutunayagam, 1965; Elsy, 1989; and Sujatha, 1997). The distribution of total K did not follow any definite trend from surface to the bottom of the profiles. In some profiles, the trend was to decrease down the profiles while in others it was found accumulated in the lower part of the profiles. In contrast to the pattern of movement of P in soils, K is a mobile element which is easily leached down the profile. A comparatively high content of K in the surface layer is due to its release from accumulated organic matter whereas the differential accumulation of K in different layers of the profiles can be attributed to its retention by the soil component exhibiting cation exchange / retention capacity like clay, organic matter etc. This is further supported by a significant and positive correlation of total K with clay (r = 0.3214**). The accumulation of K at lower zones is thought to be either due to leaching from upper surface and or due to the influence of K containing minerals.

The content of available K in the reed growing tracts varied from traces to 0.054 per cent. As in the case of N, K also was found to decrease with depth and this decrease was in direct proportion with increase in depth of profiles, the lower most layer recording the lowest values. Most of the available K on the soil surface is thought to be due to the contribution from decaying organic residus as evidenced by a highly significant and positive correlation (r = 0.4035**) between organic carbon and available K. It is reported that bamboo has the ability for rapid uptake and accumulation of K and thus conserve it and release through litter to soil surface (Rao and Ramakrishnan, 1989). In this investigation where the nutrient content of reed was examined in relation to growth performance, it was seen that reed retained a relatively high content of K. This shows that reed serves as a biological buffer in nature for the retention of K since decomposition and absorption of K by reed from surface soil is a continuous cyclic process.

2. Variation in soil characteristics due to change in location

To study the influence of location on depth wise distribution of chemical properties, there were 12 profiles at one location and hence 48 profiles at four locations. The data in general did not reveal much influence on the pattern of depth-wise distribution of soil properties due to change in location. Accumulation of litter and matting of roots were found almost similar in all the four locations studied. Formation of crumb and granular structure on soil surface followed uniform pattern in all the locations.

As already described under general properties of soil, the pH of surface soil varied under the influence of companion vegetation. In areas where reed was growing as undergrowth in teak and moist deciduous trees the topmost soils were less acidic than in pure reed areas. In pure reed areas the surface soils were more acidic compared to the subsurface layers, the probable reason for above phenomenon has already been discussed.

3. Variation in soil characteristics due to change in elevation

As expected the thickness of undecomposed litter layer was observed to vary with elevation at all the four locations studied. Undecomposed litter layer was more at higher elevations compared to lower elevations in all locations which is assumed to be due to lower decomposition rate brought about by the slow microbial activity and low atmospheric and soil temperature at higher elevation. Soil profiles struck at higher elevations were found to have thicker A horizon than those at lower elevatons. At Adimali, the thickness of organic layer at higher elevation was comparatively higher than the higher elevations of other locations. This might have happened by the entrapping of organic rich surface layers by landslides or such natural calamities and subsequent establishment of reed on newly formed surface soil. The profiles struck at lower and higher elevations of all locations showed similar pattern of distribution of physico-chemical properties from top to bottom of all the profiles. This is mainly because, usually the change in elevation results in change in the intensity of climatic factors. The variation in the of climatic intensity factors can change the degree of decomposition of

Table 6. Correlation matrix showing inter-relationship among various soil characteristics

	Clay	BD	Porosity	MWHC	OC	Ea	Eb	CEC	Total N	Av. P	Total K	Av. K
Clay	1.000											
Bd	0.3450**	1.000										
Porosity	-.2182	-0.5268**	1.000									
MWHC	0.1472	-0.6112**	0.4812**	1.000								
OC	-0.3616**	-0.7126**	0.5261**	0.5185**	1.000							
Ea	-0.0862	-0.3998**	0.2182	0.3288**	0.5167**	1.000						
E b	-0.0910	-0.0910	0.2096	0.3105**	0.5697**	0.3422**	1.000					
CEC	0.0819	-0.2355*	0.5172**	0.5250**	0.3778**	0.3337**	0.2438*	1.000				
Total N	-0.1406	-0.4613**	0.3992**	0.4142**	0.6611**	0.4005**	0.4367**	0.2758*	1.000			
Av. P	-0.3067**	-0.5042**	0.5012**	-0.4962**	0.4451**	0.2018	0.3873**	0.0771	0.2950*	1.0000		
Total K	0.3214**	-0.0759	0.1012	0.1109	-0.0063	0.0399	0.1417	0.1702	0.0193	0.2950**	1.0000	
Av. K	0.0167	-0.4105**	0.4228**	0.4589**	0.4035**	0.3757**	0.6874**	0.2438*	0.2935**	0.2697*	0.2697*	1.0000

BD=Bulk density; OC= Organic carbon; Ea=exchange acidity; Eb= exchangeable bases; CEC=Cation exchange capacity

* = significant at 5 per cent level; ** = significant at 1 per cent level

organic matter and hence the content of organic carbon and nutrients. Normally one could expect that an increase in elevation may bring down the temperature of soil and atmosphere which can lower the rate of enzymatic activity of micro-organisms resulting in a decrease in the rate of decomposition of soil organic matter. A slow rate of decomposition of organic matter could cause the retention of a relatively high magnitude of plant nutrients since organic matter contribute towards the supply of nutrient elements in the soil. The above principles also found true in the present study wherein the content of organic carbon and nutrients were relatively high in soils of high altitude. The general trend of variation due to depth was not seen altered under the influence of elevation.

4. Variation in soil characteristics due to change in topography

Variation in topography usually results in various soil characteristics such as depth of solum, thickness and organic matter content of A horizon, colour of the profile, degree of horizon differentiation, soil reaction and soluble salt content. According to Buol (1973) the most obvious relationship of a soil property to relief probably occurred in humid regions where soils on nearly level relief tended to have thicker sola than those on slope and for that he attributed either the slow geologic erosion of soil material from the soil surface or the lack of percolating water due to losses by runoff or both, occurring on the slope. Dolui *et al.* (1985) while studying the physico-chemical characteristics of some forest soils occurring in toposequance of West Bengal, could observe that the colour of the surface soils of the ridge top as dark brown, on the slope it was brownish yellow and at the bottom of the slope the soils were reddish yellow. But such a conspicuous variation in the depth of soil and colour of surface soils due to change in topography could not be observed in this study. These observations clearly prove the fact that reed plants help to prevent the loss of top soil to a great extent. With regard to physico-chemical properties also the data obtained in the present study did not reveal such a degree of magnitude in soil properties when the sloping and flat lands were compared. The drastic impact of precipitation on the surface soil is overcome by the overlying layer of undecomposed organic matter protecting the soil surface along with the fine fibrous root system. Enhanced percolation leaching and illuviation of organic matter, clay and soil nutrients would not have taken place tremendously thereby reducing the anticipated influence of topography.

5. Soil classification

The classification of soils was attempted (Table 7) according to Soil Survey Staff (1992). The soils under reed were classified under the two orders Ultisol (Profiles 1-6, 10, 13-17, 19, 25, 26-27, 29-30, 37-38, 39, 43-44 and 47-48) and Inceptisol (7-9, 11-12, 18, 20-24, 28, 31-36, 40-42 and 45-46). The Ultisols were characterised by the illuviation of clay in the B horizon to satisfy the requirement of an argillic horizon. Moreover, they exhibited low base saturation values towards lowerside of the profiles. The Inceptisols were having a cambic horizon. The accumulation of clay in the surface soils of certain profiles coming under Inceptisols may be due to either alluvial or colluvial deposits before the establishment of reed. It is also found that most of the soils of pure reed tracts were Inceptisols and the soils were reed was growing as undergrowth in moist deciduous trees were Ultisols. Previously reed was growing as undergrowth in evergreen and semievergreen forests. Due to deforestation when the canopy was opened reed started to grow vigorously and covered the entire area. So the soils of such areas were not subjected to the drastic actions of climatic factors and hence remained as inceptisols. But in areas where reed was growing as undergrowth in teak and moist deciduous trees due to wider canopy opening, the soils might have subjected to the adverse actions of rain and sun resulting in the accumulation of illuvial clay in the B horizon. Thus the conversion Inceptisols to Ultisols might have taken place.

At suborder level, the profiles coming under Ultisol were grouped under Humult and Ustult. Humults contained 0.90% or more organic carbon in upper 15 cm of argillic horizon or 12 kg/m^2 or more organic carbon between the mineral soil surface and a depth of 100 cm. Ustults were characterised by the presence of an ustic moisture regime. All the profiles under Inceptisol were qualified to be under the suborder Tropept with their characteristic iso hyper thermic temperature regime.

Table 7. Taxonomic classification of soil profiles in reed growing tracts.

Profiles	Order	Suborder	Great group	Sub group
1-2	Ultisol	Humult	Kandihumult	Ustic Kandihumult
3	Ultisol	Humult	Haplohumult	Ustic Haplohumult
4	Ultisol	Humult	Kandihumult	Ustic Kandihumult
5	Ultisol	Humult	Haplohumult	Ustic Haplohumult
6	Ultisol	Humult	Kandihumult	Ustic Kandihumult
7-9	Inceptisol	Tropept	Humitropept	Ustic Humitropept
10	Ultisol	Ustult	Kanhaplustult	Typic Kanhaplustult
11	Inceptisol	Tropept	Dystropept	Ustoxic Dystropept
12	Inceptisol	Tropept	Humitropept	Ustic Humitropept
13	Ultisol	Humult	Kanhaplohumult	Ustic Kanhaplohumult
14	Ultisol	Humult	Kandihumult	Ustic Kandihumult
15	Ultisol	Humult	Kanhaplohumult	Ustic Kanhaplohumult
16	Ultisol	Humult	Palehumult	Ustic Palehumult
17	Ultisol	Humult	Kanhaplohumult	Ustic Kanhaplohumult
18	Inceptisol	Tropept	Humitropept	Ustoxic Humitropept
19	Ultisol	Humult	Haplohumult	Ustic Haplohumult
20-21	Inceptisol	Tropept	Humitropept	Ustic Humitropept
22	Inceptisol	Tropept	Dystropept	Ustoxic Dystropept
23-24	Inceptisol	Tropept	Humitropept	Ustoxic Humitropept
25	Ultisol	Humult	Haplohumult	Ustic Haplohumult
26-27	Ultisol	Humult	Kanhaplohumult	Ustic Kanhaplohumult
28	Inceptisol	Tropept	Dystropept	Ustoxic Dystropept
29-30	Ultisol	Humult	Palehumult	Ustic Palehumult
31	Inceptisol	Tropept	Humitropept	Ustic Humitropept
32	Inceptisol	Tropept	Humitropept	Ustoxic Humitropept
33	Inceptisol	Tropept	Humitropept	Ustic Humitropept
34	Inceptisol	Tropept	Dystropept	Lithic Dystropept
35-36	Inceptisol	Tropept	Humitropept	Ustic Humitropept
37-38	Ultisol	Humult	Kandihumult	Ustic Kandihumult
39	Ultisol	Humult	Haplohumult	Ustic Haplohumult
40	Inceptisol	Tropept	Dystropept	Ustic Dystropept
41	Inceptisol	Tropept	Ustropept	Oxic Ustropept
42	Inceptisol	Tropept	Dystropept	Ustoxic Dystropept
43	Ultisol	Humult	Kandihumult	Ustic Kandihumult
44	Ultisol	Humult	Haplohumult	Ustic Haplohumult
45	Inceptisol	Tropept	Dystropept	Ustic Dystropept
46	Inceptisol	Tropept	Humitropept	Ustic Humitropept
47-48	Ultisol	Humult	Haplohumult	Ustic Haplohumult

At great group level, the Humults were classified under Kandihumult, Kanhaplohumult, Palehumult and Haplohumult. Kandihumults were found to have a CEC of 16 cmol (+) kg^{-1} or less at upper 100 cm of the argillic horizon. The profiles under Palehumult were not having a lithic or paralithic contact within 150 cm of the mineral soil surface. The Kanhaplohumults were having a CEC of 16 cmol(+)/kg clay or less (by I*N* NH_4OAc pH7) and an ECEC of 12 cmol(+)/kg clay or less (sum of bases extracted with IN NH_4OAc pH7, plus I*N* KCl-extractable Al) in 50 percent or more of the argillic horizon if less than 100 cm thick, or of its upper 100cm. Similarly all the profiles under Ustults were Kanhaplustults. The Tropepts were qualified to be under Humitropept, Dystropept and Ustropept. Humitropepts were characterised with their low base saturation values and 12 kg/m^2 or more organic carbon between the mineral soil surface and either a depth of 100 cm or a lithic or paralithic contact. Ustropepts were with an ustic moisture regime and a base saturation of 50 per cent or more in all horizons between a depth of 25cm from the mineral soil surface and either a depth of 100cm, a lithic, paralithic contact. All other profiles under Tropept were grouped under Dystropept.

At subgroup level, the soils under Ultisol were grouped under Ustic Kandihumult (Profiles 1-2, 4,6, 14, 37-38 and 43) Ustic Haplohumult (Profiles 3, 5, 19, 25, 39, 44 and 47-48), Ustic Palehumult Profiles (16 and 29-30), Ustic Kanha plustult (Profiles 13, 15 and 17), Ustic Kanhaplohumult (Profiles 26-27) and Typic Kanhaplustult (Profile 10). The soils under Inceptisol were grouped under Ustic humitropept (Profiles 7-9, 12, 20-21, 31, 33, 35-36 and 46), Ustic Dystropept (Profiles 40 and 45), Ustoxic humitropept (Profiles 18, 23-24 and 32), Lithic Dystropept (Profile 34), and Oxic Ustropept (Profile 41). All the profiles under Ustic Kandihumult, Ustic Palehumult, Ustic Kanhaplohumult and Ustic haplohumult were having their characteristic ustic moisture regime. Ustic Dystropepets and Ustic Humitropepts were having their characteristic ustic moisture regime. But Ustoxic humitropepts in addition to the ustic moisture regime were having a cation exchange capacity of less than 24 cmol (+) kg^{-1} clay in 50 per cent or more of the soil volume between a depth of 25 cm from the mineral soil surface and a depth of 100 cm, or a lithic or paralithic contact. Similarly Ustoxic Dystropepts were also having a cation exchange capacity of less than 24 cmol (+) kg^{-1} clay in 50 per cent or more of the soil volume between a depth of 25 cm from the mineral soil surface and a depth of 100 cm, or a lithic or paralithic contact. Oxic Dystropepts have a cation exchange capacity (by IN NH_4OAc pH7) of less than 24 cmol(+)/kg clay in 50 per cent or more of the soil volume between a depth of 25 cm from the mineral soil surface and either a depth of 100 cm, or a lithic or paralithic contact. Lithic Dystropept has a lithic contact within 50 cm of the mineral soil surface.

