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NATURAL REGENERATION OF SOME MANGROVE SPECIES IN A *MELALEUCA LEUCODENDRON* PLANTATION AT ABEL-KIRI, NIGERIA.

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ABSTRACT

Invasion of naturally regenerated halophytes (mangroves) into a non-halophytic tree (*Melaleuca leucodendron*) plantation at Abel-kiri, Nigeria was studied in 1991 and 1993 in a one hectare sample plot. The abundance of mangrove species within the melaleuca plantation was ranked as follows: *Rhizophora racemosa* > *Avicenia germinans* > *Nypa fruticans* = *Achrosticum aureum*. Simpson's and Shannon Weiner's indices indicated high mangrove species diversity. Regeneration of mangrove species occurred between furrows and near channels and dykes. *Rhizophora racemosa* occurred mainly within the soft mud in the furrows and channels as well as on the edges of the dykes; *A. Germinans* at the edges and on some parts of the dykes, *N. fruticans and A. Aureum* on open spaces caused by either human disturbances (eg. felling) or by wind thrown melaleuca trees. Quantitative data on seedling, sapling and tree densities, basal area and species composition were collected and analysed. In 1993 (after 28 years), *R. racemosa* had total basal area of 5.50 m^2ha^{-1} and total volume of 13.19 m^3ha^{-1}. *Avicenia germinans* had total basal area of 2.34 m^2ha^{-1} and total volume of 68.83 m^3ha^{-1}. *Melaleuca leucodendron* on the dykes had shallow rooting depth (70 cm) and was prone to wind throw (7%) in the "chikoko" (peaty) soil. Most melaleuca plants in the 1965 plantation were within the 5-10 m and 10-15 cm height and diameter classes respectively. Melaleuca had basal area of 11.40 m^2ha^{-1} and volume of 49.70 m^3ha^{-1}. Melaleuca's natural regeneration was primarily vegetative via root suckers. This species seems to have some autotoxic effect on its natural regeneration through wildlings.

INTRODUCTION

Mangrove species in the Niger Delta region of Nigeria have multipurpose values. The red mangrove (*Rhizophora racemosa),* known locally as "ngala", and the white mangrove (*Avicenia germinans)* are highly prized timber and fuelwood species. They are also used for the local manufacture of tannins and dyes, as well as stakes for fishing. These leaves/fronds and/or bark of these and other species, such as *Nypa fruticans,* are used as fodder.

Unregulated deforestation for timber, fuelwood and stakes for fishing has, however, reduced the area of mature mangrove forest within the Niger Delta area. The consequences of unregulated deforestation of the mangrove forests include prevalence of seedling and saplings of mangrove species, coastal erosion, reduced spawning and nursery area for many marine species of fish, reduced breeding and feeding ground for migratory birds and fish, prawns, oysters, crabs, etc. (IUCN, 1983).

There has been recent research interests in the natural regeneration of mangrove species in Nigeria. Mangrove forests have ecologically stabilizing influences on the ecosystem (Lugo and Snedaker, 1974) and viable ecological potentials (Christensen and Delmondo, 1978; Tang *et al.* 1980). However, the indigenous mangrove species in the Niger Delta region have slow land reclamation rates. Melaleuca, a non halophyte, was planted in 1965 at Abel-kiri, presumably to assist in land reclamation in a transitional environment within the mangrove ecosystem.

This paper reports the natural regeneration/invasion potentials of mangrove species in the melaleuca plantation and also the growth and yield of the melaleuca plantation.

MATERIALS AND METHODS

The study site

Abel-kiri, Abonema (4°45'N; 6°47'E), island within the Sombreiro River, is in Akukutoro Local Government Area, Rivers State, Nigeria. Abel-kiri is generally 10m above the sea level but some parts of the island are wholly inundated at high tide which occurs once daily and lasts for 8h. Abel-kiri has the following mean annual climatic data: rainfall: 2,268mm; relative humidity: 80-85%; maximum and minimum temperatures: 30°C and 23°C respectively (FDALR, 1982). The rainy season lasts from March to November and the dry season from December to February/March.

The soils are Histosol, derived from marine deposits consisting of silt, sand and organic debris while the soil texture is febrist chikoko (NEDECO; 1960).

