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PROSPECTS OF REED BAMBOO (*OCHLANDRA TRAVANCORICA*) FOR SOIL CONSERVATION ON DEGRADED SITES

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ABSTRACT

Considering the importance of reed bamboo (*Ochlandra travancorica*) in cottage and paper industries along with its indigenous ecofriendly and fast growing nature, this study was conducted to evaluate the potential of this species for revegetating and improving the degrading lateritic soils of Kerala. The specific objectives of the study were : 1. to study the impact of reed bamboo on soil characteristics and 2. to find out the growth performance of reed bamboo on degraded site. In order to study the impact of reed bamboo on soil characteristics, typical soil profiles were studied in three major reed growing and adjacent non-reed areas of the State viz., Vazhachal, Pooyamkutty and Pamba and various soil properties were compared. Results revealed the influence exerted by reed growth on soil colour, texture, structure, development of subsurface horizon and pH in comparison with the adjacent non-reed areas. Surface soils of reed growing soils were coarse textured, loose and acidic with higher content of organic matter. But the adjacent non-reed soils in general were with higher content of lateritic gravel and clay but with lower water holding capacity and organic carbon.

To find out the growth performance of reed bamboo on degraded site, both seedlings and rhizomes were planted in the degraded area at Palappilly in Chalakkudy Forest Division and the observations on survival and growth performance were recorded. Results revealed that reed plants raised from rhizomes could establish better in the degrading lateritic soils than the seedlings and if seedlings are preferred for planting on degrading lateritic soils, then they should be at least 18 months old with well developed rhizomes. After the establishment phase, the plants grow vigorously irrespective of the nature of the planting material. Reed bamboo (*Ochlandra travancorica)* can thus be recommended as a very suitable species to arrest soil degradation and improve the soils in the Western Ghats of Kerala.

ABSTRACT OF PROJECT PROPOSAL

1	Project No.	:	KFRI 262/96
2	Title of project	:	Prospects of reed bamboo (*Ochlandra travancorica*) for soil conservation on degraded sites.
3	Objectives	:	1. To study the impact of reed bamboo on soil characteristics 2. To highlight the growth performance of reed bamboo on degraded sites
4	Duration	:	3 years
5	Funding Agency	:	Science, Technology and Environment Committee
6	Project Team		
	Principal Investigator	:	M.P. Sujatha
	Associates	:	Thomas P. Thomas and S. Sankar

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(FINAL REPORT OF THE PROJECT KFRI 262/96)

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PROSPECTS OF REED BAMBOO *(OCHLANDRA TRAVANCORICA)* FOR SOIL CONSERVATION ON DEGRADED SITE

1. INTRODUCTION

Soils of Kerala, especially in the upland regions, are under severe threat of erosion caused mainly by deforestation. Most of the topsoil once under forest cover have eroded down to reservoirs and rivers leaving barren hills in the high ranges. The loss of organic rich top soil through erosion not only leads to fertility decline, but also exposes the underlying subsoil to the direct actions of adverse climatic factors finally resulting in the physical, chemical and biological deterioration of the soil. Since laterisation is the major soil forming process in Kerala, most of these soils are under various stages of laterisation. Even though the formation of laterite is a boon to keep the soil mass intact without being completely lost through erosion, its management from the point of view of biomass production is a great task. Prevention of hardening of laterite that is still soft is reported to be a feasible and perhaps the most promising technique of laterite management and maintenance of moist conditions and actively growing vegetation appears to be associated with the softening process. This points out that the immediate strategy for protecting and improving the health of denuding lateritic soils is by revegetating with some fast growing, economically viable and eco-friendly plant species. The available reports indicate the suitability of plant species tolerant to Al, Fe, and Mn toxicities for laterite management. Further, monocots rank first in revegetating the degraded lands than dicots. In view of the above facts, this study was formulated to find out the feasibility of reed bamboo for revegetating the degrading lateritic soils of the Western Ghats in Kerala.
Reed bamboo is one among the important species of bamboo prevalent in the acidic soils of the Western Ghats of Kerala, occurring as an associate of natural forests and also in pure brakes. It is an important source of long fibre to reed based paper and cottage industries, but doesn't meet the increasing demands of growing population. Considering the above situations, the present study was launched with the following objectives :

1. To study the impact of reed bamboo on soil characteristics
2. To highlight the growth performance of reed bamboo on degraded sites

2. REVIEW OF LITERATURE

Reclothing of degraded lands with multipurpose tree species has been accepted and adopted as one of the global strategies to minimise the ill effects of deforestation and soil degradation along with the supply of food, fodder, fuel, fibre etc. Suitability of both endemic and exotic species to hostile edaphic conditions and the influence of these species on the health of degrading soils have been reported by various workers in different climatic zones across the world. This section mainly reviews the works carried out on the suitability of various species to the degrading soils and their contributions to the health of soil.

As part of the social forestry programme, several multipurpose tree species including *Acacia* spp., *Eucalyptus* spp., *Leucaena leucocephala* , *Shorea robusta, Sesbania grandiflora, Anacardium occidentale, Cassia* spp., *Casuarina equisetifolia, Bambusa* spp. etc. have been tested for their suitability to different climatic conditions and soil types throughout India and several technologies have been suggested for their survival and growth on degraded soil. Pratap and Watson (1994) introduced a new system of cultivation on degraded slopes for soil improvement. In this system (Sloping Agricultural Land Technology) degraded slopes were divided into strips of land (4-6 m wide) for cultivation, separated by double hedge rows of nitrogen fixing trees or bushes planted along contour lines. According to Grewal *et al*. (1994) agroforestry system involving *L. leucocephala* and napier grass was more conservation-effective on eroded marginal soil of Chandigarh than traditional cropping system. Similarly Pant *et al.* (1995) could bring out a best combination of pit sizes and fertiliser for the survival and growth of *Cassia siamea* on degraded soil in Jabalpur. Prasad *et al.* (1996) found better survival and growth for *Eucalyptus* spp*., Anacardium occidentale, Sesbania grandiflora, Acaica auriculiformis and Leucaena leucocephala* on degraded soil in West Bengal. According to Totey (1995) the heavy mortality of *Shorea robusta* in South Raipur Forest Division was associated with soil compaction, increased runoff and other nutritional factors. Puri *et al*. (1995) advocated the use of 1m deep holes for *E. tereticornis* in areas with inherent physical and chemical soil constraints. Use of mycorrhizal and nitrogen fixing symbionts in reforestation of degraded acid soils of Kerala has been suggested by Sharma *et al*. (1996). According to Maikhuri *et al*. (1997) agroforestry incorporating water management would be a more effective option for rehabilitating degraded community lands .

The importance of bamboo in the afforestation programme and maintenance of the fertility of forest soils was reported by Neginhal (1949) and Singh *et al.* (1995). The positive influence of bamboo for the rehabilitation of watersheds has been proved by Singh *et al.* (1995) in the Indian Punjab Shivaliks. Improvement of soil fertility due to the growth of moso bamboo was also reported by Chen (1999) in China. Ming and Shou (1993) could evolve an agroecosystem model dominated by bamboo on steep hills and field crops in valleys. Soil improvement with respect to pH, exchangeable Ca^{++}, Mg^{++} and K^{+} was reported by Pant *et al.* (1993) due to the growth of bamboo. Christanty *et al.* (1997) reported that bamboo recovered much of the nutrients leached deeper into the soil profile and deposited them at or near the soil surface as above ground litter and dead fine roots. Improvement in hydrological regime due to the growth of moso bamboo was reported in China (Wang and Liu, 1995). In Kerala, even though detailed studies on soil supporting bamboo (Thomas, 1998) and reed bamboo (Sujatha,1999) are available, the subject of afforestation of degraded lands with reed bamboo finds no place in literature and hence the present study forms the primary trial on this line at the global level.