So, in general, the pedological / taxonomical studies revealed that reed growing soils were characterised by the abundant litter and thick root mat on soil surface. Reeds were found to flourish on both shallow and deep soils. In pure reed tracts where upper canopy was closed the undergrowth was completely absent. The gravel content was found dominated by rock fragments. The texture of surface soil in general was sandy loam while subsurface layers showed both sandy loam and sandy clay loam. In most of the profiles the subsoil was massive with good drainage conditions. The bulk density was found increase with increasing depth of profiles while porosity and maximum water holding capacity were found to decrease towards lower side of the profiles. They were strongly to moderately acid in reaction with higher content of organic carbon, cation exchange capacity and nutrients (except phohorus) at soil surface. The depthwise distribution of all the properties showed similar pattern irrespective of location, elevation and topography. They were classified under Ustic Kandihumult, Ustic Palehumult, Ustic Haplohumult, Ustic Kanhaplohumult, Typic Kanhaplohumult, Ustic Humitropept, Ustoxic Humitropept, Ustic Dystropept, Ustoxic Dystropept, Lithic Dystropept and Oxic Ustropept at sub group level.

PART 2. FERTILITY STATUS OF SOILS SUPPORTING REED

This part of the investigation was undertaken to assess the fertility status of reed growing soils. Reed bamboo being a fast growing plant with fibrous root system, most of the nutrient transformations are expected to be associated with the soil up to a depth of 15 cm from the surface. So the fertility status of these soils with respect to various physico-chemical properties was studied by collecting surface soil samples to a depth of 15 cm. For this study, the same locations used for pedological study viz., Vazhachal, Pooyamkutty, Adimali and Pamba were selected. Under each location, two elevations and under each elevation two types of topography were identified as done under the pedological study. Then eight surface soil samples (0-15 cm) were collected at random from each topography. Thus there were 16 samples under each elevation and 32 samples under each location.

1. General soil properties

Various physical properties of reed growing soils (0-15 cm) and the impact of location, elevation and topography are given in Table 8. The surface soils of reed growing tracts generally exhibited low content of gravel (13.61 per cent) and it was found dominated by rock fragments than secondary gravels. Secondary gravel formation is usually due to the exposure of soil to the direct actions of rain and sun as a result of which the hardening of soil aggregates and formation of concretions take place consequent to the partial leaching of soil constituents. Soils under reed is not supposed to be exposed to the actions of sun and rain due to the presence of a thick vegetative canopy. This could explain the relatively low content of secondary gravel observed in these soils. Moreover, the accumulation of litter and matting of fine roots protect the soil from the drastic weathering processes under the influence of heavy rainfall. The textural make up of these soils was found dominated by sand (76.45 per cent) with very little silt and clay. So, in general, the texture of these soils was sandy loam. According to the Geological Survey of India (1976), the soils in these areas were derived from rocks such as charnockites, gneisses and granites. These are silica rich and coarse grained soils. This can be the reason for the dominance of sandy loam texture of

Table 8. Mean values of physical properties of surface soils (0-15cm) in reed growing tracts

Eln	Tpy	Gravel %	Sand %	Silt %	Clay %	MWHC %	BD gm cm^{-3}	PD gm cm^{-3}	Porosity %
Vazhachal									
–	Sloping	24.77	70.27	12.19	17.50	36.80	1.06	2.38	55.42
–	Flat	26.58	73.93	9.70	16.13	37.64	1.01	2.21	54.29
		ns	ns	ns	ns	ns	ns	ns	ns
Low	–	26.61	71.68	11.95	16.13	36.99	1.15	2.37	51.31
High	–	24.73	72.52	9.74	17.55	37.85	0.92	2.21	58.41
		ns	ns	ns	ns	ns	s*	ns	s**
Low	Sloping	25.07	69.25	13.75	17.00	35.50	1.14	2.50	54.40
Low	Flat	28.15	74.10	10.15	15.25	38.48	1.16	2.24	48.21
		ns	s*	ns	ns	ns	ns	ns	ns
High	Sloping	24.46	71.28	10.62	18.10	38.09	0.98	2.25	56.44
High	Flat	25.01	73.75	9.25	17.00	36.79	0.86	2.17	60.37
		ns	ns	ns	ns	ns	ns	ns	s*
Pooyamkutty									
–	Sloping	6.56	78.94	8.32	12.76	36.64	0.98	2.11	57.60
–	Flat	6.10	76.04	9.32	14.63	35.63	1.07	2.17	51.57
		ns	ns	ns	ns	ns	s*	ns	s*
Low	–	5.68	74.57	10.13	15.32	36.56	1.12	2.02	50.30
High	–	6.98	80.44	7.51	12.07	35.71	0.93	2.26	58.87
		ns	s	ns	ns	ns	s*	ns	s*
Low	Sloping	5.29	74.63	10.25	15.13	35.79	1.09	1.99	53.77
Low	Flat	6.07	74.50	10.00	15.50	35.53	1.14	2.05	46.83
		ns	ns	ns	ns	ns	ns	ns	s*
High	Sloping	7.83	83.25	6.38	10.38	35.68	0.86	2.23	61.43
High	Flat	6.13	77.63	8.63	13.75	35.73	1.00	2.29	56.30
		ns	s*	ns	ns	ns	ns	ns	s*
Adimali									
–	Sloping	5.24	81.63	6.50	11.88	36.59	0.89	2.37	62.8
–	Flat	7.08	78.82	7.75	13.44	36.49	0.86	2.14	59.66
		ns	ns	ns	ns	ns	ns	ns	ns
Low	–	8.07	76.51	9.00	14.25	36.23	1.00	2.27	55.90
High	–	4.26	83.69	5.25	11.07	36.85	0.75	2.23	66.54
		s*	s*	s*	ns	ns	s*	ns	s*
Low	Sloping	6.42	79.00	8.00	13.00	36.92	1.01	2.50	59.60
Low	Flat	9.71	74.50	10.00	15.50	35.53	0.98	2.05	52.20
		ns	s*	ns	ns	ns	ns		s*
High	Sloping	4.06	84.25	5.0	10.75	36.25	0.76	2.23	65.92
High	Flat	4.45	83.13	5.50	11.38	37.45	0.73	2.22	67.12
		ns	ns	ns	ns	ns	ns	ns	ns
Pamba									
–	Sloping	16.87	76.00	9.41	14.60	40.35	1.00	2.49	59.84
–	Flat	15.66	76.07	9.63	14.32	44.47	0.96	2.30	58.43
		ns	ns	ns	ns	s*	ns	ns	ns
Low	–	18.93	75.00	9.81	15.10	39.61	1.15	2.42	52.47
High	–	13.60	77.07	9.13	13.82	41.69	0.81	2.37	65.77
		s*	ns	ns	ns	ns	s*	ns	s*

Table 8. (continued)

Eln	Tpy	Gravel %	Sand %	Silt %	Clay %	MWHC %	BD gm cm^{-3}	PD gm cm^{-3}	Porosity %
Low	Sloping	16.59	75.00	9.81	15.20	39.29	1.17	2.48	52.88
Low	Flat	21.27	75.00	10.00	15.00	38.95	1.13	2.36	52.12
		ns	ns	ns	ns	ns	ns	ns	ns
High	Sloping	17.15	77.00	9.00	14.00	41.40	0.83	2.50	66.80
High	Flat	10.04	77.13	9.25	13.63	49.98	0.79	2.24	64.74
		s*	ns	ns	ns	s*	ns	ns	ns
Pooled mean									
–	Sloping	13.36	76.71	9.15	14.19	38.70	0.98	2.34	58.91
–	Flat	13.85	76.22	9.41	14.63	37.48	0.97	2.21	55.80
		ns	ns	ns	ns	ns	ns	ns	ns
Low	–	14.82	74.50	10.38	15.20	37.56	1.11	2.27	52.50
High	–	12.40	78.43	8.16	13.63	37.81	0.86	2.27	62.40
		ns	ns	ns	ns	ns	s*	ns	s**
Low	Sloping	13.34	72.10	10.45	16.84	36.88	1.10	2.37	55.16
Low	Flat	16.30	77.51	10.35	13.70	37.12	1.10	2.18	49.84
		ns	ns	ns	ns	ns	ns	ns	s*
High	Sloping	13.38	80.22	7.85	12.66	37.86	0.86	2.30	62.65
High	Flat	11.41	76.04	8.47	7.94	39.99	0.85	2.23	62.13
		ns	ns	ns	ns	ns	ns	ns	ns
Vazhachal		25.67	72.10	11.66	16.84	37.42	1.04	2.29	54.86
Pooyamkutty		6.33	77.51	8.81	13.70	36.14	1.03	2.14	58.87
Adimali		6.16	80.22	7.13	12.66	36.54	0.88	2.25	66.22
Pamba		16.26	76.04	9.13	14.46	40.65	0.98	2.39	59.12
Location mean		13.61	76.47	9.11	14.42	37.69	0.98	2.27	59.77
		s**	s**	s*	s*	s*	s*	s*	s**

Eln = Elevation; Tpy = Topography; s = significant; ns = non significant; * = at 5% level ; ** = at 1% level

these soils. Studies in different species of bamboo (Kadambi, 1949; Kaul, 1964 and Koppar, 1980) also indicate that they thrive well in well drained coarse textured soils with adequate moisture.

The water holding capacity of these soils in spite of coarse texture was moderately high (37.69 per cent) which can be the reflections of high content of organic carbon. This is supported by a significant and positive correlation (r=0.4355**) between these two properties. The mean values of particle density and bulk density were 2.27 and 0.98 g cm^{-3} respectively. Low values of bulk density in spite of sandy loam texture can be due to the fine roots interspersing through soil particles coupled with high content of organic carbon. Relationship with organic carbon is proved by its highly significant and negative correlation (r=-0.6162**) between them. Since porosity is a function of bulk density and particle density, the high porosity of these soils also may be the reflection of high content of organic carbon and fine roots present on soil surface. The organic substances released from soil fauna (both micro and macro) and plants roots are also thought to have a great role in reducing bulk density and thus increasing the porosity of these soils.

With respect to chemical properties (Table 9), these soils were strongly acid in reaction with a mean pH of 4.93. Quershi *et al.* (1969) also reported that bamboo (*Bambusa arundinanceae*) growing soils were acidic. Koppar (1980) was also of the opinion that Indian bamboos preferred acidic to neutral pH. The acidity is thought to be contributed mainly from the non calcareous rocks from which the soils are formed. Selective removal of bases under the influence of climate gives rise to acid soils from these rocks. The organic acids released during decomposition of organic residues also play a great role in increasing the acidity of these soils. The relation of pH with organic carbon is more pronounced (r=-0.5132**) in areas where reed grow in pure patches, the reason for which has already been discussed under pedological / taxonomical study.

Higher content of organic carbon (2.86 per cent) noted in these soils when compared with other forest plantations of the State can be attributed to the litter cover on soil surface together with the fine fibrous ramifying root system characteristic of this plant (Fig. 4). The contents of available N and K were also higher, but the status of available P was in very low. The high content of N and K can be a function of the higher level of organic carbon (r=0.6759** for N and 0.4022** for K respectively). As described under pedological study, the low available P in these soils can be due to its fixation at low pH. The level of P in plant is usually 1/4th to 1/8th of that of N in the acid soils of Kerala. This explains the relatively low content of available P in these soils in spite of the heavy accumulation of litter and dense root matting observed in soils under reed. The mean content of exchangeable bases were also higher than recorded in acacia plantations (Sankaran *et al.*, 1992) of Kerala. The cation exchange capacity of these soils was also high (10.35 cmol (+) kg^{-1} (Fig. 5). The cation exchange capacity normally depends upon the content and type of clay present. Since these

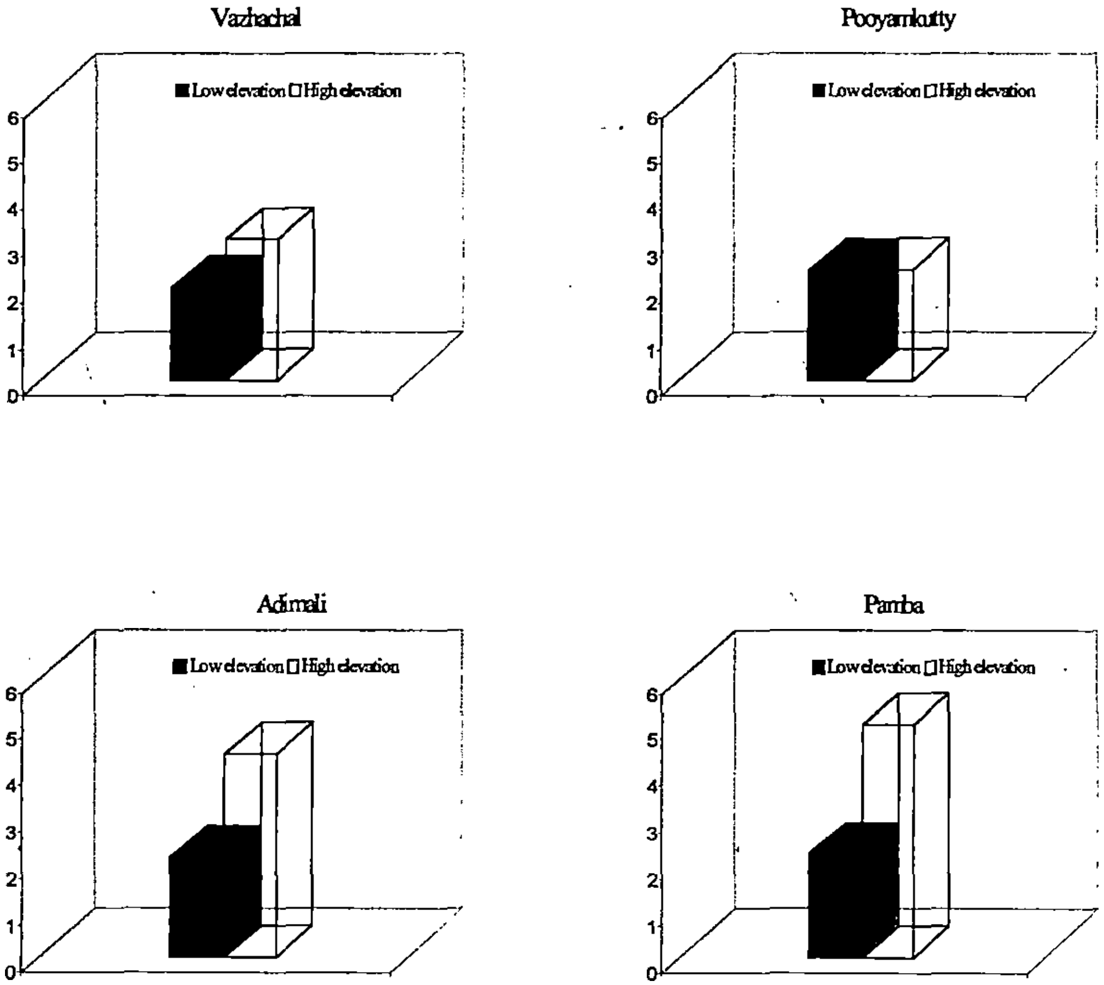


Fig. 4. Organic carbon status of surface soils (0-15 cm) in reed growing tracts

soils are dominated by sand, and the clay is kaolinitic in nature, the exchange capacity is thought to be contributed mainly by the high content of organic carbon. This is supported by the highly significant and positive correlation (r=0.6885**) between cation exchange capacity and organic carbon. The highly significant positive correlation of exchangeable bases with organic carbon (r=0.4980**) helps to assume that these bases are released by the decomposition of organic matter. As normally expected in an acidic soil, the per cent base saturation (31.90) was low in these soils.