The soil within the mangrove forest at Abel-kiri is hydromorphic. It is typically blue alluvium with brownish grey discoloration at the surface (SKOUP, 1980). The soil is soft when newly deposited but is eventually held together by a mat of under composed fibrous roots, mangrove rootlets and dead mangrove plants forming a thick, peaty layer known locally as the "chikoko". As the root raft builds up in parts of the forests at Abel-kiri, the surface level rises until the soil is shallowly flooded at the highest parts. The soil has a pH 5.8 and the following chemical properties: N 0.2% with a range of 0.1-0.4%, C4.2%, C:N ratio 20.0; available P3 ppm; K (x 100) 55%; Cl (in dry soil) 0.13% (Isirimah *et al.*, 190). The salinity of the Sombreiro River fluctuates according to season, being high during the dry season and low during the rainy season.

Inundation occurs 2-3 times daily with each inundation lasting for 8-10 h. There are usually low and high tides during the second or third inundation (SKOUP, 1980). Mudflats in lower littoral zones at Abel-kiri are usually visible at low tides. Floristically, the following mangrove species are common at Abel-kiri: *Rhizophora racemosa, Avicenia germinans; Laguncularia racemosa, nypa fruticans* and the grass, *Paspahum vaginatum.*

Fishing is the main occupatin of the people although a few of them are public servants, traders and farmers. Some of the farmers keep small ruminants, mainly goats and sheep, with an average livestock holding per farmer of 4 goats and 2 sheep. The livestock browse, or are fed with fronds of *N. fruticans,* barks and, sometimes, leaves of *R. racemosa and A. germinans.*

Methodology

A randomized complete block design (RCBD) with five replications was used in a 100 m x 100 m plot established in June, 1991 within a 4 ha *Melaleuca leucodentron* (melaleuca): *Casuarina equisetifolia* (Casuarina) inter-planting at Abel-kiri, Abonema, Rivers State, Nigeria. The original mangrove forest at the study site was clear-felled for the tree crop establishment. The 1 ha plot was sub-divided into five adjacent sub-plots (each 20 m x 100 m), according to the ordination techniques of Williams (1976), to study the stand attributes of melaleuca and also the spatial and regeneration patterns of the mangrove species in each sub-plot.

Melaleuca and casuarinas were planted in June, 1965 in a 1:1 ratio at 2 m spacing along 2 m wide x 0.7 m high dykes of "chikoko" soil. A narrow furrow, 1 m wide x 0.7 m deep, separated the dykes carrying the forest tree species. The melaleuca and casuarinas were planted at 2 m x 3 m spacing with a density of 1666 plants ha^{-1} for both species or 833 plants ha^{-1} per species. Wildlings of *R. racemosa, A. germinans, N. fruticans and A. aureum* were counted within each sub-plot. All trees with diameter-at-breast height (dbh) for non-prop root plant diameter-above prop roots (dap) of 10 cm or more were identified and measured for total height and diameter. Saplings (diameter-at-breast height (dbh) for plants without prop roots, or dap = 2.0 cm – 9.9 cm) were also assessed for total height and diameter while seedlings (dap or dbh < 2.0 cm) were only counted. Total height and height of tallest prop root per tree/sapling were measured with either Haga altimeter or a caliberated pole. Both crown diameter and diameter of root spread were obtained for the trees and saplings. Crown diameter was measured, first along the longest axis, and, second, perpendicular to the first measure according to the methods of Nwoboshi (1985).

Since the survival percentage and growth rate of *C. Equisetifolia* were extremely poor (6% and 2 m high respectively), the measurements of casuarinas were discarded. Attention was paid to melaleuca in terms of total height, dbh (over bark), bark thickness, survival percentages, percentages of root suckers, wind thrown trees and double stems/leaders per tree as well as the rooting depth and diameter of root spread.

Data analysis

Relative density(%) of the mangrove species was obtained by summing up the total number of stems of a species on a plot and dividing by the total number of stems of all species on the plot (Albert and barness, 1987). Relative dominance (%) was relative density using basal instead of stem number. The height and diameter classes of the trees and saplings were obtained. Basal areas ($\frac{\pi}{4} d^2$) of trees and saplings were computed for *R. racemosa and A. germinans*. The volumes of the trees and saplings were computed as follows:

$(\frac{\pi}{4} d^2)$ h x f.f. where π = 3.141593, d = diameter value, h = height and f.f = form factor (0.4) for *R. racemosa and A germinans* (Putz and Chen 1996) and also for melaleuca.

Simpson's and Shannon-Weiner's indices of mangrove species diversity within the melaleuca plantation were computed according to the produres of Odum (1975). Hix's (1983) over values (%), as modified by Albert and Barnes (1987), were calculated to indicate abundance of ground cover (mainly seedlings) in the sub-plots. The cover value for each mangrove ecological group was obtained by dividing the total coverage of the group for each sub-plot by the number of the species of the group (Albert and Barnes, 1987).