3. IMPACT OF REED BAMBOO ON SOIL CHARACTERISTICS

Having established well on a particular soil, any vegetation exerts significant impact on that soil. This change may be morphological, physical, chemical and biological and it can be found out only by comparing the soil before and after the establishment of the vegetation. But no information is available on the soils of reed growing tracts before the establishment of reed. So, to find out the impact of reed on soil, adjacent non-reed soils which do not differ in climate, elevation and topography were compared with the soils of reed growing tracts.

3.1 Study area and method

The State of Kerala, located at the southwestern corner of the Peninsular India enjoys tropical climate. The annual rainfall of the State, especially the Western Ghat region, varies from 2500 mm in the south to about 5000 mm in the north. Predominantly reed growing areas of the State viz., Vazhachal, Pooyamkutty and Pamba (Fig.1) were selected for this study.

Plate No. 1 Clumps of *Ochlandra travancorica*

The area occupying pure reed brakes, selected at Vazhachal, was a moderately sloping land with northern aspect and situated at an elevation of about 550 m. The adjacent non-reed area was an open land with some moist deciduous tree seedlings and grasses.

Plate No.2 Non- reed area almost surrounded by reed at Vazhachal

At Pooyamkutty, the reed tract selected was at about 450 m elevation and the adjacent non – reed area was occupied by a

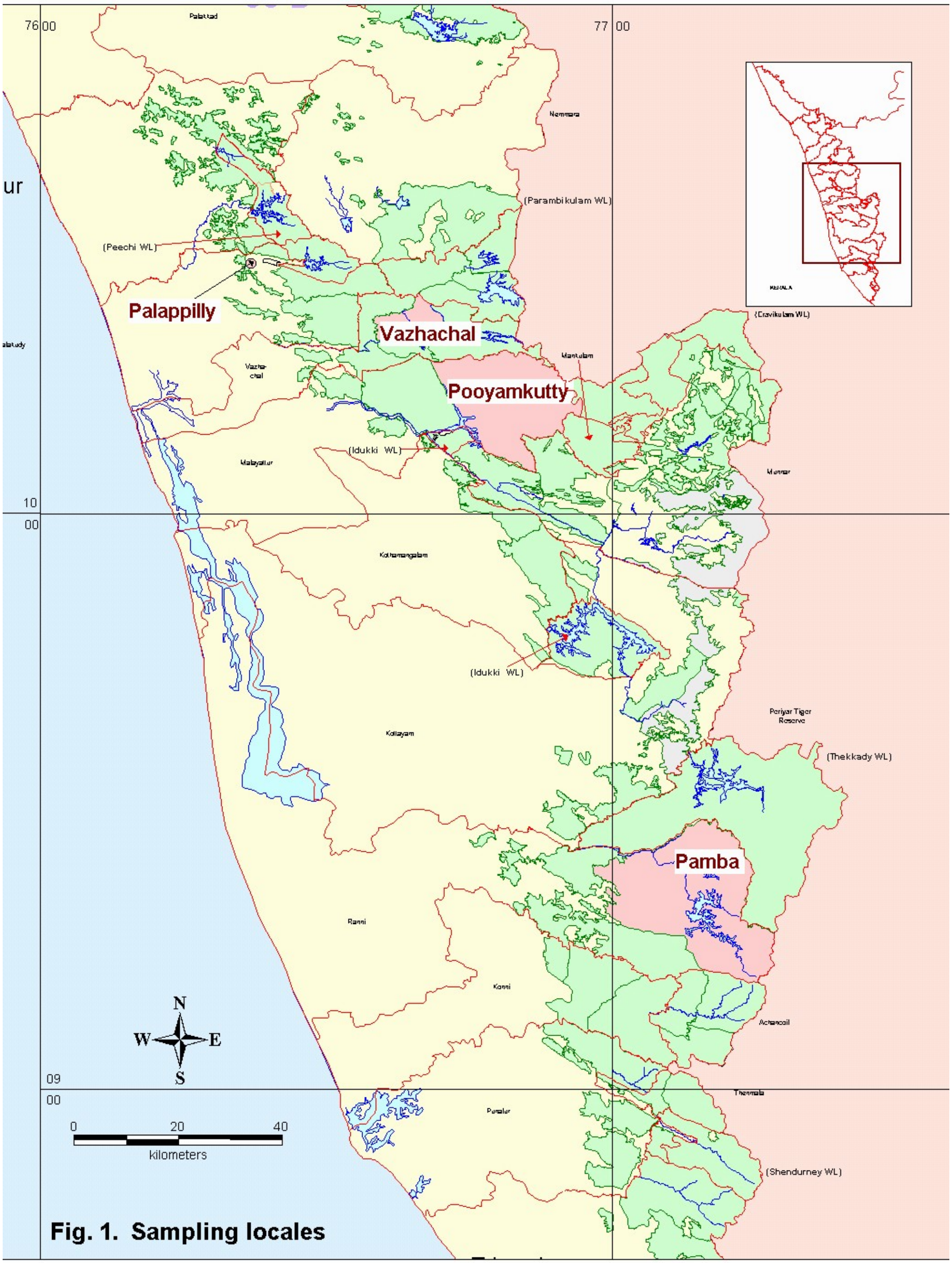

Fig. 1. Sampling locales

degraded moist deciduous forest. Both vegetations were on steeply sloping land with southern aspect. At Pamba, the selected reed patch was at 600 m above mean sea level and the adjacent non-reed area was a moist deciduous forest. The landscape was moderately sloping with northern aspect.

Typical soil profiles were struck in reed growing and adjacent non-reed areas and these profiles were examined for various morphological properties as per Soil Survey Staff (1992). In addition to the samples from the genetic horizons of the soil profiles, 15 soil samples (0-15 cm) from each vegetation at random were also collected. Various physical and chemical properties viz., gravel, texture, bulk density, water holding capacity, pH, organic carbon, exchange acidity and exchangeable bases were determined using standard procedures (Jackson,1958 and Black *et al.*,1965). Comparison of means of various surface soil properties was made using Students 't' test.

1.2 Results and Discussion

1.2.1 Site and morphological features of soil profiles in reed and adjacent non-reed areas

Plate No. 3 Soil profile in reed tracts at Vazhachal

Plate No. 4 Soil profile in adjacent non reed tracts at Vazhachal

The profile-wise morphological features of the soils of reed growing and adjacent non-reed areas are highlighted in Table 1. The Profiles 1, 2 and 3 represent pure reed brakes and 4, 5 and 6 represent adjacent non-reed areas at Vazhachal, Pooyamkutty and Pamba respectively. As revealed in Table 1, soils of pure reed growing tracts at all the sites were characterised by abundant litter on surface which was under varying degrees of decomposition. The major portion of the fine fibrous roots occupied the surface layer and functioned like a thick mat. It was also observed that in pure reed brakes, where upper canopy was closed, undergrowth was completely absent. This is thought to be due to the prevention of sunlight by the closed canopy and inhibition of regeneration of other species by the root mat of reed.