Table 9. Mean values of chemical properties of surface soils (0-15 cm) in reed growing tracts

Eln	Tpy	pH	OC	Av.N	Av.P	Av.K	Ea	Eb	CEC	PBS
			%	$g\ kg^{-1}$	ppm	$g\ kg^{-1}$	cmol (+) kg^{-1}			
Vazhachal										
–	Sloping	5.22	2.44	0.454	1.87	0.123	2.9	4.58	9.48	49.14
–	Flat	5.24	2.59	0.353	4.08	0.201	3.2	5.29	10.49	51.46
		ns	ns	ns	ns	ns	ns	ns	ns	ns
Low	–	5.31	1.99	0.367	2.49	0.159	1.65	4.75	8.40	56.40
High	–	5.14	3.03	0.440	3.46	0.164	4.45	5.11	11.56	44.20
		ns	s**	ns	ns	ns	ns	ns	s*	s*
Low	Sloping	5.48	2.12	0.404	1.84	0.154	1.60	4.25	7.85	54.14
Low	Flat	5.15	1.86	0.330	3.15	0.165	1.70	5.25	8.95	58.66
		ns	ns	ns	ns	ns	ns	ns	ns	ns
High	Sloping	4.95	2.75	0.503	1.90	0.901	4.20	4.90	11.10	44.14
High	Flat	5.32	3.31	0.376	5.01	0.237	4.70	5.32	12.02	44.26
		ns	ns	ns	ns	ns	ns	ns	ns	ns
Pooyamkutty										
–	Sloping	4.77	2.14	0.577	1.20	0.117	4.9	3.78	10.68	36.06
–	Flat	4.81	2.13	0.738	3.34	0.164	3.8	3.89	9.69	40.27
		ns	ns	ns	ns	ns	ns	ns	ns	ns
Low	–	4.90	1.87	0.592	2.26	0.128	3.70	3.67	11.00	33.66
High	–	4.68	2.40	0.722	4.75	0.152	5.00	4.00	9.37	42.67
		ns	s*	ns	ns	ns	ns	ns	ns	ns
Low	Sloping	4.65	2.48	0.672	0.07	0.131	5.50	4.18	9.68	43.18
Low	Flat	4.71	2.31	0.772	4.48	0.173	4.50	3.82	9.06	42.16
		ns	ns	ns	s*	ns	ns	ns	ns	ns
High	Sloping	4.88	1.79	0.482	2.33	0.102	4.30	3.38	11.68	28.94
High	Flat	4.91	1.95	0.703	2.20	0.155	3.10	3.96	10.32	38.37
		ns	ns	ns	ns	ns	ns	ns	ns	s*
Adimali										
–	Sloping	4.66	3.30	1.82	5.37	0.125	6.45	3.52	11.47	30.55
–	Flat	4.88	3.25	0.977	3.36	0.10	4.30	3.41	10.21	33.97
		ns	ns	s*	ns	ns	ns	ns	ns	ns
Low	–	4.83	2.12	0.783	3.98	0.091	4.20	3.47	9.67	35.94
High	–	4.70	4.37	1.102	3.74	0.134	6.50	3.47	12.02	28.58
		ns	s**	s*	ns	ns	ns	ns	ns	s*
Low	Sloping	4.79	2.30	0.800	5.75	0.094	4.90	2.92	9.82	29.70
Low	Flat	4.87	2.05	0.772	2.20	0.089	3.50	4.01	9.51	42.17
		ns	ns	ns	s*	ns	ns	ns	ns	s*
High	Sloping	4.52	4.29	1.023	4.98	0.156	8.00	4.12	13.12	31.40
High	Flat	4.88	4.45	1.181	2.51	0.111	5.10	2.81	10.91	25.76
		s*	ns	ns	ns	ns	ns	ns	s*	ns
Pamba										
–	Sloping	4.90	3.62	1.423	3.36	0.417	4.35	4.74	10.59	48.40
–	Flat	4.95	3.49	1.407	4.22	0.367	3.95	4.68	10.13	46.01
		ns	ns	ns	ns	ns	ns	ns	ns	ns
Low	–	5.18	2.21	1.022	3.11	0.340	1.35	3.77	7.12	52.76
High	–	4.67	5.00	1.804	4.47	0.444	6.95	5.65	13.60	41.66
		s*	s**	s*	ns	ns	s*	ns	s**	s*

Table 9. (continued)

Eln	Tpy	pH	OC	Av.N	Av.P	Av.K	Ea	Eb	CEC	PBS
			%	g kg^{-1}	ppm	g kg^{-1}	cmol (+) kg^{-1}			
Low	Sloping	5.16	2.23	1.180	2.61	0.333	0.90	4.37	7.27	60.11
Low	Flat	5.19	2.18	0.870	3.60	0.347	1.80	3.16	6.96	45.40
		ns	ns	ns	ns	ns	ns	ns	ns	s**
High	Sloping	4.64	5.21	1.665	4.10	0.501	7.80	5.10	13.90	36.69
High	Flat	4.70	4.79	1.943	4.84	0.387	6.10	6.20	13.30	46.62
		ns	ns	ns	ns	ns	ns	ns	ns	s**
Pooled mean										
–	Sloping	4.90	2.74	0.633	2.95	0.195	4.65	4.16	11.06	41.04
–	Flat	5.00	2.85	0.848	3.20	0.202	3.69	4.32	10.13	42.93
		ns	ns	ns	ns	ns	ns	ns	ns	ns
Low	–	5.06	2.05	0.691	2.96	0.180	2.73	4.00	8.64	46.94
High	–	4.80	2.96	0.977	3.45	0.212	5.73	4.48	12.05	37.03
		ns	s**	s*	ns	ns	s*	ns	s*	s*
Low	Sloping	5.02	2.28	0.764	2.57	0.178	3.23	3.93	8.65	46.78
Low	Flat	5.03	2.01	0.669	2.79	0.189	2.53	4.00	8.62	57.64
		ns	ns	ns	ns	ns	ns	ns	ns	ns
High	Sloping	4.69	3.68	0.966	2.76	0.220	6.38	4.37	12.45	35.29
High	Flat	4.90	3.72	1.068	4.21	0.227	5.10	4.57	11.64	36.25
		ns	ns	ns	ns	ns	ns	ns	ns	ns
Vazhachal		5.22	2.51	0.403	2.98	0.162	3.05	4.93	9.98	50.30
Pooyamkutty		4.79	2.14	0.657	3.51	0.140	4.35	3.84	10.19	38.17
Adimali		4.76	3.25	0.942	3.86	0.112	5.38	3.47	10.85	32.26
Pamba		4.93	3.51	0.413	3.79	0.392	4.15	4.71	10.36	47.21
Location mean		4.93	2.86	0.854	3.53	0.202	4.23	4.24	10.35	41.98
		s*	s**	s**	ns	s*	ns	ns	ns	s**

Eln = Elevation;Tpy = Topography; CEC = Cation exchange capacity; PBS = Percentage base saturation ; s = Significant; ns = Nonsignificant . * = at 5% level, ** = at 1% level

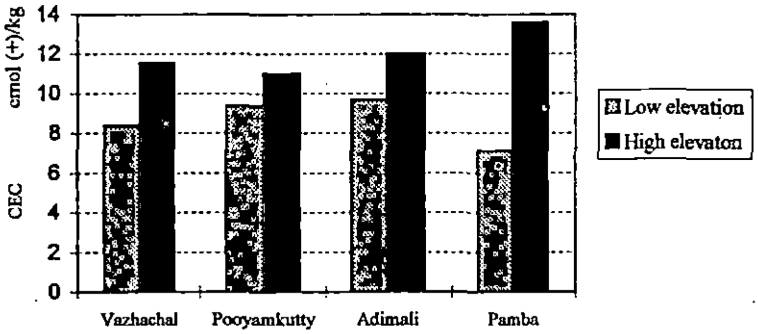


Fig. 5. Cation exchange capacity in the surface soils of (0-15 cm) reed growing tracts.

So it is found that in general, in reed growing soils, the factors related to soil fertility are mainly governed by the organic matter, which again depends on the litter fall and its consequent decomposition. Since litter fall is a function of number of culms per unit area, the density of vegetation is found to play a significant role in deciding the fertility status of reed growing soils. Moreover, the quantity and distribution of ramifying root system will be high in a thickly populated reed stand which help to withhold enormous quantity of fertile soil without being lost through erosion and run off.

Table 10. Coefficients of correlation (r) among properties of surface soil (0-15 cm) in reed growing tracts.

Variables			r
Organic carbon	vs	Bulk density	-0.6162**
Organic carbon	vs	Water holding capacity	0.4355**
Organic carbon	vs	pH in pure reed areas	-0.5132**
Organic carbon	vs	pH in under growth of teak	0.2261
Organic carbon	vs	Available N	0.6759**
Organic carbon	vs	Cation exchange capacity	0.6885**
Organic carbon	vs	Bulk density at Adimali	-0.7381**
Organic carbon	vs	Bulk density at Pamba	-6910**
Organic carbon	vs	Porosity at Adimali	0.4889**
Organic carbon	vs	Porosity at Pamba	0.5360**
Organic carbon	vs	pH in pure reed at Vazhachal	-0.3962**
Organic carbon	vs	pH in pure reed at Pamba	-0.4011**
Organic carbon	vs	Available N at high elevation	0.4922**
Organic carbon	vs	Available P	0.6016**
Organic carbon	vs	Exchangeable bases	0.4980**
Organic carbon	vs	Exchange acidity	0.2771*
Organic carbon	vs	Available K	0.4022**
pH	vs	Exchange acidity	-0.4361**
pH	vs	Exchangeable bases	0.4684**
Bulk density	vs	Porosity	0.5285**
Bulk density	vs	Water holding capacity	0.6264**

* = significant at 5% level ** = significant at 1% level

2. Influence of location on physico-chemical characteristics of reed growing soils (0-15 cm)

Significant variations with respect to all the physico-chemical properties were observed due to change in location.

In the case of gravel, Vazhachal recorded a significantly higher content than other three locations. In some of the sampling sites at Vazhachal reed was growing as undergrowth with comparatively less number of plants per unit area. This might have caused the exposure of soil to the direct action of rain and sun to a certain extent resulting in a higher content of gravel. Next to Vazhachal, Pamba also recorded a significantly higher content of gravel, which can be attributed to the reason already described. Significantly higher content of sand recorded at Adimali can be related to the nearness of some of the sampling sites to permanent water courses where the texture was sandy. The soils of Vazhachal also contained significantly higher content of finer fractions (silt and clay) compared to other locations. This indicates a high intensity of soil forming processes at this location. In laterite soils gravel is formed in the surface soil mainly from the clay rich patches under the influence of high rainfall and therefore it is often observed that soils in which gravels are seen relatively high are high in clay content though the clay is of low activity type. Once the gravel is formed by the process of compaction and hardening its colloidal properties are completely lost.

Significant variation in the particle density between all locations indicates dissimilarity in the content of primary minerals in these soils. Change in the content of organic matter also can give rise to change in the particle density. Significantly low values of bulk density and higher porosity observed at Adimali and followed by Pamba is thought to be the reflections of high content of organic matter at these locations. This is evident from a highly significant and negative correlation of bulk density (r=-0.7381**, -0.6910**) and significant and positive correlation of porosity (r=-0.4889*, -0.5360**) with organic carbon at Adimali and Pamba respectively. Significantly higher content of sand at Adimali could explain the low status of water holding capacity at this location in spite of its higher content of organic carbon.

Among the four locations studied, the soils of Vazhachal was less acidic followed by Pamba, Pooyamkutty and Adimali. At Vazhachal and Pamba, some of the sampling sites were characterised by undergrowth of reed in teak and moist deciduous trees. The base rich leaf litter of these trees might have helped to elevate the values of pH to a certain extent at these locations as explained under pedological studies. Significant and negative correlation of pH with organic carbon in pure reed patches of Vazhachal (r=-0.3962**) and Pamba (r=-0.4011**) reveals that the acidity is contributed mainly by the organic residues of reed. The content of organic carbon was significantly high at Pamba and Adimali followed by Vazhachal and Pooyamkutty. The content of organic carbon can be related to the density of reed stand. It was observed that in a densely populated reed stand, the litter cover on soil surface was more than poor reed stand. In addition to litter fall, the ramifying root system also plays an important role in influencing the organic carbon content of reed growing soils.