Duncan's New-Multiple Range Test (DNMRT) and Student's "t" –test were used to test (at P ≥ 0.05) for significant differences between the results of relative densities, basal area, and relative dominance of the mangrove forest species, melaleuca and the various plant life forms of the tree species at Abel-kiri, Nigeria in 1991 and 1993. All statistical analyses were computed according to the procedures of Steel and Torrie (1980).

RESULTS

Natural regeneration of invading mangrove species in Melaleuca plantation

The abundance, diversity indices and other important values of invading mangrove species in the melaleuca plantation at Abel-kiri, Nigeria are summarized in Table 1:

Table 1: Abundance and other importance values of naturally regenerating/invading mangrove species in 1965 *Melaleuca leucocephala* plantation at Abel-kiri, Nigeria.

Species and Other Attributes	Plant life Form: T	Sp	S	Total	Attributes per species: Relative density (%)	Basal area ($m^2 ha^{-1}$)	relative dominance (%)	Volume ($M^3 ha^{-1}$)
				1991				
Rhizophora racemosa	196	1513	3187	4896	42.6^{a}	4.2752^{a}	70.5^{a}	9.3995^{a}
Relative density (%)	$(4)^{n}$	$(30.9)^{m}$	$(65.1)^{k}$	(100.0)				
Avicenia germinans	71	705	2645	3421	29.8^{b}	1.7848^{b}	29.5^{b}	4.7336^{b}
Relative density (%)	$(2.1)^{i}$	$(20.6)^{g}$	$(77.3)^{f}$	(100.0)				
Nypa fruticans	-	-	1679	1679	146^{c}	-	-	-
			(100.0)	100 0)				
Achrosticum aureum	-	-	1491	1491	13.0^{c}	-	-	-
			(100.0)	(100.0)				
Total	267	2218	9002	11487	100.0	6.0573	100.0	14.1331
Relative density (%)	2.3^{c}	19.3^{b}	78.4^{a}	100.0				
Average Cover (%)		19.6						
Simpson's index			0.726	0.692				
Shannon-Weiner's index			0.966	0.916				
				1993				
Rhizophora racemosa	204	1628	3550	5382	41.3^{a}	5.496^{a}	70.2^{a}	13.1904^{a}
Relative density (%)	$(3.8)^{n}$	$(30.2)^{m}$	$(66.0)^{k}$	(100.0)				
Avicenia germinans	74	791	3109	3974	30.5^{b}	2.3355^{b}	29.83^{b}	6.8335^{b}
Relative density (%)	$(1.9)^{i}$	$(19.9)^{g}$	$(78.2)^{f}$	(100.0)				
Nypa fruticans	-	-	2091	2091	16.0^{c}	-		-
			(100.0)	(100.0)				
Achrosticum aureum	-	-	1589	1589	12.0^{c}	-		-
			(100.0)	(100.0)	100.0			
Total	278	2419	10339	13036		7.8315	100.0	20.0239
Relative density (%)	2.1c	18.6b	79.3a					
Average Cover (%)			19.3					
Simpson's index			0.727	0.696				
Shannon-Weiner's index			0.966	0.921				

Different superscripts within each column or row indicate significant difference at P ≥ 0.05 for each attribute (e.g.) relative density, basal areas, relative dominance and volume), using Duncan's New Multiple Range Test (DNMRT).

Key: T = Tree (diameter ≥ 10.0 cm); Sp = Sapling (diameter: 2.00 – 9.99 cm); S = Seedling (diameter < 2.0).

Rhizophora racemosa and *Avicenia germinans* had significantly higher relative densities than *Nypa fruticans* and *Achrosticum aureum* throughout the studyperiod, in the following significant ranking order: *R. racemosa* > *A. germinans* > *N. fruticana* = *A. aureum*. The various plant life forms (trees, sapling, seedlings) also had the following significant order: seedling > saplings > trees. Seedling of the invading mangrove species in the 1965 melaleuca plantation had an average cover class value of 19.8%. The tree components of *R. racemosa and A. germinans* had significantly the lowest relative density. However, *R. racemosa* had significantly higher basal area and relative dominance than *A. germinans* in both study periods. The Simpson's and Shannon-Weiner's indices showed high mangrove species diversity in the melaleuca plantation. *Rhizophora racemosa* also predominated within the soft mud in the furrows and/or the edges of the dykes. *Nypa fruticans* and *A. aureum* were found mainly on dykes between the melaleuca trees. *Avicenia germinans* occurred predominantly on the edges of, and, sometimes, on the dykes.