When soils of adjacent non-reed areas were considered, at Vazhachal due to the scarcity of vegetation the litter layer was absent but the soil was mostly covered with grasses and the site was opened. At Pooyamkutty and Pamba, since the moist deciduous forests occupied the adjacent non-reed area, there were plenty of litter on soil surface but not as much as in reed area.. Although sunlight reached the soil surface and encouraged under growth, the soil was found exposed at several places.

In all the profiles of reed growing areas, the uppermost A horizon carried high content of decomposing litter. The colour of the soils was mostly in the hue of 7.5 YR, 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 and this is attributed to the depletion of organic matter at lower depth. The extensive fine fibrous root system which ramifies vertically and horizontally binds the soil particles together resulting in the formation of granular and crumb structure especially in the surface horizon. The good structural development may also be due to the binding action of the byproducts of microbes, sesquioxides and good drainage conditions. The soils of the subsurface layers were generally structureless in pure reed tracts. The cementing action exerted by the fine fibrous roots of reed is concentrated mainly in the surface layers. This, together with low

Plate No. 5 Reed growing on a shallow soil profile at Pooyamkutty

Table 1. Soil profile morphology of reed and adjacent non-reed areas

Profile No. 1

Site features

Middle of a hill at Vazhachal, elevation 550 m asl, northern aspect, pure reed patch, closed canopy, no undergrowth and abundant litter on soil surface.

Depth cm	Horizon	Characteristics
0-6	A1	Dark brown (7.5 YR 3/4), sandy loam, crumb and granular structure, loose, non plastic, abundant roots, presence of partly decomposed litter
6-62	A2	Brown (7.5 YR 5/4), sandy loam, crumb and granular, friable, non plastic, abundant roots and big stones
62-80	Bw1	Brown (7.5 YR 5/4), gravelly sandy clay loam, massive, loose, non plastic, plenty of roots
80-108	Bw2	Brown (7.5 YR 4/3), sandy clay loam, massive, loose, non plastic, no roots
108-126+	Bw3	Brown (7.5 YR 4/3), sandy loam, massive, loose, plastic, presence of weathering pieces of rocks

Profile No. 2

Site features

Valley of a hill at Pooyamkutty, pure reed patch, closed canopy, no undergrowth, very near to water course, abundant litter on soil surface, plenty of exposed rocks.

Depth Cm	Horizon	Characteristics
0-4	A	Dark brown (7.5 YR 3/4), sandy loam, crumb, loose, non plastic, abundant roots, presence of partly decomposed litter
4-48	Bw	Strong brown (7.5 YR 4/6), sandy loam, crumb, loose, non plastic, abundant roots, presence of big stones
48+	C	Weathered rock

Profile No. 3

Site features

Lower middle of a hill at Pamba, pure reed patch, no under growth, plenty of litter on soil surface.

Depth cm	Horizon	Characteristics
0-4	A1	Dark brown (7.5YR 3/4), sandy loam, crumb, loose, non plastic, abundant roots, presence of partly decomposed litter
4-64	A2	Brown (7.5 YR 5/4), sandy loam, granular, loose, non plastic, abundant roots
64-95	Bw	Brown (10 YR 5/8), sandy loam, loose, friable, non plastic, presence of rock fragments and roots.
95+	C	Weathered rock

Profile No.4

Site features

Middle of a hill at Vazhachal, elevation 550 m asl, northern aspect, open land with scattered distribution of moist deciduous seedlings.

Depth cm	Horizon	Characteristics
0-8	A1	Dark brown (7.5YR 3/4), gravelly sandy clay, granular, slightly plastic, moist friable, plenty of fine roots
8-22	A2	Dark reddish brown (5YR 3/3), clay loam, weak development of sub angular blocky, moist firm, slightly plastic, presence of fine roots
22-60	Bt1	Reddish brown (5YR 4/3), clay loam, sub angular blocky structure, firm, sticky and plastic, presence of lateritic gravel
60-150+	Bt2	Reddish brown (5YR 4/3) clay loam, sub angular blocky structure, firm, sticky and plastic, presence of concretions and hard lateritic gravel

Profile No. 5

Site features

Valley of a hill at Pooyamkutty, degraded moist deciduous forest, canopy opened, plenty of under growth, very near to water course, abundant litter on soil surface, plenty of exposed rocks.

Depth cm	Horizon	Characteristics
0-18	A	Dark reddish brown (5YR 3/2), sandy loam, granular, friable, presence of roots and very few decomposing litter
18-60	Bt1	Dark red (2.5YR 3/6), gravelly sandy clay, granular, yellow mottling with red and black admixture, very few roots.
60-108	Bt2	Dark red (2.5YR 3/6), gravelly sandy clay loam, sub angular blocky structure, yellow mottling with red and black admixture, no roots
108+	C	Rocky layer

Profile No. 6

Site features

Lower middle of a hill at Pamba, degraded moist deciduous forest , lot of under growth and litter on soil surface, canopy is almost opened.

Depth cm	Horizon	Characteristics
0-4	A	Very dark brown (10YR 2/2), gravelly sandy clay loam, granular, friable, presence of decomposing litter, abundant roots
48-75	Bt1	Yellowish red (5YR 4/6), sandy clay loam, development of sub angular blocky structure, slightly firm, few roots, presence of red mottles
75-150+	Bt2	Red (2.5 YR 4/8), sandy clay loam, sub angular blocky, presence of lateritic gravel, few roots

cambic horizon was noted in all the profiles indicating that these soils are in the early stages of development. The gravel content was dominated by rock fragments rather than secondary lateritic gravels in all the profiles. As revealed in Profiles 1 and 2, reed was found to grow on both deep and shallow soils.

With regard to the morphological features of soil profiles in the adjacent non-reed areas at Vazhachal, the surface horizon was endowed with plenty of fine fibrous roots contributed by the grassy cover. But in comparison with reed, they were devoid of fallen decomposing litter due to the absence of trees contributing this. As in the case of reed, the colour of the surface soil was dark brown, but the sub surface layers showed decrease in dark colour along with simultaneous dominance of red colour. This is thought to be due to the depletion of organic matter at lower depth coupled with the increase in the content of sesquioxides. The surface horizon showed both crumb and granular structure while the development of sub angular blocky structure was observed at subsurface layers. Both gravelly clay loam and gravelly clayey texture types were present with an accumulation of clay at subsurface to satisfy the requirement of an argillic horizon. Unlike in reed growing soils, the gravel content was dominated by secondary lateritic gravels. The surface horizons of the soil profiles in the adjacent non-reed areas of moist deciduous forests of Pooyamkutty and Pamba carried decomposing litter similar to that of reed, but fine fibrous root systems were absent in these soils. An increase in the intensity of either red or yellow colour with increase in the depth of soil profiles was also noticed. The surface horizon showed granular structure while the subsurface layers showed sub angular blocky structure. In these soils, the texture of surface horizon was gravelly sandy loam and the subsurface layers carried higher content of clay revealing the presence of an argillic horizon.

Hence the results, in general, confirm that colour, structure, texture and the development of subsurface horizons are greatly influenced by the growth of reed when compared with the adjacent non-reed areas. The dominance of brown colour and coarse texture throughout the soil profiles and the presence of cambic horizon seems to be characteristic of reed growing soils when compared with the adjacent non-reed soils. This points out the fact that reed might have established on these soils at an early stage of soil development and hitherto plays a great role on its overall development through the protective umbrella of canopy, litter and root mat.