Among the available nutrients studied, significant variation due to change in location was not observed in the case of P, may be due to its low status, a common feature of acidic soils. All other nutrients viz., N and K were significantly high at Pamba followed by Adimali, which might be the contributions from high content of organic matter at these locations. Cation exchange capacity showed similar values in all the locations but the per cent base saturation was significantly high at Vazhachal, which can be the contributions of base rich leaves of companion vegetation.

3. Influence of elevation on physico-chemical characteristics of reed growing soils (0-15 cm)

Variation in elevation was found to exert a significant impact on certain physico-chemical properties of reed growing soils. Among the physical properties studied the impact of elevation was significant on bulk density and porosity. Higher elevation recorded significantly low bulk density and high porosity than lower elevation, thought to be due to the high content of organic matter due to low rate of decomposition taking place at high altitudes under the influence of low temperature. This is supported by the highly significant and negative correlation of bulk density with organic carbon (r=-0.6162**) and significant and positive correlation of porosity (r= 0.5285**) with organic carbon.

When the impact of elevation at each locations was considered separately, the higher elevations of Pooyamkutty and Adimali were found to record significantly higher content of sand compared to their respective lower elevations. This is assumed to be due to the nearness of certain sampling sites to permanent water courses, where the texture was sandy. The general impact of elevation on bulk density and porosity was also observed at all the four locations studied.

When the general impact of topography at low and high elevation was considered separately, no significant and definite trend of variation could be observed with respect to all the properties at both the elevations. Similarly at all the four locations also the general impact of topography was not significant.

At low and high elevations of Vazhachal, the change in topography did not exert any significant impact on most of the properties studied. But in other locations eventhough some significant variations could be observed with regard to certain properties the impact of topography did not follow any definite trend at both the elevations studied.

So the results in general convey that reed growing soils are acidic in reaction with moderate to high content of organic carbon and available nutrients except P. The variation in location exerted significant impact on most of the properties studied and elevation exerted significant impact on certain properties like bulk density, porosity organic carbon, cation exchange capacity and percentage base saturation. But the influence of topography was not clearly seen in any of the properties studied. Based on the results it is concluded that reed bamboo can be recommended for soil management in erosion prone areas of Western Ghat region of Kerala.

PART 3. PERFORMANCE OF REED IN RELATION TO SOIL FERTILITY

This part of the study was to evaluate the changes in soil and plant nutrient content in relation to the different growth performance of reed . Three classes of reed vegetation viz. Class I, Class II and Class III were selected in a natural habitat of reed at Vazhachal within an elevation of 520-550 m above msl. Since the study aims at delineating soil fertility characters responsible for the growth performance of reed, care was taken to select sites which don't differ much in elevation and topography. Another possible factor other than soil fertility that can exert overwhelming influence on the performance of reed is the presence of other trees at the selected sites. Therefore, site was selected purposively where interference by the other species of plants was at minimum. Since there was no standard criterion to differentiate these growth classes, the initial selection was carried out based on visual observations. The performance of reed has to be evaluated in terms of total out turn of usable culms produced from an area. And therefore, the best parameter for characterising this attribute was taken as the number of matured culms/ha. However, related growth parameters like number of matured culms/clump, number of matured culms/ha, number of clumps/ha spacing between each clump, maximum height of each clump and maximum girth at first node were also taken into consideration in assessing the overall performance of reed in a particular site (Table 11).

Table 11. Growth parameters in different growth classes of reed

Sl. No.		Class I		Class II		Class III	
		Mean	Range	Mean	Range	Mean	Range
1.	No. of culms / clump	25	10-70	11	2-42	7	3-18
2.	No. of culms / ha	70250	49600-78400	54175	31200-60000	18326	15200-29200
3.	No. of clumps / ha	2810	2000-3600	6925	6800-7200	2618	2400-3200
4.	Spacing between clumps, m	1.08	0.6-1.5	0.87	0.55-2.0	1.69	1.10-2.35
5.	Maximum girth at first node, cm	11.7	11-14	8.8	5-12	8.9	5-12
6.	Circumferance of each clump, cm	2.68	1.5-4.8	1.10	.80-2.98	1.16	0.45-2.5

Site characteristics, soil fertility status, plant nutrient uptake and their relation with the growth performance of reed are presented and discussed in the following part of this study.

1. Site characteristics

The area occupying Class I reed was selected at 550 m above msl at Kollathirumedu range of Vazhachal Forest Division. The site was characterised by sloping land , northern aspect, pure reed patch with closed canopy, absence of under growth and thick litter layer under varying stages of decomposition.

The Class II reed area was located at 520 m above msl at Vazhachal range of Vazhachal Forest Division. The area was a sloping land with northern aspect. In addition to reed, seedlings of some moist deciduous species were also noticed.

The Class III stand of reed was located at 550 m above msl at Vazhachal. The growth of reed was comparatively poor with scattered distribution. Seedlings of some moist deciduous species were also noticed.

2. Soil fertility status

The soil fertility status of different classes of reed was assessed based on pH, OC and status of available N, P and K. Data pertaining to these parameters are presented in Table 12 and graphically represented in Fig. 6.

The values of mean soil pH recorded in Class I, II and III were 4.53, 4.72 and 5.44 respectively. The soils of Class I and II were significantly acidic compared to Class III. Since the soils under the three different classes of reed are supposed to be derived from rocks of similar minerological make up and they enjoy similar climatic conditions, the variation in soil reaction is assumed to be due to the change in vegetative cover and subsequent accumulation of litter. A highly significant and negative correlation of pH with organic carbon (r=-0.8325**) indicates that soil pH is greatly influenced by the content of organic matter. However this relationship was more pronounced where relatively high accumulation of litter was seen. So, significantly low acidity recorded in Class III reed can be attributed to the comparatively low accumulation of reed leaf litter which causes low level of organic matter in soil. The decomposition of these organic residues results in relatively low acidity.

The mean contents of organic carbon in the Class I, II and III reed stands were recorded as 2.14, 2.00 and 1.36 per cent respectively and the statistical analysis revealed that the organic carbon content of soil supporting Class III reed was significantly low compared to the other two stands. This can be clearly attributed to the comparatively higher rate of litter fall in relation to the increase of reed culms per unit area. This is further strengthened by a highly significant and positive correlation (r=0.8688**) between the number of culms and organic carbon. As shown in Table 11, the number of culms per ha is the highest in Class I followed by Classes II and III. Along with the number of culms per unit area, the ramifying root system also will be more in Class I. Both these, together with the

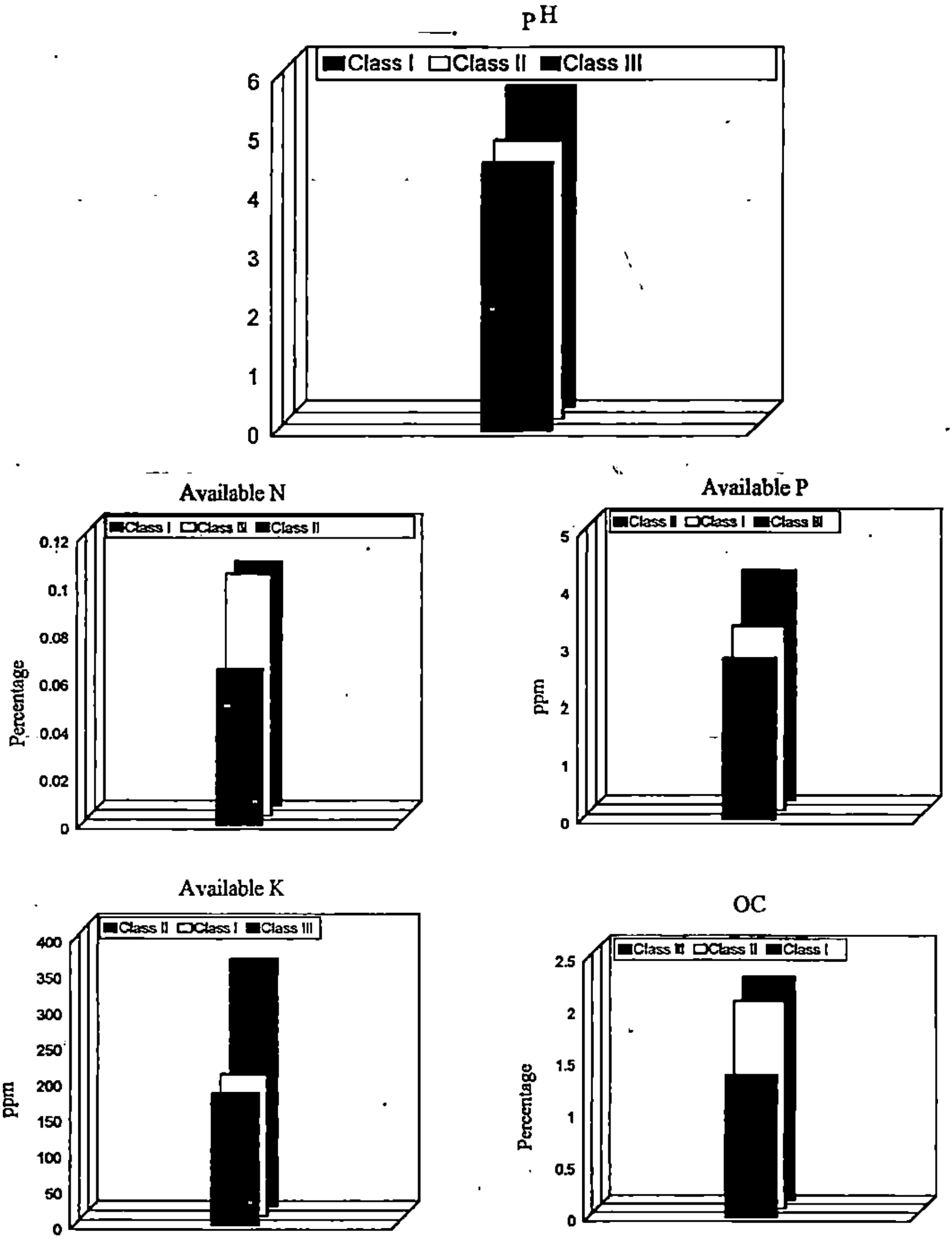


Fig. 6. Soil fertility status in different growth classes of reed

Table 12. Soil fertility status in different growth classes of reed

Sl. No.	pH			Organic carbon, %			Availabe N, %			Available P, ppm			Available K, ppm		
	Class														
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
1	4.59	4.69	5.38	2.01	1.53	1.49	0.059	0.065	0.153	2.8	2.5	3.2	179	164	291
2	4.52	4.65	5.39	2.04	1.97	1.56	0.062	0.094	0.147	2.5	2.0	4.2	207	256	251
3	4.47	4.65	5.40	2.33	2.15	1.32	0.062	0.011	0.082	3.0	4.2	4.5	216	103	296
4	4.45	4.72	5.36	2.84	1.94	1.10	0.082	0.082	0.106	3.8	2.0	3.2	205	157	376
5	4.61	4.70	5.48	2.43	1.68	1.44	0.074	0.071	0.082	3.3	1.2	3.6	175	206	551
6	4.59	4.79	5.45	2.04	1.82	1.74	0.064	0.075	0.111	2.6	3.2	3.0	196	238	250
7	4.52	4.80	5.54	1.83	2.18	1.38	0.059	0.129	0.100	4.4	3.1	5.3	219	268	435
8	4.54	4.80	5.45	1.95	2.19	1.57	0.064	0.082	0.082	2.2	3.2	7.4	215	142	368
9	4.46	4.75	5.50	2.45	2.19	1.57	0.070	0.288	0.012	2.2	3.6	3.3	210	209	254
10	4.48	4.74	5.53	2.54	2.29	1.40	0.074	0.124	0.082	2.9	2.9	2.5	197	199	292
11	4.50	4.75	5.50	1.80	1.73	1.03	0.050	0.124	0.082	3.3	3.0	4.2	195	166	439
12	4.61	4.72	5.48	1.80	1.82	1.00	0.050	0.071	0.147	5.9	3.0	4.2	166	179	294
13	4.51	4.69	5.40	1.91	2.19	1.15	0.062	0.065	0.147	2.4	3.0	3.3	194	137	271
14	4.52	4.70	5.40	1.94	2.19	1.29	0.062	0.076	0.094	2.8	3.0	4.2	193	204	364
15	4.51	4.71	5.41	2.16	2.18	1.38	0.082	0.071	0.088	4.2	3.0	4.2	191	123	441
Mean	4.53	4.72	5.44	2.14	2.00	1.36	0.065	0.102	0.101	3.2	2.8	4.0	197.2	183.4	344.8
CD (0.05)	0.198			0.323			0.021			ns			19.20		

dead remains of soil fauna help to elevate the level of organic carbon in Class I reed.

The data on available N presented in Table 12 indicated that its content in reed stands of Class I, II and III were 0.065, 0.102 and 0.101 per cent respectively. Significantly, low status of available N in spite of high organic carbon status in Class I reed stand proclaim the higher uptake of N by the fast growing densely populated reed stand. The data on plant N content provided in Table 14 also support the above statement. Eventhough Class II recorded relatively higher content of organic carbon than Class III, the status of available N was almost similar in these two stands. This is also thought to be due to the accumulation of more N in the biomass of Class II stand.

The status of available P recorded almost similar values in all the Classes of reed vegetation. The mean values recorded were 3.2, 2.8 and 4.0 ppm in Class

I, II and III reed. This reveals that soil available P was not influenced by the density of reed growth. Similar observation was already seen and explained under soil fertility status of reed.

In the case of available K, Class III reed stand recorded significantly higher content figuring 344.8 ppm. The Class I and II stands respectively recorded 197.2 and 183.4 ppm. The high organic carbon status and poor soil available K in Class I reed stands prove that reed plant is a great absorber of K. This is further strengthened by a highly significant and negative correlation (-0.7200**) of available K with number of culms/ha.

Table 13. Coefficient of simple linear correlation (r) between various soil fertility characteristics and number of culms in different growth classes of reed

	No . of culms	Soil pH	Org. carbon	Av. N	Av. P	Av. K
No. of culms	1.0000					
Soil pH	-0.8986**	1.0000				
Org. carbon	0.8688**	-0.8325**	1.0000			
Av. N	-0.2695'	0.2803	-0.1771	1.0000		
Av.P	-0.4523**	0.4880**	-0.4210**	0.1675	1.0000	
Av. K	-0.7200**	0.7595**	-0.6656**	0.1944	0.4639**	1.0000

3. Relationship between soil fertility status and growth of reed

The results and discussion furnished so far clearly indicate that the soil fertility status of reed growing soils is greatly influenced by the density of reed growth. Since the density of reed growth was judged by the number of matured culms/ha an attempt has been made to work out the relationship between soil fertility status and number of culms/ha. A response function relating number of culms to different soil properties viz., soil pH, organic carbon, available N, P and K was fitted using stepwise regression technique. The model fitted through stepwise regression was $Y=501.0420 - 179.881920x_1 + 16.1516x_1^2 + 1.9450x_1x_2$ where y = number of culms/ha , x_1= soil pH and x_2 = organic carbon.