Table 2 summarizes the height and diameter classes of *R. racemosa* and *Avicenia germinans* in the melaleuca plantation.

Table 2: Height and diameter classes of *R. racemosa and A germinans* in a melaleuca plantation at Abel-kiri, Nigeria.

	Species									
	R. racemosa					***A germinans***				
Diameter Class (cm)	Height classes (m) 2-5	2-10	10-15	Total	Relative density (%)	Height classes (m) 2-5	5-10	10-15	Total	Relative density (%)
2-5	914*	102	-	1016	59.4^{a}	401	130	-	531	64.4^{a}
5-10	109	291	97	497	29.1^{b}	-	162	12	174	22.4^{b}
10-15	-	58	79	137	8.0^{c}	-	-	53	53	6.8^{c}
15-20	-	-	59	59	3.5d	-	-	18	18	2.[illegible]
Total	1023	451	235	1709		401	297	83		
Relative Density (%)	59.9^{a}	26.4^{b}	13.8^{c}			51.7^{a}	37.6^{b}	10.7^{c}		
					1993					
2-5	988	114	-	1102	60.2^{a}	472	139	-	611	70.6^{a}
5-10	123	302	101	526	28.7^{b}	-	167	13	180	20.8^{b}
10-15	-	63	81	144	7.9^{C}	-	-	55	55	6.4^{C}
15-20	-	-	60	60	3.3^{d}	-	-	19	19	2.2^{d}
Total	1111	479	242	1832		54.6^{a}	35.4^{b}	10.1^{a}		
Relative Density (%)	60.6^{a}	26.1^{b}	13.2^{c}							

Key: * = No. of plants per size class

Different superscripts indicate significant differences between the relative density values of different size classes using Duncan's New-Multiple Range Test (DNMRT).

Saplings (dap = 2-9.9 cm) were dominant in both species. The relative densities of saplings (dap = 2.0-9.9 cm) and trees (dap ≥ 10 cm) of *R. racemosa* were 88.5% and 11.5% respectively in 1991 and 88.9% and 11.2% respectively in 1993. the relative densities of saplings and trees of *A. germinans* were 90.8% and 9.1% respectively in 1991 and 91.4% and 8.6% respectively in 1993. The height of the two species fell mainly within the range of 2-10 cm class.

Prop roots constituted approximately 13% of the mean height of *R. racemosa* within the melaleuca plantation (Table3).

Table 3: Some quantitative characteristics of *R. racemosa and A germinans* within a melaleuca plantation at Abel-kiri, Nigeria.

	Mean value per plant per study period					
	R. racemosa			*A. germinans*		
Attributes	T	Sp	Total (mean)	T	Sp	Total (mean)
			1991			
Total height (m)	11.4 ± 0.4	4.6 ± 0.2	6.3 ± 0.55	10.8 ± 0.9	5.2 ± 0.4	6.6 ± 0.3
Prop root height (m)	1.8 ± 0.4	1.1 ± 0.2	0.8 ± 0.2	-	-	-
Prop root: total height (%)	15.8 ± 3.7	23.9± 4.8	12.7 ± 2.1	-	-	-
Diameter above prop root (cm) or dbh	12.9 ± 1.1	3.8 ± 0.4	5.6 ± 0.3	12.8 ± 1.3	4.0 ± 0.3	5.4 ± 0.4
Crown diameter (m)	4.3 ± 0.4	2.8 ± 0.2	3.7 ± 0.2	3.8 ± 0.4	2.1 ± 0.1	2.8 ± 0.3
Diameter of root spread (m)	7.4 ± 1.7	5.9 ± 0.6	6.1 ± 0.4	5.2 ± 0.8	3.8 ± 0.2	4.4 ± 0.4
Crown diameter: diameter of root spread (%)	58.1 ± 2.7	47.5± 3.8	60.7 ± 3.8	73.1 ± 3.1	55.3 ± 3.3	63.6 ± 3.3
			1993			
Total height (m)	11.0 ± 0.8	5.0 ± 0.6	6.9 ± 0.5	11.7 ± 1.3	5.8 ± 0.6	7.3 ± 0.4
Prop root height (m)	1.9 ± 0.5	1.4 ± 0.2	0.9 ± 0.3	-	-	-
Prop root: total height (%)	16.0 ± 3.3	17.5 ± 4.1	13.0 ± 2.8	-	-	-
Diameter above prop root (cm) or dbh	13.4 ± 1	4.2 ± 0.3	6.2 ± 0.6	13.2 ± 1.4	4.6 ± 0.5	5.9 ± 0.6
Crown diameter (m)	4.4 ± 0.5	2.7 ± 0.3	3.8 ± 0.3	4.0 ± 0.6	2.3 ± 0.3	2.7 ± 0.4
Diameter of root spread (m)	7.6 ± 1.2	6.1 ± 0.8	6.5 ± 0.6	5.5 ± 0.8	3.8 ± 0.3	4.8 ± 0.4
Crown diameter: diameter of root spread (%)	57.9 ± 2.4	44.3± 3.1	58.5 ± 3.3	72.7 ± 3.3	60.5 ± 2.9	56.3 ± 3.0