1.2.2 Physical and chemical properties of soil profiles in reed and adjacent non-reed areas

With regard to the physical properties of reed growing soils (Table 2), gravel content was relatively low throughout the profiles and found dominated by rock fragments rather than secondary lateritic 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 are not exposed to the actions of sun and rain due to the presence of the 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. Among the textural constituents, the sand fraction dominated and no definite pattern in the case of sand and silt was observed with increase in depth of soil profiles. These soils showed low values of illuvial clay in the B horizon. Bulk density of soil, especially at the surface layer, was very low caused by the high accumulation of organic matter and fibrous root mat and it increased with depth. But in contrast, the water holding capacity was decreasing towards the lower horizons of the profiles which can be attributed mainly to the lesser content of organic matter and fine soil particles at lower layers.

But the profiles struck at adjacent non-reed areas in all the locations revealed the dominance of secondary lateritic gravels. Unlike in reed growing soils, higher content of clay was observed throughout the profiles and noticeable content of illuvial clay to satisfy the requirement of an agillic horizon was prevalent in these soils. The adjacent area at Vazhachal was completely open and at other two locations it was more or less open compared to reed area. This might have played a great role in intensifying the process of soil development resulting in higher content of illuvial clay and lateritic gravel. Bulk

Table 2. Physical properties of soil profiles in reed and adjacent non reed areas

Profile No.	Veget-ation	Depth cm	Hor-izon	Grav-el, %	Sand %	Silt %	Clay %	BD gcm^{-3}	MW C%
1	Reed	0-6	A1	9.3	75.9	9.1	15.0	0.89	36.8
		6-62	A2	10.9	72.3	13.2	14.5	1.02	35.9
		62-80	Bw1	21.2	72.0	12.0	16.0	1.18	34.4
		80-108	Bw2	15.5	72.7	11.0	16.3	1.41	35.4
		108-126+	Bw3	3.0	76.0	11.0	13.0	1.46	27.8
2	Reed	0-4	A	6.2	75.8	9.8	14.4	0.88	39.2
		4-48	Bw	12.0	72.6	12.6	14.8	1.00	35.1
3		0-4	A1	3.4	73.9	12.0	14.1	0.92	38.8
	Reed	4-64	A2	12.5	78.1	7.4	14.5	1.06	34.3
		64-95+	Bw	10.8	77.5	9.0	13.5	1.18	31.7
4	Non	0-8	A1	18.4	66.0	2.4	31.6	0.98	48.9
	reed	8-22	A2	28.6	57.1	8.9	34.0	1.07	45.3
		22-60	Bt1	62.5	53.0	8.6	38.4	1.14	46.0
		60-150+	Bt2	78.2	40.7	10.4	48.9	1.24	45.4
5	Non	0-18	A	21.6	74.0	14.0	16.0	1.28	38.8
	reed	18-60	Bt1	15.4	58.0	16.0	42.0	1.30	34.6
		60-108	Bt2	26.8	57.8	12.0	30.0	1.34	36.0
6	Non	0-48	A	17.6	58.0	20.0	22.0	1.30	37.9
	reed	48-75	Bt1	23.3	64.0	9.0	27.0	1.38	32.4
		75-150+	Bt2	26.6	59.8	11.1	17.3	1.41	29.1

density also showed an increasing trend with depth in the profiles as in reed growing soils. At Vazhachal, the lower bulk density of surface horizon is thought to be mainly due to the influence of fine fibrous roots of grasses while at other two locations the decomposing litter might have played a major role. But in reed growing soils, both these factors influence the bulk density. Maximum water holding capacity was highest in the surface horizon of the profiles at all locations.

As revealed in Table 3, reed growing soils were strongly to moderately acidic in reaction and the acidity was more in the surface than the layer just below it. The higher acidity of

Table 3 Chemical properties of soil profiles in reed and adjacent non reed areas

Pro-file No.	Vegetation	Depth (cm)	Hori-zon	pH	OC %	Exch. acidity cmol (+)/kg	Exchangeable bases cmol (+) /kg					Bray extrac-table P (ppm)
							Ca^+	Mg^+	K^+	Na^+	Tot-al	
1	Reed	0-6 6-62 62-80 80-108 108-126+	A1 A2 Bw1 Bw2 Bw3	4.65 4.81 4.80 5.01 5.01	2.98 1.38 0.72 0.52 0.30	3.10 2.60 2.40 1.00 1.50	1.7 1.3 1.4 1.9 1.1	1.4 0.9 0.9 0.4 0.8	0.32 0.13 0.04 0.04 0.03	0.10 0.09 0.08 0.09 0.08	3.52 2.42 2.42 2.43 1.29	4.8 3.6 4.4 2.8 3.0
2	Reed	0-4 4-48	A Bw	4.70 4.85	2.56 1.82	2.20 0.60	2.8 1.4	0.40 0.10	1.17 0.28	0.05 0.07	4.42 1.85	8.2 2.5
3	Reed	0-4 4-64 64-95+	A1 A2 Bw	4.71 5.11 5.02	2.38 1.68 1.17	2.12 0.70 0.30	2.40 0.60 0.70	0.20 0.20 0.10	0.26 0.15 0.08	0.06 0.06 0.05	2.92 1.01 1.03	9.9 3.6 2.4
4	Non reed	0-8 8-22 22-60 60-150+	A1 A2 Bt1 Bt2	4.48 4.54 4.85 5.05	1.40 1.26 1.18 0.84	2.22 1.58 1.40 1.00	1.00 1.60 1.54 0.72	0.68 0.42 0.31 0.34	0.08 0.03 0.03 0.05	0.05 0.05 0.08 0.06	1.81 2.10 1.96 1.17	3.2 3.2 2.4 2.0
5	Non Reed	0-18 18-60 60-108	A Bt1 Bt2	5.28 4.76 5.01	1.68 0.64 0.42	1.60 1.01 0.64	2.56 2.85 2.21	1.20 1.25 0.85	1.45 1.34 1.40	0.06 0.06 0.04	5.27 5.50 4.50	3.9 6.4 4.2
6	Non reed	0-48 48-75 75-150+	A Bt1 Bt2	5.32 4.80 4.82.	1.74 0.95 0.50	1.42 1.24 0.20	2.32 2.64 1.16	1.02 1.13 0.06	1.32 1.48 0.17	0.05 0.04 0.04	4.71 5.29 1.43	4.1 2.4 traces

surface soils may be due to a relatively higher prevalence of organic matter at varying stages of decomposition which can release large amounts of organic acids. Thomas and Sujatha (1992) also reported an increase of pH with depth in pure reed patches of Ranni Forest Division in Kerala. These soils contained relatively higher content of organic carbon and as expected a progressive decrease towards lower layers of the profiles was prevalent. Unlike in other forest vegetations, addition of organic matter through an extensively ramifying root systems also contributes to the total pool of organic matter. Sanalkumar *et al.* (1998) had recorded high diversity of soil faunal groups in reed growing soils of Vazhachal and majority of them were found to help in the degradation of reed leaf litter. An accumulation of bases on soil surface and their decrease with increase in depth of soil profiles was also noted in this study. This highlights the influence of organic residues of reed in enriching the soil surface with bases. The closed canopy of reed and fast uptake of nutrients 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 greater role in reducing the loss of bases through gravitational flow of water especially in dense reed stands. Among the exchangeable bases, Ca dominated followed by Mg and K. The data also revealed that the contribution of Na in deciding the exchangeable base status of these soils was not remarkable which is the case with acid soils in general. The values of exchange acidity were higher in the surface horizons of all the profiles and this is attributed to the dominating influence of organic acids released during the decomposition of reed leaf litter.