The adjusted R^2 for the above model is 0.86053. It is understood from the model that nearly 86 per cent of the variation in the number of culms is explained by soil pH and organic carbon. Soil pH had a significant quadratic effect on the number of culms and there was a positive interaction between soil pH and organic carbon.

4. Nutrient content and uptake

Contents of nutrients viz. N, P and K were determined in various plant parts like leaf, culm root and rhizome in all the three growth classes of reed (Table 14, Fig. 7). Results indicated a higher content of N in the leaf in all the three growth classes. The order of its abundance was leaf > root > rhizome> culm in Class I and leaf > root > culm > rhizome in Classes I and II. Among the three classes, Class I was found to record a significantly higher content of N in the leaf than the other two classes. As in the case of N, in all the classes leaf contained highest content of P. The order of its abundance was leaf > root > rhizome > culm in all the growth classes. Higher concentration of P in the below ground portion of the plant indicates its immobile nature. Moreover, for the fast growth of roots and rhizomes, a common feature of reed may be demanding P in greater quantities. In the case of K, the order of abundance was in the order leaf > culm > rhizome > root in Class I and culm > leaf > rhizome > root in Class II and root > culm > leaf> rhizome in Class III. Since there was no significant relation between number of culms/ha and plant nutrient content, the uptake of nutrients by culms and leaves was determined (Fig. 8). The data in Table 15 indicate a higher uptake of N, P and K in the above ground biomass of Class I reed as compared to the other two. It should be kept in mind that the total number of culms/ha is relatively high in Class I and therefore it could be expected that total uptake of nutrients by reed will be high in Class I as compared to Class II and III. When the three classes of reed were considered together, the dry weight of culms/ha was found significantly and positively correlated with the uptake of N (r=0.8547**), P (r=0.9277**) and K (r=0.9458**) in the culms. Similarly the dry weight of leaves/ha was also significantly and positively correlated with N (r=0.9894**), P (r=0.9287**) and K (r=0.9367**) in the leaves.

Table 14. Mean values of nutrient content in various parts of reed in different growth classes

Nutrient	Plant part	Class I	Class II	Class III	C.D (0.05)
Nitrogen %	leaf	2.04	1.53	1.64	0.34
	culm	0.69	1.34	1.07	0.36
	rhizome	0.83	0.86	0.76	0.19
	root	1.03	1.38	1.10	0.48
Phosphorus %	leaf	0.09	0.09	0.09	ns
	culm	0.05	0.04	0.05	ns
	rhizome	0.06	0.06	0.07	ns
	root	0.08	0.08	0.08	ns
Potassium,%	leaf	0.26	0.17	0.25	0.04
	culm	0.21	0.20	0.26	0.05
	rhizome	0.12	0.11	0.09	0.06
	root	0.04	0.09	0.31	0.03

Lower availability of N and K in soil and its higher uptake in the culms and leaves of Class I reed clearly indicate the accumulation of these nutrients in the above ground biomass. It is reported that (Rao and Ramakrishnan, 1989) bamboo has the ability for rapid uptake and accumulation of K in the above ground biomass. The results obtained in the present study evidently substantiate the above findings in the case of reed also.

Based on the above findings an attempt has been made to work out the relationships between above ground biomass and uptake of N,P and K. Two response functions relating dry weight of culms/ha and dry weight of leaves / ha to the uptake of N, P and K in culms and leaves respectively were fitted using stepwise regression technique. The models fitted through stepwise regression was

$$Y_1 = -1294.29 + 37.265\ N + 321.410\ P + 226.442\ K$$

$$Y_2 = 2.10 + 38.403\ N + 187.200\ K$$

Where Y_1 is the dry weight of culms/ha and Y_2 is the dry weight of leaves/ha. In the first model, adjusted $R^2 = 0.9540$ and in the second model adjusted $R^2 = 0.9823$. This gives the idea that 95 per cent variation in the dry weight of culms/ha can be explained by the uptake of N,P and K and 98.23 per cent variation in the dry weight of leaves/ha can be explained by the uptake of N and K. The data on

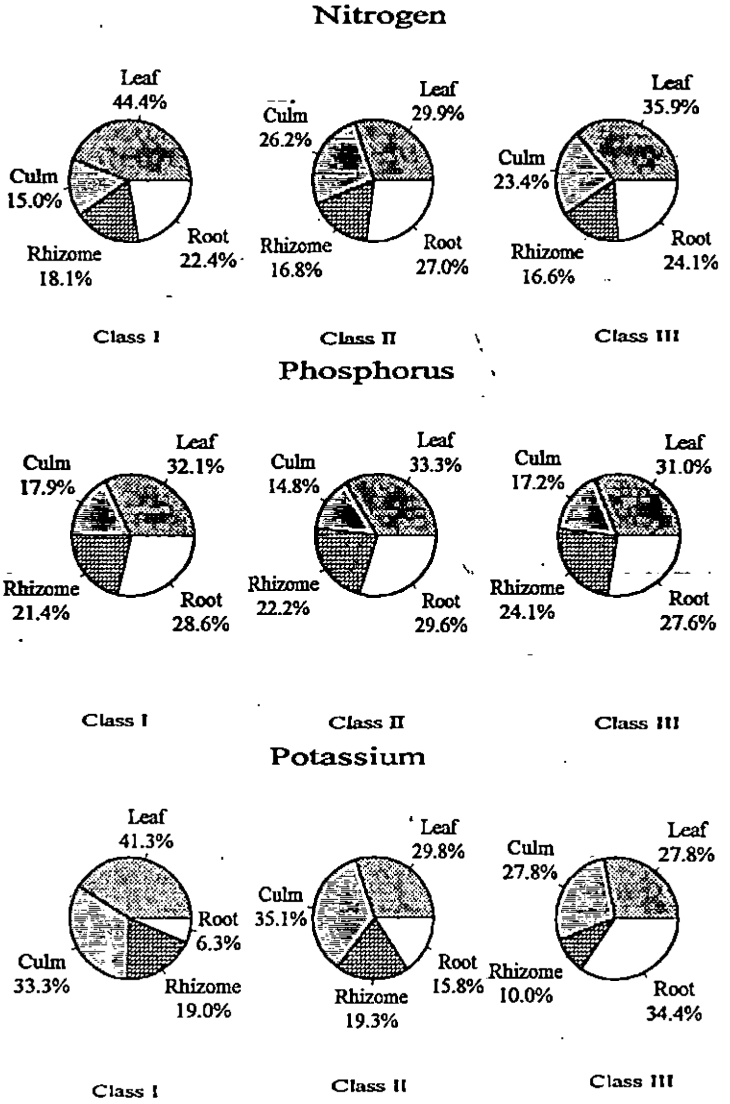


Fig. 7. Nutrient content in various parts of reed in different growth classes

partial regression coefficients reveal that 30.0 per cent variation in the dry weight of culm / ha is explained by the uptake of N, 20.4 per cent by the uptake of P and 54.1 per cent by the uptake of K. In the case of dry weight of leaves/ha, 83.7 per cent variation is explained by the uptake of N and 16.6 per cent variation is explained by the uptake of K.

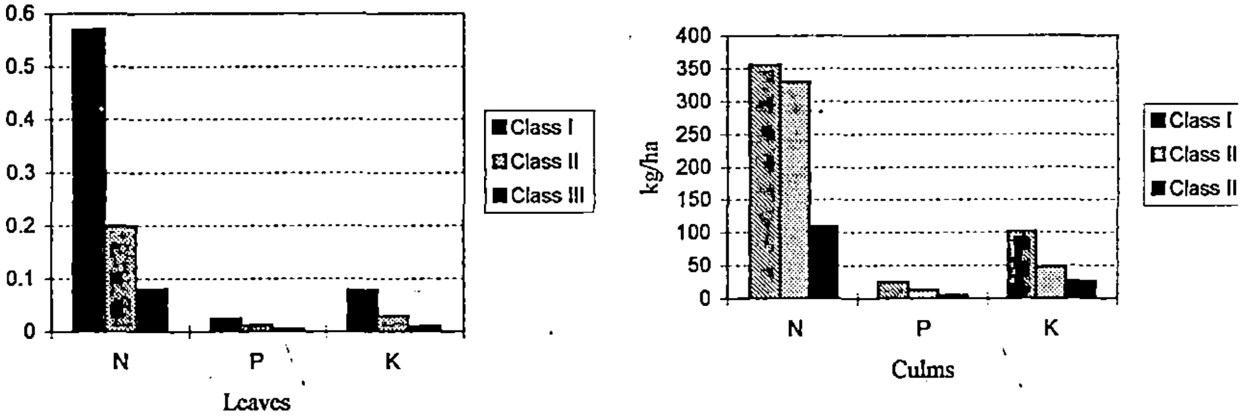


Fig. 8. Nutrient uptake by culms and leaves of reed in different growth classes

Table 15. Mean values of nutrient uptake by culms and leaves of reed in different growth classes.

Growth class	Culm				Leaf			
	Biomass kg ha^{-1}	Uptake. Kg ha^{-1}			Biomass kg ha^{-1}	Uptake, kg ha^{-1}		
		N	P	K		N	P	K
I	44012.3	355.7	24.3	101.6	28.3	0.57	0.024	0.078
II	24813.6	329.04	13.08	48.3	13.4	0.20	0.012	0.03
III	1034.1	109.6	5.08	25.9	5.01	0.08	0.005	0.01
CD (0.05)	196.7	81.9	3.82	12.64	3.48	0.06	0.002	0.008

Table 16. Coefficients of simple linear correlation (r) between above ground biomass and nutrient uptake in reed

Variables	r
Culm weight vs N uptake	0.8547**
Culm weight vs P uptake	0.9277**
Culm weight vs K uptake	0.9458**
Leaf weight vs N uptake	0.9894**
Leaf weight vs P uptake	0.987**
Leaf weight vs K uptake	0.9367**

So from the above results it can be concluded that the growth performance of reed is greatly judged by the number of matured culms/ha and it is greatly influenced by soil pH and organic carbon. Class I reed recorded higher uptake of N, P and K in both culms and leaves than other two classes. Culm weight was found greatly influenced by the uptake of N, P and K and leaf weight was found greatly influenced by the uptake of N and K.

PART 4. LITTER DECOMPOSITION AND NUTRIENT RELEASE

A huge part of solar energy and earth's minerals are trapped into plants during their constructive phase of metabolism. For the release of these nutrients, dead plant parts must decompose releasing bound energy for the utilisation of growing plants. In forest ecosystem, the litter on the forest floor acts as an energy source for heterotrophic organisms and a nutrient reservoir for intrasystem cycling. The availability of the nutrients for plant uptake depends upon the reabsorption and retranslocation of the nutrient before leaf fall and subsequently on decomposition and mineralisation of the organic matter. The rate of litter decomposition depends upon the physico-chemical environment and the quantity and quality of decaying residues. This part of the study was to find out the rate of decomposition and nutrient release from reed leaf litter. The study was carried out for a period of one year in two reed growing sites selected at Vazhachal. Since the litter bags were withdrawn on the 4th day of every month the data were considered relevant for the preceeding month.

1. Soil moisture status

Considering the importance of soil moisture in the degradation of leaf litter, soil samples for moisture determination were also collected along with the monthly withdrawal of leaf litter bags (Table 17, Fig. 9). At site I the variation in soil moisture was in the range from 11.15 to 28.3 per cent and at site II it was from 10.35 to 32.78 per cent. The variation in the content of soil moisture at both the sites followed similar pattern and the maximum value was recorded during September. This can be due to the similar climatic and soil conditions prevailing at both the sites. Moreover, the growth of reed was in medium to dense patch which further helped to make a similar vegetative cover at both the sites. The values of soil moisture obtained in the present study are relatively higher than the soil moisture status of acacia plantations in Kerala (Sankaran *et al.*, 1992). Compared to acacia, reed plants were found to conserve higher amount of moisture in soil even during dry periods.

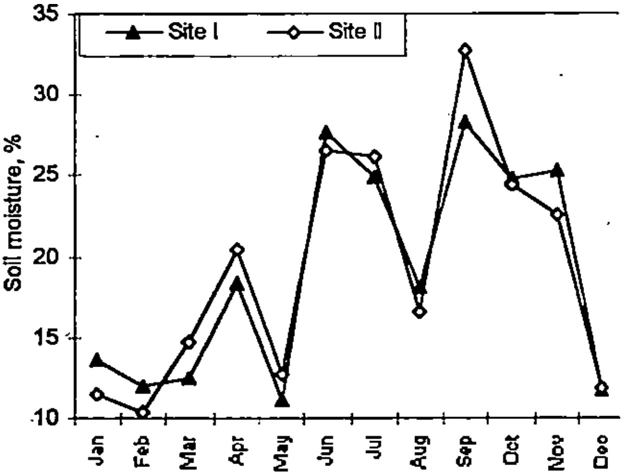


Fig. 9. Soil moisture status in reed growing tracts at Vazhachal

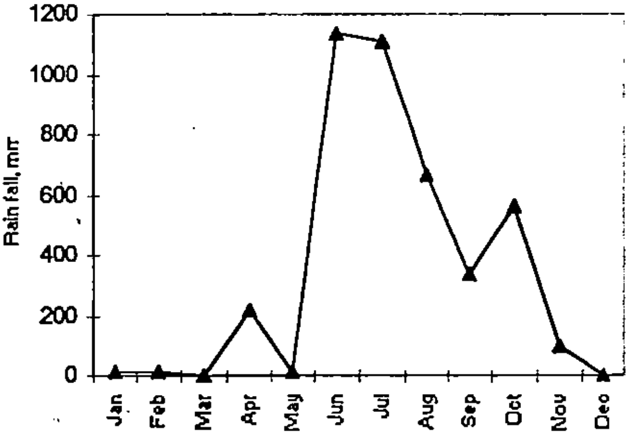


Fig. 10. Rainfall distribution during the year '94 at Vazhachal

Table 17. Soil moisture status and rainfall during the year 1994 in reed growing tracts at Vazhachal (Percentage)

Site	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Soil moisture, %												
	14.36	13.53	13.62	18.23	12,52	27.02	24.30	20.10	27.71	24.30	26.13	14.80
	14.47	12.43	11.60	18.59	10.89	30.44	24.45	17.99	29.00	25.81	26.17	12.73
I	11.84	10.12	12.14	18.26	10.05	25.36	25.99	16.30	28.19	24.30	23.50	14.55
Mean	13.56	12.03	12.45	18.36	11.15	27.61	24.90	18.13	28.30	24.80	25.30	11.80
	10.14	10.69	13.70	21.20	10.38	25.40	25.32	22.03	33.03	24.26	22.92	11.80
	11.23	9.82	11.36	20.40	12.35	26.78	25.39	10.13	30.45	24.63	18.91	12.73
II	13.11	10.54	12.20	19.73	15.40	27.70	27.69	17.46	34.85	24.32	25.86	11.17
Mean	11.49	10.35	14.75	20.40	12.71	26.60	26.13	16.54	32.78	24.40	22.60	1.90
Rain fall, mm												
	32.40	14.80	Nil	217.50	16.00	1138.5	1107	669	334	559	96.5	Nil

In reed growing tracts, the litter layer acts as a mulch on soil surface and thereby prevents the evaporation to a great extent. Moreover, the closed canopy of reed also gives an added effect to lessen the soil moisture loss. As expected, higher soil moisture was observed in rainy months. This was further supported by a highly significant and positive correlation between soil moisture content and the amount of rainfall received (r=0.6550**).