The soils of adjacent non-reed areas, in general, were also acid in reaction and the acidity of surface horizon was comparatively less than that of the sub surface layers especially at Pooyamkutty and Pamba. This is thought to be due to the contribution from the decomposing vegetational residues containing more bases than reed area. With regard to the content of organic carbon, the surface horizon of all the profiles invariably recorded higher values and a steady decrease with depth was observed as in the case of reed. At Vazhachal, the organic enrichment of surface horizon was mainly from the fine roots of grasses while at other two locations the litter from the moist deciduous trees enriched the organic pool. Among the exchangeable cations, Ca dominated in all the profiles and the order of abundance was Ca > Mg > K> Na. The distribution of these bases with depth was irregular for all the pedons studied and it was more in subsurface layer than surface, attributed mainly to the leaching through the gravitational water. As observed in reed growing soils, the exchange acidity was higher in the surface horizons, and it decreased towards lower side of the profiles.

The results, reveal that the trend in the depth-wise distribution of various soil properties is similar in both reed and adjacent non-reed areas except in the case of lateritic gravel, clay, pH and exchangeable bases. A high dominance and increase in the content of lateritic gravel and accumulation of clay in the subsurface layers were noted in non-reed soils compared to that of reed soils. In reed growing areas the subsurface was less acidic than the surface soil while the reverse was the case of moist deciduous forests occupying the adjacent areas. So also the general trend of the exchangeable bases was to decrease with depth in reed growing soils while some sort of accumulation was observed in the subsurface horizons in the other case.

3.2.3 Fertility status of soils (0 -15 cm) in reed and adjacent non reed areas

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 physical and chemical properties was studied by collecting soil samples to a depth of 15 cm. A total of 15 soil samples were collected at random from reed and adjacent non-reed areas separately at each location and the soil properties were compared (Fig. 2).

Surface soils of reed growing tracts generally exhibited low content of gravel and it was found dominated by rock fragments rather than secondary gravel . The textural make-up of these soils was dominated by sand with little silt and clay. So, in general, the texture of these soils was sandy loam. Sujatha (1999) also reported that reed growing soils are coarse-textured in nature. 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 rocks. This can be the reason for the dominance of sandy loam texture of these soils. Studies on different species of bamboo (Kadambi, 1949; Kaul, 1964 and Koppar, 1980) also indicate that thrive well in well drained coarse textured soils with adequate moisture. 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. The organic substances released from soil fauna (both micro and macro) and plant roots are also thought to have a greater role in reducing bulk density and thus increasing the porosity of these soils. The water holding capacity of these soils

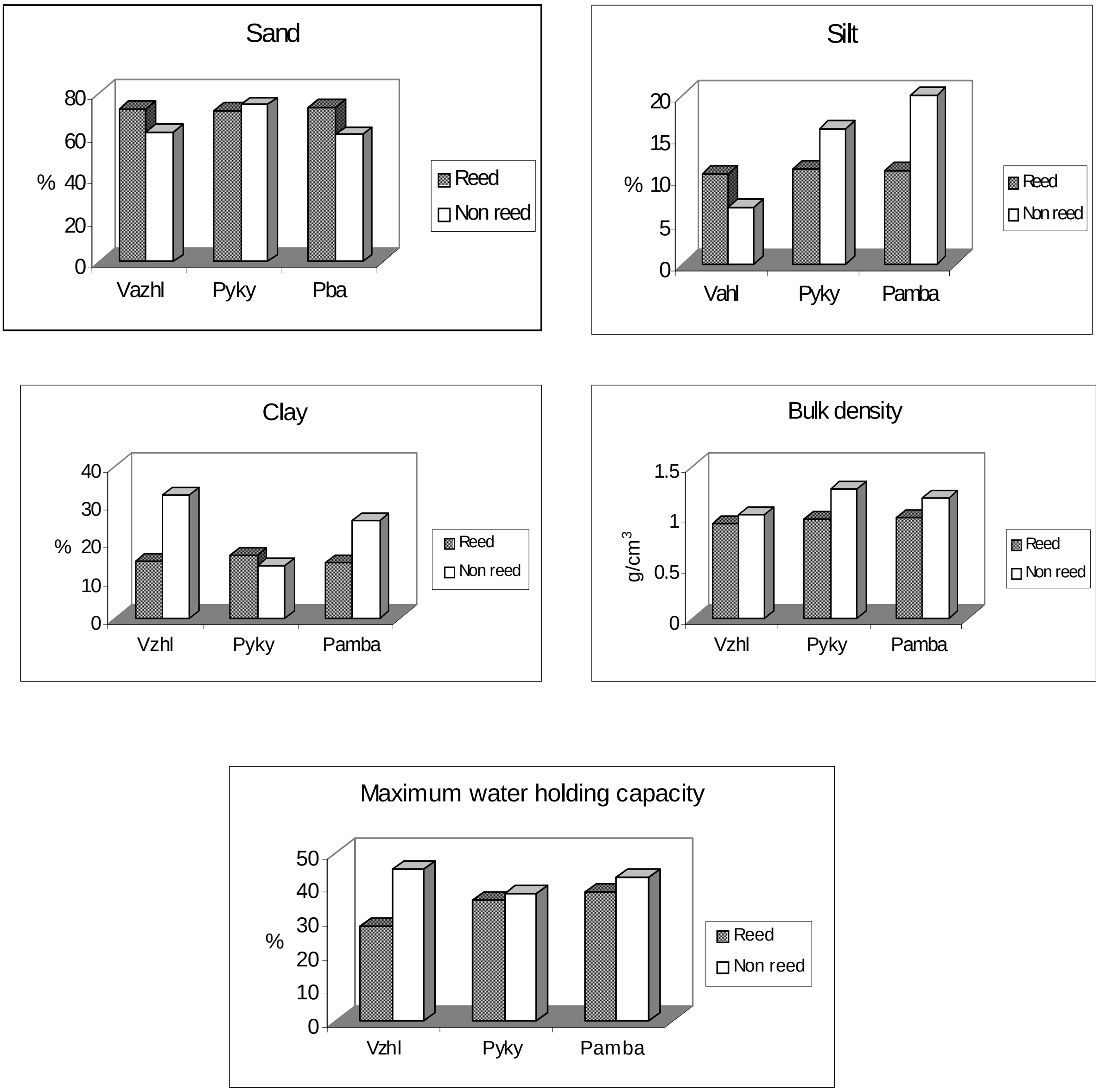

Fig.2. Physical properties of surface soils in reed and adjacent non reed areas

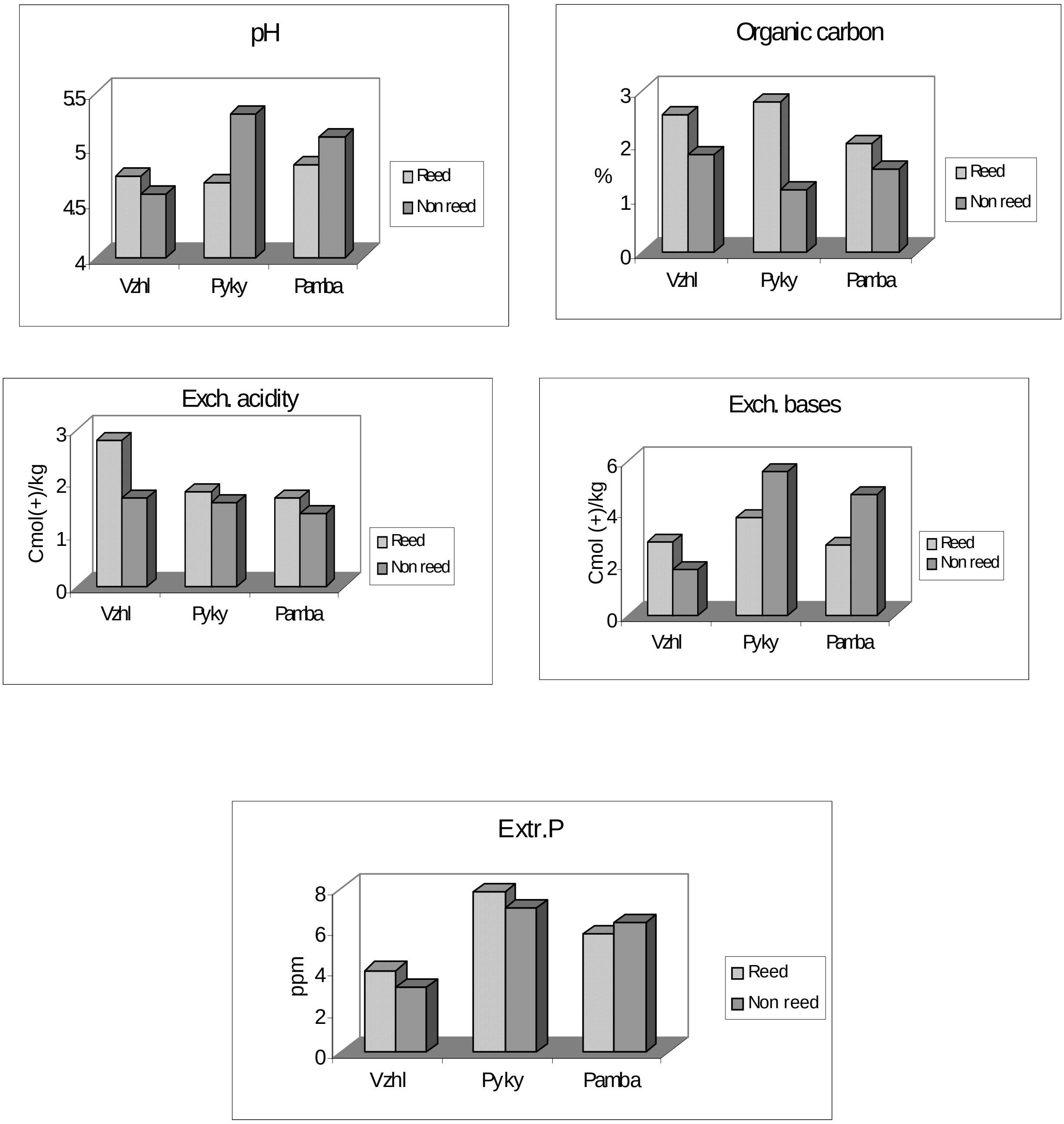

Fig.3. Chemical properties of surface soils in reed and adjacent non reed areas

in spite of coarse texture was moderately high which can be the reflection of high content of organic carbon.

With respect to chemical properties (Fig. 3), these soils were strongly acid in reaction with pH values ranging from 4.68 to 4.74. Quershi *et al.* (1969) also reported the acidic nature of bamboo (*Bambusa arundinaceae*) growing soils. Koppar (1980) was also of the opinion that Indian bamboos preferred soils of acidic to neutral pH. The acidity is thought to be contributed mainly from the non-calcareous rocks from which the soils are formed. The organic acids released during decomposition of organic residues also play a major role in increasing the acidity of these soils. Higher content of organic carbon (2-2.5 %) noted in these soils when compared with other forest plantations of the State can be attributed to the contribution from thick litter cover on soil surface together with the fine fibrous ramifying root system, characteristic of this plant. The status of extractable P was low. The low extractable P in these soils can be due to its fixation at low pH. The content of exchangeable bases was moderate and it is assumed that these bases were released by the decomposition of organic plant residues.

In the surface soils of adjacent non-reed soils, significantly higher content of secondary lateritic gravel was observed at all the locations irrespective of the kind of vegetation, the reason for which has been explained under the profile study. But the textural make-up differed with location and vegetation. Compared to reed, significantly lower content of sand and higher content of clay were observed at Vazhachal and Pamba. The soil was more compact as indicated by the higher values of bulk density at Pooyamkutty and Pamba, and this might be due to the lack of fine fibrous roots which make the soil more porous. The water holding capacity did not show significant difference between reed and non-reed soils except at Vazhachal, attributed mainly due to the higher content of fine soil separates.

The acidity of soil did not differ much when both reed and non-reed soils were compared at Vazhachal. But at other two locations, the soils of adjacent non-reed area were less acidic and this is thought to be due to the influence of bases released due to the decomposition of base rich leaf litter. Significantly lower content of organic carbon was observed in these soils at all the locations but the exchangeable base status was higher in non-reed soils occupied by moist deciduous forests.

So the results, in general, imply that the surface soils of reed growing areas were coarse-textured, loose and acidic with higher content of organic matter. But in comparison, the soils of adjacent non-reed areas with grassy cover were with higher content of lateritic gravel, clay and lower water holding capacity and organic carbon. The soils of adjacent moist deciduous forests were less acidic and contained more bases than that of reed area.

4. GROWTH PERFORMANCE OF REED BAMBOO ON DEGRAED SITE

During early periods reed bamboo was occurring as an undergrowth in natural forests of the Western Ghat region of Kerala preferably along the sides of rivers and streams sticking to wet soil conditions. But when the upper canopy was removed due to deforestation, this species started to grow rapidly and occupied the whole area forming extensive reed patches. In this part of the study an attempt was made to evaluate the feasibility of establishing this plant on a deagraded lateritic area, where the edaphic conditions are quite different compared to its natural habitat.

4.1 Study area and method

Establishment of nursery

Under natural conditions reed bamboo flowers occasionally and propagates through seeds. Since the availability of seeds was uncertain, rhizomes of reed were collected from Athirappilly Range of Chalakkudy Forest Division during February 1997. Based on the information from the local inhabitants, flowering of reed had taken place five years before in this area and hence the rhizomes collected were about five years old. While collecting the rhizomes, care was taken not to disturb the daughter rhizome. They were planted in polythene bags and kept in the nursery of the Field Research Centre of KFRI at Palappilly situated in Chalakudy Forest Division and they were watered regularly twice a day.

Seeds of reed bamboo were also collected from Ranni Forest Division during April 1997 and they were sown in nursery beds at KFRI Peechi campus. Seeds were germinated within 3-4 days and two-week-old seedlings were transferred to polythene bags containing potting mixture and they were watered regularly.

Establishment of field plots

For planting reed in the field, a degraded area was selected at the Field Research Centre at Palappilly. The area selected for planting was a moderately sloping land with southern aspect, medium erosion and dominated by lateritic gravel with low content of organic carbon and available N, P and K. The vegetation comprised of some residual coppice growth of previous teak germplasm collection, *Cynadon dactylon, Chromolaena odorata etc.*

Plate No. 6 Reed planted on a degraded area

After conducting necessary weeding operations, six plots of 40 x 40 m size were aligned in the field. Variation in soil characteristics due to change in slope gradient was minimised by taking two plots lying side by side at the top (3&6), middle (2&5) and lower (1&4) parts of the slope. Planting was done in 30 x 30 x 30 cm pits in the second week of July, during monsoon showers, by adopting quincuncial method of planting. Quincuncial method of planting was adopted to minimise the loss of soil through run off. Planting in the 1^{st}, 2^{nd} and 3^{rd} plots was carried out with a spacing of 5 x 5 m (77 plants/plot) and in the 4^{th}, 5^{th} and 6^{th} plots the spacing adopted was 3 x 3 m (196 plants/plot). The plants raised from rhizomes were planted in the 1^{st} plot and also as buffer plants along the boundaries and in all the other plots three-month-old seedlings were used for planting. Temporary fencing for both the whole plot and individual plants was provided. Necessary weeding and fire line works were also carried out. Gap filling was done in June, 1998 with 15-month-old seedlings retained in the nursery. All the plants were fed with 500 g of cowdung and 25 g of neem cake immediately after the onset of premonsoon showers in 1998.