2. Mass loss during decomposition

Mass loss from decomposing reed leaf litter was determined from the mass remaining in litter bags (Table 18) and the monthly loss for a period of one year was accounted (Table 19, Fig. 11). The values pertaining to the periodical disappearance of litter indicated that the total mass loss increased with increase in time, but the monthly loss was not uniform over different months. The mean monthly loss at Site I ranged from 0.74 - 6.0 g and Site II it ranged from 0.24 - 5.77 g. At Site I, the mean mass loss was minimum in March and maximum in July. But at Site II it was minimum in October and maximum in July.

Table 18. Mass remaining in litter bags during decomposition of reed leaf litter, g

Site	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
I	23.48	22.69	22.00	19.42	17.20	13.04	5.85	2.85	2.00	1.37	0.96	0.32
	23.62	22.45	21.85	18.24	17.95	15.20	9.92	7.02	4.85	2.35	1.51	0.56
	23.79	22.54	21.60	19.76	18.16	15.79	10.25	7.55	5.16	2.80	1.75	1.09
Mean	23.63	22.56	21.82	19.14	17.77	14.68	8.67	5.81	4.00	2.17	1.41	0.66
II	23.55	22.92	22.15	19.83	18.12	12.65	7.02	5.85	3.20	3.10	2.98	2.08
	23.53	22.28	21.64	18.79	16.62	12.44	7.55	4.17	2.00	1.59	1.05	0.68
	23.22	22.69	21.88	19.55	18.18	13.75	6.96	4.00	2.06	1.94	1.12	0.46
Mean	23.43	22.63	21.89	19.39	17.64	12.95	7.18	4.67	2.42	2.21	1.72	1.07

Table 19. Mass loss during decomposition of reed leaf litter, g

Site	Fresh litter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
I	25	1.52	0.79	0.69	2.58	2.22	4.16	7.19	3.00	0.85	0.63	0.41	0.64
	25	1.38	1.77	0.60	3.61	0.29	2.75	5.28	2.90	2.17	2.50	0.84	0.95
	25	1.21	1.25	0.94	1.84	1.60	2.37	5.54	2.70	2.39	2.36	1.05	0.66
Mean		1.37	1.07	0.74	2.68	1.37	3.09	6.00	2.87	1.80	1.83	0.77	0.75
II	25	1.45	0.63	0.77	2.32	1.71	5.47	5.63	1.17	2.65	0.10	0.12	0.90
	25	1.47	1.25	0.64	2.85	2.17	4.18	4.89	3.38	2.17	0.49	0.54	0.37
	25	1.78	0.53	0.81	2.33	1.37	4.43	6.79	6.79	1.94	0.12	0.82	0.66
Mean		1.57	0.80	0.74	2.50	1.75	4.69	5.77	3.78	2.25	0.24	0.49	0.64

At both the sites mean mass loss was comparatively low during January, February and March. In the month of April, there was a sudden increase in the mass loss of decaying leaf litter, which is thought to be due to the few showers

Plate 12. Litter bags around reed clumps for decomposition study

obtained during that period. After that with the onset of monsoon showers in June, there was a sudden uplift in the decaying processes and consequent mass loss. At both the sites maximum disappearance of mass was in July. After that during the following months, the mass loss was found to decrease. But this decrease was in varying quantities over different months at both the sites studied. At Site I, this decrease was minimum in November and at Site II it was in October.

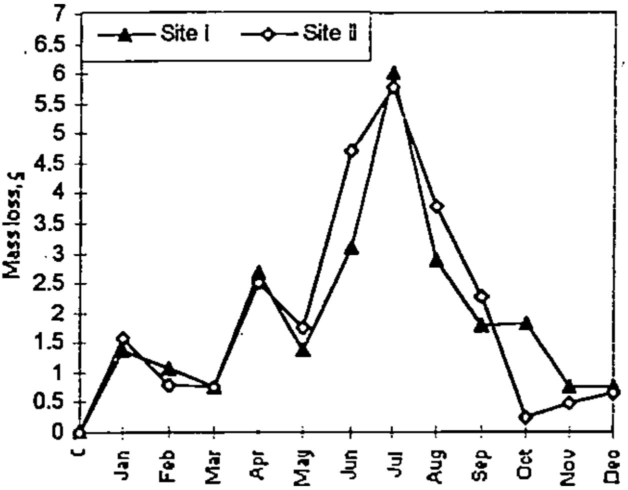


Fig. 11. Mass loss during decomposition of reed leaf litter

The reported studies indicate that temperature and moisture as critical environmental factors for high rates of decomposition and the litter decomposition is maximum during rainy season. The slow process of decomposition observed during the initial three months of decomposition in this study is attributed to the low rainfall received during that time. During rainy season, due to the rapid multiplication and intense activity of microbes, most of the easily decomposable substances are lost from the system. As a result, relatively more resistant materials remain in the litter bags and this causes a decrease of mass loss during the following months.

Table 20. Decomposition parameters of reed leaf litter

Plot	Annual decomposition rate constant (K)	Time required for 50% (half life) decomposition	Time required for 95% decomposition
I	0.23395 ($R^2 = 0.90$)**	3 months	13 months
II	0.22868 ($R^2 = 0.92$)**	3 months	13 months

To estimate the rate of decomposition, the data on mass loss was tested for the fitness of 25 models in the curve fit and based on the value of R^2 (0.9970) the best fitting exponential model was selected. The K values (annual decomposition rate constants) determined using this model at Site I and Site II were 0.234 and 0.229 respectively (Table 20). The R^2 values indicated that the contribution of independent variable (months) in the total variation of Y (mass loss) was 90 per cent at Site I and 92 per cent at Site II. The time required for 50 per cent (half life) and 95 per cent decomposition were found to be the same for both the sites, the 50 per cent decomposition within three months and a decay of 95 per cent was anticipated within a time span of 13 months. A comparative study of decomposition rate constants at two sites yielded no significant difference statistically. The data reported in the literature indicated that the rate of decomposition of reed leaf litter in general was slightly lower than that of leaf litter of different moist deciduous species like *Tectona grandis* (0.32), *Pterocarpus marsupium* (0.44), *Xylia xylocarpa* (0.35), *Dillenia pentagyna* (0.33), *Grewia tiliaefolia* (0.34), *Terminalia paniculata* (0.29), (Kumar and Deepu, 1992) and *Albizia falcataria* (0.14) (Sankaran, 1993) in Kerala. Relatively low decomposition rate constant obtained in the present study in spite of higher content of N in the litter is assumed to be due to the change in the time of placement of leaf litter in the field. Since mass loss was strongly and positively correlated with rainfall (r=0.6080**), the decomposition would have been much quicker if the litter bags were placed just before the monsoon showers. Hence it is hoped that the decomposition rate constant of reed leaf litter can be raised to a certain extent if the time of placement of litter bags is extended to June, just after the onset of monsoon showers.

The nylon bag used in the study is also found to have some influence on reducing the rate of decomposition. Field observations indicate that the litter placed in the litter bags was less susceptible to the attack of soil macro fauna compared to the litter present on soil surface.

Sanalkumar *et al.* (1998) studied the dominant faunal groups with their decomposing status and frequency in the reed growing soils of Vazhachal (Table 21). A high diversity of (16 classes) of faunal groups, majority having significant role in decomposing process was noted in this soil. The dominal faunal groups occurring in the reed growing soils are Isopoda, Chilopoda, Acarina, Collembola, Isoptera and Oligochaeta. All these groups except Chilopoda help in the degradation of litter and enrich the soil with highly fertile humus.

Table 21. Dominal faunal groups, their decomposing status and frequency in reed growing soils of Vazhachal

Sl. No.	Faunal	Decomposing group	Frequency status
1.	Oligochaeta	+	2
2.	Copepoda	0	3
3.	Isopoda	+	1
4.	Chilopoda	-	2
5.	Diplopoda	+	3
6.	Araneida	0	4
7.	Acarina	+	1
8.	Pauropoda	0	4
9.	Palpigradi	0	4
10.	Gamasida	+	4
11.	Collembola	+	1
12.	Protura	0	2
13.	Diplura	+	4
14.	Isoptera	+	1
15.	Coleoptera	+	1
16.	Diptera (larva)	+	2

+ Highly significant; O - Significant; - Not significant

1 - Abundantly present in all seasons

2 - Abundant in spring and less abundant in summer

3 - Less abundant in all seasons

4 - Represented only in few months of the year

Table 22. Correlation matrix between various parameters related to decomposition of reed leaf litter

	Soil moisture	Mass loss	Rain fall
Soil moisture	1.0000		
Mass loss	0.2922	1.0000	
Rain fall	0.6550**	0.6080**	1.0000

3. Nutrient release

The initial concentration of various nutrients in the leaf litter of reed and monthly changes occurred in the content of these nutrients during decomposition for a period of 12 months are given in (Table 23, Fig. 12). The results reveal that in general the reed leaf litter contains highest amount of N (1.98%) followed by K (0.46%), Ca (0.16%), Mg (0.12%) and P (0.085%). The releasing pattern of these nutrients from the reed leaf litter undergoing decomposition are discussed hereunder.

Table 23. Nutrient concentration in the remaining mass of decomposing reed leaf litter, %

	Nitrogen		Phosphorus		Potassium		Calcium		Magnesium	
Month	Site I	Site II	Site I	Site II	Site I	Site II	Site I	Site II	Site I	Site II
Fresh litter	1.98	1.98	0.09	0.09	0.46	0.46	0.16	0.16	0.12	0.12
January	1.95	1.94	0.09	0.09	0.43	0.45	0.16	0.16	0.12	0.12
February	1.92	1.90	0.09	0.09	0.40	0.44	0.16	0.15	0.11	0.12
March	1.91	1.90	0.09	0.09	0.40	0.42	0.15	0.16	0.11	0.10
April	1.94	1.93	0.10	0.10	0.40	0.41	0.15	0.17	0.10	0.10
May	1.98	1.98	0.10	0.10	0.37	0.39	0.17	0.17	0.10	0.11
June	2.18	2.10	0.11	0.12	0.32	0.33	0.18	0.19	0.11	0.11
July	2.67	2.59	0.12	0.12	0.25	0.29	0.18	0.18	0.14	0.12
August	2.95	2.87	0.13	0.12	0.18	0.20	0.19	0.18	0.16	0.17
September	3.18	3.05	0.11	0.11	0.14	0.16	0.17	0.16	0.10	0.13
October	2.21	2.10	0.08	0.09	0.08	0.12	0.14	0.12	0.11	0.11
November	1.60	1.48	0.05	0.07	0.04	0.07	0.11	0.12	0.08	0.13
December	0.22	0.30	0.05	0.06	0.03	0.04	0.08	0.08	0.04	0.05
Percentage loss	88.9	84.8	44.4	33.3	93.5	91.3	50.0	50.0	66.7	58.3

3.1. Nitrogen

During decomposition of reed leaf litter, the content of N in the remaining mass was found to show variable trends at both the sites, during the early three months of decomposition, it was found to show a declining tendency. This is thought to be due to its loss through leaching, accelerated by the few showers occurred during this period. This reduction was found to vary from 3.5 to 4.0 per cent of its original content. But the following months showed an accumulation phase and this was continued up to the month of September. During this time the percentage increase reached even up to 60.6 per cent of its initial content. This can be definitely due to the intense immobilization activity of microbes including N fixing ones during these most favourable climatic conditions. Addition through precipitation also might have helped to elevate the values of N. A similar hike of N during decomposition was also observed by several workers (Maclean and Wein, 1978; Das and Ramakrishnan, 1985). After September, it was found to show a diminishing tendency and at the end of one year period, the content of N got reduced to 0.22 per cent at Site I and 0.30 per cent at Site II. Thus, the results in general indicated that 84.80 to 88.90 per cent of N got released from reed leaf litter within 12 months of decomposition.

The data on the absolute content (determined by multiplying the nutrient concentration and the mass remaining at each month) of N (Table 24, Fig. 13) showed a gradual decrease with increase in time of decomposition. This is explained by the relatively higher mass loss compared to the change in the concentration of nutrient with increase in time. The nitrogen release estimated based on the absolute content was 99.7 per cent at Site I and 99.4 per cent at Site II.

3.2. Phosphorus

The concentration of P in the remaining mass of decomposing litter remained similar during early four months at both the sites studied, revealing a very slow release of this nutrient. But after the onset of monsoon showers, there was a sudden uplift in the P content of litter mass, which might be the contribution from the mycelial growth of fungus multiplied during this time. This increase was recorded up to 44.4 and 33.3 per cent at Sites I and II respectively. But after that the values started coming down and in the month of December the content of P in the remaining mass varied from 55.6 - 66.7 per cent. The data in general showed that the release of P from reed leaf litter occurred only in the later stages of decomposition. But Srivastava *et al.* (1972) reported uniform return of P from the leaf litter in Sholas. The slow release of P from the reed leaf litter can be due to its immobile nature. Similar release pattern of P was also observed by Bockheim and Jepsen (1991) in north-western Wiscohsin and Bahuguna *et al.* (1990) in *Shorea robusta* and *Eucalyptus* *camaldulensis* in India. As in the case of N, the absolute content of P also showed a gradual decrease with increase in time of decomposition, the reason attributed to N is applicable here also. Based on the absolute content, the total release of P was 98.7 per cent at Site I and 97.4 per cent at Site II.

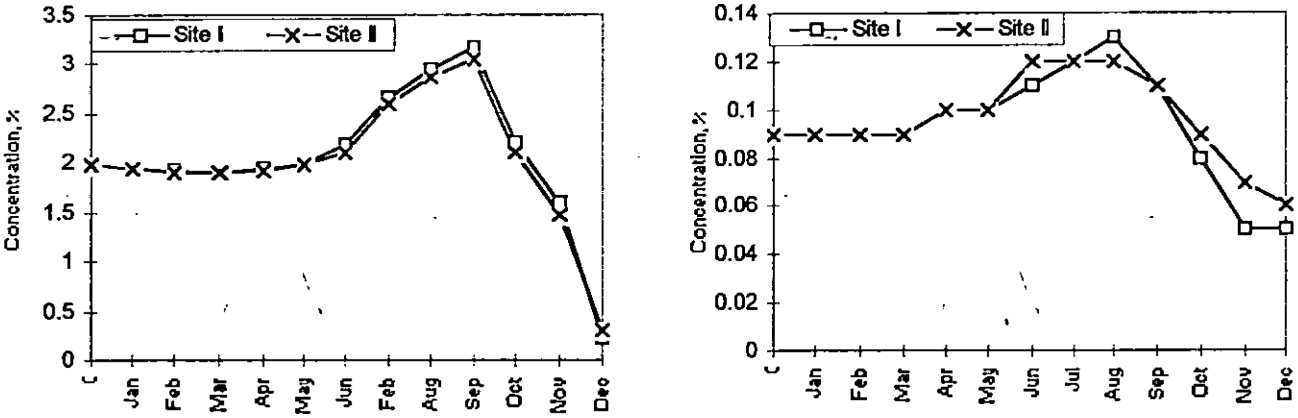
3.3. Potassium

The data pertaining to the content of K in the remaining mass of reed leaf litter revealed that the loss in K occurred at all stages of decomposition, but it was more pronounced during rainy months. Both the sites showed similar pattern of release of this nutrient. The loss in general was found to be as 10.9 to 13.0 per cent before the on set of monsoon showers, 45.6 to 47.9 per cent during rainy season and 32.6-34.8 per cent after rainy season. Attiwill (1968) found it as most mobile element and this reasons for the rapid release of this nutrient. In contrast to N and P, K is not bound as a structural component in plants and is highly water soluble (Gosz *et al.*, 1973). The present study indicated that almost 91.3 to 93.5% of K got released within a time span of one year.

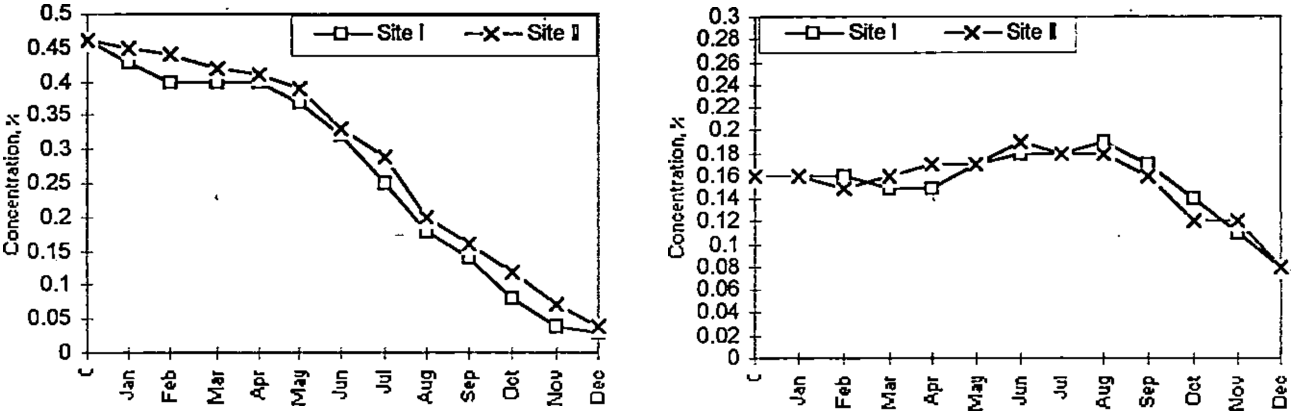
But these results are not in agreement with the results reported by Bahuguna *et al.* (1990) wherein they could observe an increase of K concentration during later stages of decomposition in *Shorea robusta.* The heavy rainfall prevailed during the later stages of decomposition might have removed this most mobile element from the reed residue and this explains the low value recorded in the present study. Similar decrease of K and its close successive correlation with the loss in total organic matter in *Eucalyptus globulus* had been reported by Upadhyay (1982).

The data on the absolute content of K showed a gradual decrease of this nutrient with increase in time of decomposition and the maximum release was recorded during July. At the end of one year period, the total release of K was 99.8 per cent at Site I and 99.7 per cent at Site II.

Nitrogen Phosphorus



Potassium Calcium



Magnesium

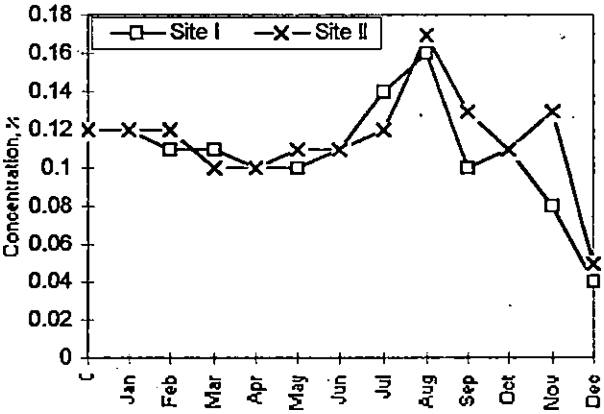
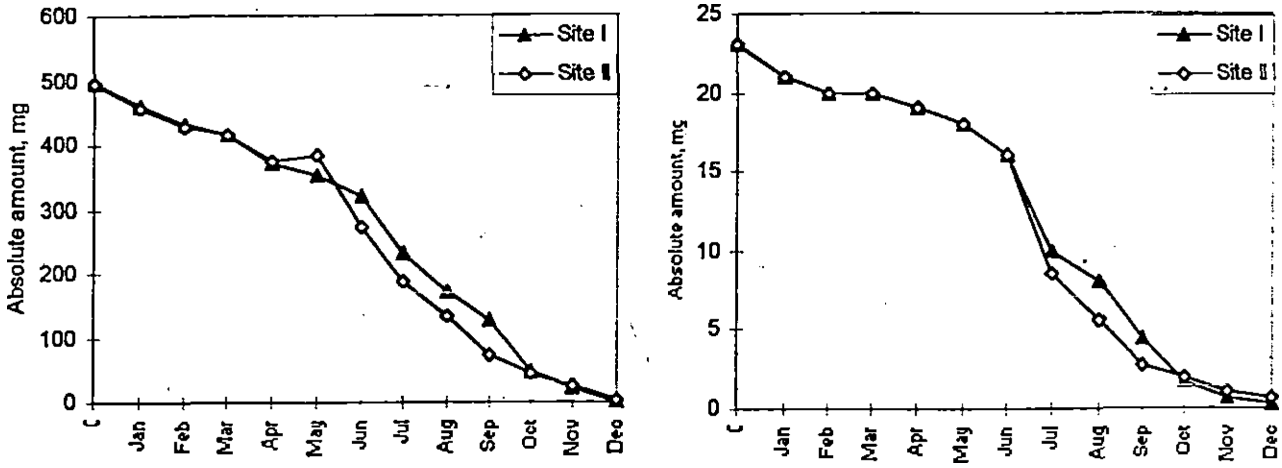


Fig. 12. Nutrient concentration in the remaining mass of reed leaf litter during decomposition

Nitrogen Phosphorus



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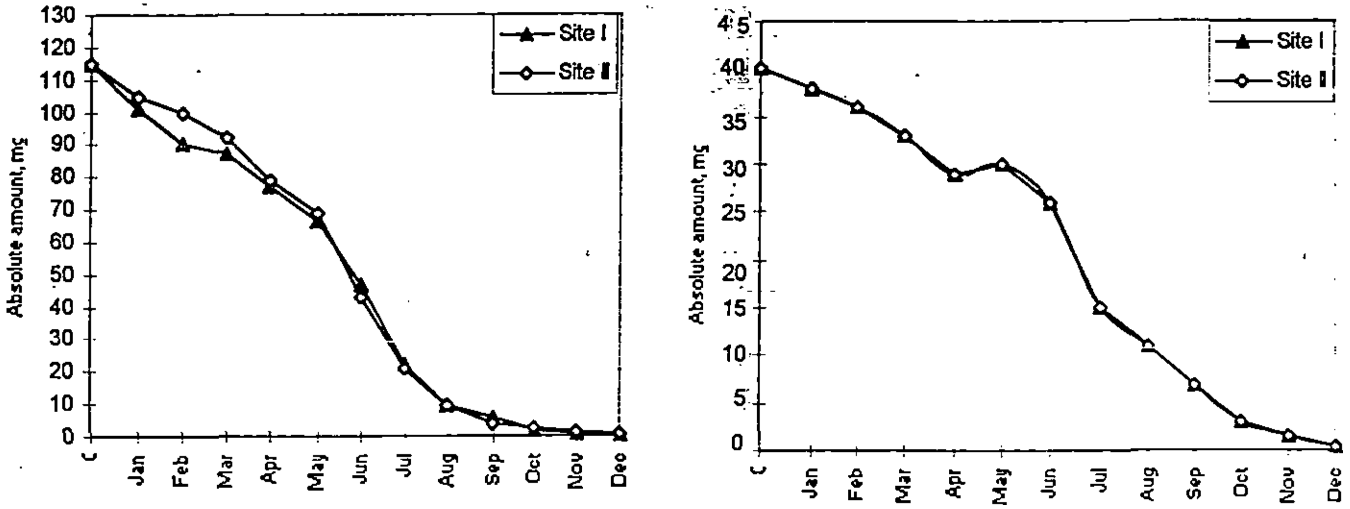

Magnesium

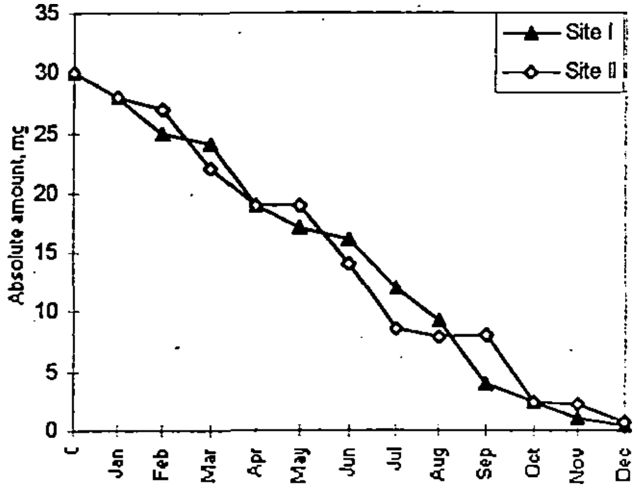

Fig. 13. Absolute content of nutrients in the remaining mass of reed leaf litter during decomposition

3.4. Calcium

The content of Ca in the original litter sample was not affected much during the early months of decomposition. But after the onset of monsoon showers, due to the faster rate of multiplication of soil fauna, immobilisation occurred and hence the content of Ca in the remaining litter mass was elevated to the maximum of 0.19 per cent recording the immobilisation increase to 18.8 per cent. After that, starting from September a gradual decline of this nutrient was noticed. However, within a time span of one year, the total loss accounted was only 50 per cent of its original content at both the sites studied.

Burges (1956) showed that Ca was retained within the litter until the major breakdown of cellwall tissue occurred. Attiwill (1968) could observe a very little leaching of Ca which he attributed to the immobility of the element. The results of the present study indicated that release of Ca from decomposing reed leaf litter occurred very slowly and the major loss was noticed during last months of decomposition.

3.5. Magnesium

As in the case of K, a gradual loss of Mg was observed starting from the early months of decomposition at both the sites during the early four months. This loss was computed as only 20 per cent of its initial content. Eventhough the values conveyed some immobilization trends during monsoon period, the data showed some fluctuation towards the last months of decomposition. It was estimated that a total release of 58.3 to 66.7 per cent of Mg occurred within a time span of 12 months. Bockheim and Jepsen (1991) could observe a gradual release of Mg in decomposing jack pine and northern pine oak leaf litter.

But in bamboo timber stands of China, Maoyi *et al.* (1988) reported an increase in the content of Mg with successive decomposition of leaf litter. This help to assume that the heavy rainfall obtained in the present study site might have helped to remove this nutrient from the system to a certain extent.

Table. 24. Absolute content of nutrients in the remaining mass of decomposing reed leaf litter, mg

	Nitrogen		Phosphorus		Potassium		Calcium		Magnesium	
Month	Site I	Site II	Site I	Site II	Site I	Site II	Site I	Site II	Site I	Site II
Fresh litter	495	495	23	23	115	115	40	40	30	30
January	461	457	21	21	101	105	38	37	28	28
February	433	430	20	20	90	100	36	39	25	27
March	417	416	20	20	87	92	33	35	24	22
April	371	376	19	19	77	79	30	33	19	19
May	352	384	18	18	66	69	29	30	17	19
June	320	272	16	16	47	43	26	25	16	14
July	231	186	10	8.6	22	21	15	13	12	8.6
August	171	134	8	5.6	9.3	9.3	11	8.4	9.3	7.9
September	127	74	44	2.7	5.6	3.8	6.8	3.9	4.0	3.1
October	47	46	1.7	2.0	1.7	2.7	3.0	2.7	2.4	2.4
November	23	25	0.7	1.0	0.6	1.2	1.6	2.1	1.1	2.2
December	1.5	3.2	0.3	0.6	0.2	0.4	0.5	0.9	0.3	0.6
Percentage loss	99.7	99.4	98.7	97.4	99.8	99.7	98.8	97.8	99.0	98.0

As in the case of other nutrients the absolute content of Mg also showed a gradual decrease with increase in time of decomposition. The total loss was 99.0 per cent at Site I and 98.0 per cent at Site II within a period of 12 months.