4.2 Results and discussion

Survival

Seedlings of reed planted in the field were browsed by animals especially the spotted deer residing nearby the area. Fencing was provided around each plant with locally available materials, but they were found attacked by termite and the termite started to feed on the young roots of reed and hence they were removed. Fencing with splitted bamboo culms, the bottom dipped in tar was found somewhat better in this regard. But in some cases they were broken down by grazing deer.

A general scrutiny of the survival percentage of the plants after a period of one year (Table 4) indicated that most of the plants failed to get through. This was mainly because, young seedlings as well as young shoots emerging were grazed by animals and thus prevented further growth of the plant. Comparatively higher survival percentage was recorded in the Plots No.1 and 6 . The planting materials used in the Plot No.1 were raised from rhizomes and the underground rhizomes were not adversely affected by the biotic pressure and hence they were able to produce more number of shoots compared with less developed rhizomes of few month old seedlings. This can be the reason for the higher survival

Table 4. Survival percentage of reed bamboo after 1st and 2nd year of planting

1st year				2nd year		
Plot No.	Total No. of plants	No.of plants survived	Survival percentage	Total No.of plants	No.of plants survived	Survival percentage
1	77	50	64.9	77	61	79.2
2	77	26	33.8	77	46	58.7
3	77	28	36.4	77	43	55.8
4	196	68	34.7	196	104	53.1
5	196	59	30.1	196	114	58.1
6	196	107	54.6	196	134	68.4

recorded in the Plot No.1. But Pandalai and Sankar (2000) could record only a low survival (49%) in *Ochlandra travancorica* when rhizomes were planted in the denuded reed growing areas. Reed seems to be demanding shade especially during its early growth stages. This is proven by the relatively higher survival of seedlings in the 6^{th} Plot. Compared to the Plots 2-5, this plot contained denser standing vegetation which provided shade to the young reed seedlings.

It was also noted that the survival percentage of the seedlings was higher during the second year than the first year. This is thought to be because most of the replanted seedlings which were retained in the nursery for 15 months with more developed rhizomes could establish better than few weeks old seedlings in the first year. Moreover the application of cow dung and neem cake might have increased the vigour of the seedlings.

Growth performance

Plate No. 7 Reed clump - 3 years after planting

Data on various growth parameters given in Tables 5-8 showed that reed performed remarkably well in the planted site. It could attain a maximum height of 163 cm within one year, 354 cm within two years and 556 cm within three years on degraded soil. Also it could produce a maximum of 13, 20 and 36 culms within one, two and three years respectively. Data in the Tables 5-8 also showed that mean values of height increased from around 50 cm at the time of planting to around 200 cm, 36 months after planting. Number of culms increased from around 3 to 13 per clump, girth from 1.0

Table 5. Growth parameters of reed bamboo at the time of planting

Plot No.	Height (cm)			No. of culms/clump			Maximum girth at collar region (cm)			Circumference of the clump (cm)		
	Mean	Min.	Max	Mean	Min .	Max	Mean	Min.	Max	Mean	Min.	Max
1	52.9	28	85	3.3	2	6	1.4	1.0	1.8	13.4	10	20
2	48.4	20	86	3.1	1	7	1.1	0.8	1.5	10.2	8	14
3	54.5	31	102	2.9	2	6	0.8	0.6	1.0	10.9	9	15
4	52.8	20	93	2.8	1	6	0.8	0.6	1.3	11.0	8	17
5	51.7	27	95	3.0	2	5	1.1	0.7	1.3	9.2	5	18
6	55.1	26	110	2.9	1	6	1.1	1	1.5	11.5	9	17

Table 6. Growth parameters of reed bamboo 12 months after planting

Plot No.	Height (cm)			No. of culms/clump			Maximum girth at collar region(cm)			Circumference of the clump (cm)		
	Mean	Min.	Max.	Mean	Min	Max	Mean	Min.	Max.	Mean	Min.	Max
1	78.4	18	162	3.2	1	6	1.6	1	3	44.4	12	68
2	73.3	10	160	3.2	1	6	1.3	0.8	2	31.1	8	49
3	69.0	16	163	3.9	1	13	1.2	0.8	2	33.8	9	52
4	67.9	11	128	3.4	1	6	1.4	1	3	36.7	7	59
5	67.2	12	163	3.21	1	8	2.0	1.2	4	38.9	6	64
6	69.2	16	158	3.2	1	10	1.9	1.2	3	45.5	10	72

Table 7. Growth parameters of reed bamboo 24 months after planting

Plot No.	Height (cm)			No. of culms/clump			Maximum girth at collar region (cm)			Circumference of the clump (cm)		
	Mean	Min.	Max	Mean	Min	Max.	Mean	Min.	Max	Mean	Min.	Max
1	128.8	54	255	5.91	2	12	2.6	2	5	58.91	14	111
2	116.5	74	218	6.0	2	10	1.2	1	3	64.52	30	103
3	97.5	25	1.97	7.57	1	20	1.6	1	4	86	18	160
4	98.4	36	202	7	7	16	1.2	1	3	59.34	27	88
5	158.1	71	354	8.03	4	17	1.9	1	4	67.45	35	102
6	134.7	70	304	6.92	3	12	1.3	1	4	67.14	22	139

Table 8. Growth parameters of reed bamboo 36 months after planting

Plot No.	Height (cm)			No. of culms/clump			Maximum girth at collar region(cm**)**			Circumference of the clump (cm)		
	Mean	Min	Max	Mean	Min	Max	Mean	Min.	Max	Mean	Min.	Max
1	268	42	490	11.8	3	25	5.8	4.00	9.00	93.7	60	148
2	181	43	412	9.8	4	23	5.1	1.00	9.00	79.2	28	147
3	152	50	345	15.3	3	36	5.1	3.00	13.00	122	50	217
4	182	30	426	13.1	3	34	4.6	2.00	8.00	92.5	35	160
5	311	45	556	14.7	2	36	6.0	2.00	8.00	118	16	265
6	265	63	520	13.5	3	30	5.8	2.00	13	105	26	204

to 5.0 cm and circumference of clump from 11 to 90 cm after three years. Seethalakshmi *et al.* (1991) reported the growth performance of *Ochlandra travancorica* in its natural habitat at Vazhachal. According to them, the seedlings and cuttings could attain a mean height of 93.0 and 111.9 cm respectively after two years of planting. In their study seedlings produced 5.2 sprouts and the cuttings produced 7.9 sprouts within two years. In the present study, reed was grown in the most adverse conditions and still the results are quite encouraging. Results of the study also imply that after the establishment phase, the plants grow vigorously irrespective of the nature of the planting material.

5. CONCLUSION

Results of the study show that various properties of soils viz., colour, structure, texture, lateritic gravel, illuvial clay, pH and organic carbon are greatly influenced by the growth of reed when compared with the adjacent non-reed areas. The study also reveals that reed plants raised from rhizomes can establish better in the degrading lateritic soils than the seedlings and if seedlings are preferred for planting on degrading lateritic soils, then they should be at least 18 months old with well developed rhizomes. Reed bamboo (*Ochlandra travancorica)* can thus be recommended as a very suitable species to arrest land degradation and improve soils in the Western Ghats of Kerala.

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REFERENCE

Black, C.A., Evans, D.D., Ensminger, L.E., White, J.L. and Clark, F.E. 1965. *Methods* of *Soil Analysis.* Part I. Am. Soc.Agron. Inc., Madison, Wisconsin, USA.

Chen, Q.F. 1999. Impacts of different operational patterns for moso-bamboo (*Phyllostachys pubescens)* on soil fertility. *J. Bamboo Res.* **18** (3) : 19-24

Christanty, L,, Kimmins, J. P., Mailly, D. and Huttl, R.F. 1997. 'Without bamboo, the land dies' : A conceptual model of the biogeochemical role of bamboo in an Indonesian agroforestry system. *Forest Ecology and Management* **91**(1) : 83-91

Geological Survey of India, 1976. *Geology and Mineral Resources of the States of India*. Part IX. Kerala. Miscellaneous Publication No. **30**, Government of India.

Grewal, S.S., Juneja, M.L., Singh, K. and Singh, S. 1994. A comparison of two agroforestry systems for soil, water and nutrient conservation on degraded land. *Soil Technology* **7**(2) : 145-153

Jackson, M.L. 1958. *Soil Chemical Analysis*. Prentice hall Inc. Engle Wood Cliffs, N.J., USA. Reprint (1973) by Prentice Hall of India (Pvt.) Ltd., New Delhi.

Kadambi, K. 1949. On the ecology and silviculture of *Dendrocalamus strictus* in the bamboo forest of Bhadrawati Division, Mysore State and comparative notes on the species *Bambusa arundinacea*, *Ochlandra travancorica*, *Oxytenanthera monostigma* and *Oxytenanthera stocksii*. *Indian For.* **75** : 289-299

Kaul, O.N. 1964. Bamboo in Chambal Ravines, *All India Bamboo Study Tour and Symposium*. Forest Research Institute, Dehradun.

Koppar, A.L. 1980. Soil and climatic requirements of bamboo. *Proceedings of the Third Southern Silviculturists and Forest Research Officers Conference,* Karnataka Forest Department, Dharwar, p. 51-53

Maikhuri, R.K., Senwal, R.L., Rao, K.S. and Saxena, K.G. 1997. Rehabilitation of degraded community lands for sustainable development in Himalaya : a case study in Garhwal Himalaya, India. *International Journal of Sustainable Development and World Ecology* **4**(3) : 192-203

Ming, l.S. and Shou, L.H. 1993. Agroecosystem models to prevent land degradation and improve land productivity along the Jian River Watershed, China. *J. Asian Farming Systems Association* **1 (**4) : 479-493

Neginhal, G.S. 1949. Introduction of bamboos through afforestation measures. *Indian For.* **75**(11) : 457-458

Pandalai, R.C. and Sankar, S. 2000. Regeneration Techniques for Reeds. *Research Report* No. **187**. Kerala Forest Research Institute, Peechi, Thrissur, Kerala.

Pant, N.C., Pandey, D.K. and Singh, A.K. 1993. A comparative study of soil properties under some miscellaneous forests with and without bamboos in Shahdol (M.P.). *J. trop. For*. **9 (**4) : 342-349

Pant, N.C., Pandey, D.K., Sonkar, S.D. and Banerjee, S.K. 1995. Combined influence of pit size and fertilizer on survival and growth of *Cassia siamea* in degraded soil. *Indian For*. **121**(1) : 44-50

Prasad, G.K., Singh, S.K., Das, P.K. and Nath, S. 1996. Performance of MPT species under demonstration plantation in West Bengal. Part I : site factors and growth parameters. *Van Vigyan* **34** (4) : 148-161

Pratap, T. and Watson, H.R. 1994. Sloping Agricultural Land Technology (SALT). A regeneration option for sustainable mountain farming. *ICIMOD-Occasional Paper* No. **23**

Puri, D.N. Pratap Narain, Dhyani, S.K. and Narain, P. 1995. Working technique in degraded lands - Eucalyptus hybrid. *Indian For.* **121 (**7) : 600-607

Quershi, I.M., Yadav, J.S.P. and Prakash, J. 1969. Physico-chemical study of soils in some bamboo forests of Assam. *Indian For*. **95** : 599-603

Sanalkumar, M.G., Sujatha, M.P. and Sankar, S. 1998. Population density and diversity of micro-arthropods and annelids in the reed growing soil of Vazhachal Reserve Forest, South Western Ghats of India. *J. trop. For*. **15 :** 135-143

Seethalakshmi, K.K., Surendran, T. and Somen, C.K. 1988. Vegetative propagation of *Ochlandra travancorica* and *Ochlandra scriptoria* by culm cuttings. *Bamboos Current Research.* (Ed. Rao, I.V.R., Gnanaharan, R. and Sastry,B.) Kerala Forest Research Institute, Peechi and International Development Research Centre, Canada.

Sharma, J.K., Sankaran, K.V., Balasundaran, M. and Sankar, S. 1996. Use of mycorrhizal and nitrogen fixing symbionts in reforestation of degraded acid soils of Kerala. *Research Report*. No. **112**, Kerala Forest Research Institute, Peechi, Thrissur

Singh, K., Kumar, B. and Singh, N. 1995. Impact of intensive afforestation programme on the rehabilitation of Punjab Shivaliks. *Indian For.* **121** (2): 115-121

Soil Survey Staff, 1992. *Keys to Soil Taxonomy*. SMSS Technical Monograph No. **6**, Pocahoutas Press, Inc., Blackburg.

Sujatha, M.P. 1999. Characterisation of soils under reed. (*Ochlandra travancorica* Benth.) in the Western Ghats. Ph.D. Thesis, Kerala Agricultural University, Vellanikkara, Thrissur.

Sujatha, M.P., Jose, A.I. and Sankar, S., 1996. *Ochlandra travancorica* Benth. a promising plant for sustainable soil management in the Western Ghats. Kerala. *Proceedings of 8th Kerala Science Congress, Science, Technology and Environment Committee (Ed. P.K. Iyengar),* Thiruvananthapuram , Kerala , p.36-38

Thomas T.P. 1998. Soils of bamboo (*Bambusa bambos*) brakes in Kerala Forest. Ph.D.thesis, Forest Research Institute (Deemed University), Dehra Dun.

Thomas, T.P. and Sujatha, M.P. 1992. Environmental importance of *Ochlandra travancorica* with particular reference to soil conservation. A case study of Ranny Forest Division, Kerala, India. *Bamboo and Its Use* (ed. Shilin, Z., Weidong, L., Xinping, Z. and Zhongming, W.) International Tropical Timber Organization and Chinese Academy of Forestry, Beijing, China, p.7-11

Totey, N.G. 1995. Some important factors associated with sal mortality and regeneration. *Advances in Forestry Research in India*. **13** : 13-32

Wang, Y.H. and Liu, Y.M. 1995. Hydrological characteristics of a moso-bamboo (*Phyllostachys pubescens)* forest in South China. *Hydrological Processes* **9** (7) : 797-808