The results of the study revealed that, in general, the release of various elements at successive stages of decomposition varied with type of element. Based on the concentration and the absolute content, the nutrient mobility from decomposing reed leaf litter was in the order K>N>Mg>Ca>P.

SUMMARY

SUMMARY

This study was carried out in four parts with the following objectives. (1) Pedological / taxonomical characterisation of reed growing soils. This was studied by taking typical soil profiles in two different elevations and topography from predominantly reed growing areas of the State. (2) Evaluation of fertility status of reed growing soils. To study this, surface soil samples (0-15 cm) were collected from reed growing areas belonging to different elevations and topography and the soil properties were compared. (3) Performance of reed in relation to soil fertility. Three classes of reed stands viz. Class I, Class II and Class III were selected at Vazhachal and fertility characteristics of surface soils (0-15 cm) were compared. Relationships between reed growth and soil properties were worked out. Relation of above ground biomass with uptake of nutrients was also looked into. (4) *In situ* decomposition of reed leaf litter and nutrient release pattern. This was studied in two reed growing sites at Vazhachal by adopting litter bag technique.

Part 1

1. The soils of reed growing tracts carried litter on its surface which was under varying degree of decomposition.

2. The colour of surface soils was mostly in the hue of 7.5 YR and the subsurface layers were dominated either by 5YR or 10YR. Reed was characterised by fine fibrous ramifying root system and it functioned like a thick mat on soil surface. This peculiar root system gave rise to crumb and granular structure in surface layers and in majority of the profiles the sub-soils were massive without any distinct structural development.

3. Reeds were found to flourish on both shallow and deep soils. In pure reed brakes where upper canopy was closed the undergrowth was completely absent.

4. Reed growing soils showed wide variation (4-79 per cent) in the content of gravel and it was found dominated by rock fragments rather than secondary lateritic gravel. It was comparatively lower in soils supporting pure reed patches than reed

as under growth. In pure reed areas surface soils contained low content of gravel than subsurface layers.

5. In general the texture of the surface soils was sandy loam while subsurface layers showed both sandy loam and sandy clay loam.

6. The bulk density (0.54 to 1.39 g cm^{-3}) was found to increase with increase in depth of profiles while no definite trend was observed in the case of particle density (1.47 to 2.88 g cm^{-3}).

7. The values of porosity (41.1 to 78.2 per cent) and maximum water holding capacity (27.75 to 42.2 per cent) were found to decrease with increase in depth of soil profiles.

8. These soils were strongly to moderately acidic in reaction (4.40-5.81). In areas where reed grew as an undergrowth in teak and moist deciduous forests, the soils were relatively less acidic than pure reed soils. In pure reed areas surface soils were more acidic than subsurface soils.

9. The exchangeable base status ranged from 0.33 to 9.14 cmol (+) kg^{-1} and it in general was found to decrease with increasing depth of the profiles. Among the exchangeable bases, Ca dominated followed by Mg and K.

10. The percentage base saturation (14.1 to 67.6) was higher in surface layers than sub-surface layers.

11. The values of exchange acidity was found to vary from 0.1 to 5.8 cmol (+) kg^{-1} and a decreasing tendency was observed from surface to the bottom of the profiles.

12. Cation exchange capacity by sum of cations varied from 2.2 to 13.2cmol(+) kg^{-1} and it was found to decrease with increasing depth of soil profiles.

13. Reed growing soils were rich in organic carbon (0.13-5.98 per cent) and a heavy accumulation was found in surface layers with a decreasing tendency towards deeper layers.

14. The content of both total (0.052 - 0.632 per cent) and available N (0.04 - 0.078 per cent) was relatively high and they were found to decrease towards lower depths of the profiles.

15. The content of total P (0.012 - 0.112 per cent) was also relatively high in these soils but its availability was quite low in most of the profiles.

16. The content of both total (0.19 to 1.18 per cent) and available (traces to 0.054 per cent) K was relatively in high quantities in these soils.

17. The total K was not observed to show any definite trend from surface to the bottom of the profiles while its availability was to found to follow a diminishing trend from surface to bottom of the profiles.

18. In general the changes in location, elevation and topography were not found to exert any definite impact on the pattern of depth wise distribution of soil properties in these soils.

19. These soils were classified under Ustic Kandihumult, Ustic Palehumult, Ustic Haplohumult, Ustic Kanhaplohumult, Typic Kanhaplustult, Ustic Humitropept, Ustoxic Humitropept, Ustic Dystropept, Ustoxic Dystropept, Oxic Ustropept and Lithic Dystropept at the sub group level.

Part 2

1. The surface soils of reed growing tracts generally exhibited low content of gravel (13.61 per cent) and it was found dominated by rock fragments rather than secondary gravel.

2. The texture of these soils was sandy loam with moderately high water holding capacity (37.69 per cent).

3. These soils were also characterised by low values of bulk density (0.98 g cm^{-3}) and moderately high porosity (59.77 per cent).

4. Reed growing soils were strongly acid in reaction with a mean pH of 4.93.

5. Higher content of organic carbon (2.86 per cent), available N (0.854 g kg^{-1}) and K (0.202 g kg^{-1}) were also observed in these soils. But the availability of P (3.53 ppm) was very low.

6. The cation exchange capacity of these soils was comparatively high (10.35 cmol (+) kg^{-1}) but percentage base saturation was (41.98).

7. Significant variation with respect to most of the soil properties were observed with change in location.

8. Significantly higher contents of gravel and finer fractions (silt and clay) were observed at Vazhachal.

9. Significantly low values of bulk density and porosity were observed at Adimali while higher water holding capacity was observed at Pamba.

10. Among the four locations studied, the soils of Vazhachal was less acidic followed by Pamba but the content of organic carbon was significantly high at Pamba and Adimali.

11. Among the available nutrients, the impact of location was not observed in the case of P while all other nutrients viz., N and K were significantly high at Pamba followed by Adimali.

12. Cation exchange capacity showed similar values in all the locations but the percentage base saturation was significantly high at Vazhachal.

13. In general the variation in elevation was found to exert a significant impact on bulk density, porosity, organic carbon, available N, exchange acidity, cation exchange capacity and percentage base saturation.

14. Higher elevations recorded significantly low bulk density and high porosity, organic carbon, exchange acidity and cation exchange capacity.

15. In general variation in topography was not found to exert any significant and definite impact on various soil properties studied. This proclaims the fact that reed plays a significant role in conserving soil and its fertility even on sloping lands.

Part 3

1. Among the three classes of reed studied, Class I was found to have higher number of matured culms / ha (70250) followed by Class II (54175) and Class III (18326) and the number of matured culms / ha was found to be a better parameter in judging the growth performance of reed.

2. Soils of Class I and Class II reed were significantly acidic than Class III.

3. The organic carbon content of soils supporting Class III reed was significantly low compared to the other two classes.

4. The availability of N and K in soils was significantly low in Class I when compared with Class III. But the status of available P was almost similar in all the three classes of reed stand.

5. Among the various plant parts of reed, a higher content of N was recorded in the leaf in all the three growth classes.

6. Among the three classes, Class I was found to record a significantly higher content of N in the leaf than the other two classes.

7. In all the three growth classes, higher content of P was also recorded in the leaf. In the case of K, Class I reed recorded higher content in the leaf, it was in the culm in Class II and in Class III higher content was recorded in the root.

8. The model fitted through step wise regression relating number of culms to different soil properties viz., soil pH, organic carbon, available N, P and K was $Y=501.0420 - 179.881920x_1 + 16.1516x_1^2 + 1.9450\, x_1x_2$ where Y= number of culms/ha, x_1 = soil pH and x_2 = organic carbon.

9. Dry weights of both culms and leaves per ha were significantly high in Class I followed by Class II and Class III.

10. The uptakes of nutrients viz. N, P and K were significantly high in Class I followed by Class II and Class III.

11. The models fitted through step wise regression relating dry weight of culms and leaves with uptake of N, P and K were $Y_1=-1294.29+37.265\ N+321.410\ P+226.442\ K$, $Y_2=2.10 + 38.403 + 187.200\ K$ where Y_1 is the dry weight of culms/ha and Y_2 is the dry weight of leaves/ha.

Part 4

1. The soil moisture status in the reed growing areas of Vazhachal was found varying from 10.35 to 32.78 per cent.

2. At both the sites maximum disappearance of mass was in July and it was strongly and positively correlated with rainfall.

3. The exponential model proposed by Olson (1963) was found to be the best fitting model to work out the annual decomposition rate constant.

4. The annual decomposition rate constant did not vary significantly at both the sites studied. The annual decomposition rate constant was 0.234 at Site I and 0.229 at Site II.

5. At both the sites the time required for 50 per cent and 95 per cent decomposition was found to be the same. The 50 per cent decomposition was within three months and the 95 per cent decay was anticipated within a time span of 13 months.

6. The leaf litter contained highest content of N (1.98 per cent) followed by K (0.46 per cent), Ca (0.16 per cent), Mg (0.12 per cent) and P (0.085 per cent).

7. Release of various elements at successive stages of decomposition varied with type of elements.

8. Based on the concentration and absolute content, the nutrient mobility from decomposing reed leaf litter was in the order K > N > Mg > Ca > P.

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ABSTRACT

ABSTRACT

A study was carried out at the Kerala Agricultural University and the Kerala Forest Research Institute during 1993-1996 mainly to characterise the reed growing soils of Western Ghats. The study comprises four parts, viz., pedological / taxonomical characterisation of reed growing soils, evaluation of fertility status of reed growing soils, assessment of growth performance of reed in relation to soil fertility and study on litter decomposition and nutrient release from reed leaf litter.

The pedological / taxonomical characterisation was carried out by digging representative soil profile (with 3 replications) at two different types of topography (flat-undulating and sloping) in two different elevations (200-300 m and 600-800 m) at four locations viz. Vazhachal, Pooyamkutty, Adimali and Pamba. Reed growing soils were found to carry litter on soil surface which was under varying stages of decomposition. The colour of the surface soils was mostly in the hue of 7.5 YR and subsurface layers were dominated by either 5 YR or 10 YR. Fine fibrous roots were found to mat the soil surface giving granular and crumb structure. The subsurface layers were generally massive without any distinct structural development. Reeds were found to flourish on both shallow and deep soils. In pure reed brakes where upper canopy was closed, the undergrowth was completely absent.

The content of gravel, especially the secondary gravel, was very low in these soils. In most of the cases the textural make up turned from sandy loam to sandy clay loam from top to bottom of the profiles. Bulk density was found to increase with increase in depth of the profiles while porosity and water holding capacity to showed a diminishing trend.

These soils were strongly to moderately acid in reaction and in pure reed areas surface soils were more acid than subsurface soils. But in areas where reed was growing as undergrowth in teak and moist deciduous forest, surface soils were less acidic than subsurface soils. In general, exchangeable bases, exchange acidity, cation exchange capacity and percentage base saturation were found to show a diminishing tendency from surface to bottom of the profiles. Distribution of organic

carbon, total and available N, total and available P and available K was in a decreasing trend with increase in depth of the profiles while total K was found concentrated in lower layers.

In general, the change in location, elevation and topography was not found to exert any definite impact on the depth wise distribution of soil properties in these soils.

These soils were classified under Ustic Kandihumult, Ustic Palehumult, Ustic Haplohumult, Ustic Kanhaplohumult, Typic Kanhaplustult, Ustic Humitropept, Ustoxic Humitropept, Ustic Dystropept, Ustoxic Dystropept, Oxic Ustropept and Lithic Dystropept at sub group level.

The content of gravel, especially the secondary gravel was low in the surface soils of reed growing soils. These soils were sandy loam in texture with low bulk density and moderately high water holding capacity and porosity.

In general, these soils were strongly acidic in reaction with high content of organic carbon and available N and K. But the status of available P was very low. Contents of available Ca and Mg were in moderate quantities. Cation exchange capacity was also high, but the percentage base saturation was low.

Significant variation with respect to various soil properties viz., gravel, silt, clay, bulk density, porosity, water holding capacity, pH, organic carbon, available N, K, Ca, Mg and percentage base saturation was observed due to change in location. Change in elevation was found to exert significant impact on bulk density, porosity, organic carbon and cation exchange capacity. In general variation in topography was not found to exert any significant and definite impact on various soil properties. Results in general reveal that reed bamboo play a significant role in conserving soil and its fertility.

Number of matured culms / ha was found to be a better parameter in judging the growth performance of reed and Class I reed was found to have higher number of matured culms / ha than Class II and Class III. Soils of Class I reed was significantly acidic and contained higher organic carbon but lower available N and K than the class III. The model fitted through stepwise regression relating number of culms to different soil properties viz., soil pH, organic carbon, available N, P and K was $Y = 501.0420 - 179.881920x_1 + 16.1516x_1^2 + 1.9450x_1x_2$ where Y= number of culms / ha, x_1 = soil pH and x_2 = organic carbon.

Dry weight of both culms and leaves per hectare and uptake of N, P and K were significantly high in Class I than the other two classes. The models fitted through stepwise regression relating dry weight of culms and leaves with the uptake of N, P and K were $Y_1=-1294.29 + 37.265N + 321.410\,P + 226.442K$, $Y_2=2.1 + 38.403 + 187.2\,K$ where Y_1 is the dry weight of culms / ha and Y_2 is the dry weight of leaves / ha.

Reed growing soils were found to conserve comparatively higher content of soil moisture. Mass loss during decomposition of reed leaf litter was highly influenced by rainfall and the annual decomposition rate constant did not vary significantly (0.229 and 0.234) at two sites studied. The time required for 50 per cent and 95 per cent decomposition was 3 and 13 months respectively. Based on the concentration and absolute content, the nutrient mobility from decomposing reed leaf litter was in the order K > N > Mg > Ca > P.