Key: T = Tree (diameter > 10.0 cm
Sp =Sapling (diameter: 2.0 cm – 9.9 cm).

The mean diameter of root spread values for the prop roots of *R. racemosa* and the breathing roots of *A. germinans* in 1993 were 6.4 m and 4.8 m respectively. The overall mean crown diameter: diameter values for *R. racemosa and A. germinans* in 1993 were 3.8 m and 2.7 m respectively. The overall mean percentages of the crown diameter of root spread ratios for *R. racemosa and A. germinans* in 1993 were 58.5% and 56.3% respectively.

Generally, trees had higher means height, diameter above prop roots or diameter at breast height, crown diameter, diameter of root spread and the crown diameter: diameter of root spread ratios than saplings. No significant difference existed between the 1991 and 1993 values of the various attributes of the mangrove species.

Table 4 summarizes the basal areas and volumes of the naturally regenerated mangrove timber species.

Table 4: Basal area and volume (plant –1 and ha –1) of naturaly regenerated *R. racemosa and A germinans* at Abel-kiri, Nigeria.

Attibutes	T	Sp	Total	T	Sp	Total
			1991			
No. (life form^{-1})	196	1513	1709	71	705	776
Basal area						
(m^2 plant $^{-1}$)	0.0131	0.0011	0.0025	0.0129	0.0013	0.0023
(m^2 ha-^{1})	2.5676	1.6643	4.2725	0.9159	0.9165	1.7848
Volume						
(m^3 plant $^{-1}$)	0.0503	0.0015	0.0055	0.0557	0.0027	0.0061
($m^3 ha^{-1}$)	9.8588	3.3695	9.3995	3.9547	1.9035	4.7336
			1993			
No. (life form^{-1})	204	1628	1831	74	791	865
Basal area						
(m^2 plant $^{-1}$)	0.0141	0.0014	0.0030	0.0137	0.0017	0.0027
(m^2 ha-^{1})	2.8764	2.2792	5.4960	1.0138	1.3447	2.3355
Volume						
(m^3 plant $^{-1}$)	0.0513	0.0020	0.0072	0.0641	0.0039	0.0079
($m^3 ha^{-1}$)	10.4652	3.2560	13.1904	4.7434	3.0849	6.8325

Trees, as expected, had higher basal areas and volumes than saplings. In 1993 (after 28 years), R. racemosa had total basal areas of 0.0030 m^2 $plant^{-1}$ and 5.4960 m^2 ha^{-1} as well as valumes of 0.0072 m^3 $plant^{-1}$ and 13.1904 m^3 ha^{-1}. *A. germinans* had total basal areas of 0.0027 m^2 $plant^{-1}$ and 2.3355 m^2 ha^{-1} and total volume values of 0.0079 m^3 $plant^{-1}$ and 6.8335 m^3 ha^{-1}.

Growth attributes of melaleuca

Trees (dbh $\geq$ 10 cm) constituted about 71% of the total density of stems of melaleuca in the plantation while saplings (29%) consisted of either coppices of exploited trees or regenerations of melaleuca via root suckers (Table 5). Most (about 84%) of the melaleuca fell within the 5-10 m height class. Table 5 shows that there was a significant reduction (1.2%) in stand density between 1991 and 1993 due to wind throw and human disturbances (eg. Illega l felling).

Table 5: Height and diameter classes of melaleuca in a 1 ha sample plot at Abel-kiri, Nigeria

Diameter classes (cm)	Number of plants per size class Height classes (m) 5-10	10-15	Total	Relative density (%)
		1991		
2-5	21	-	21	3.5[c]
5-10	146	-	146	24.6[b]
10-15	239	23	262	44.2[a]
15-20	88	52	140	23.6[b]
20-25	-	24	24	4.0[c]
Total	494	99	593	
Relative density (%)	83.3[a]	16.7[b]		
	1993			
2-5	32	-	32	5.5[c]
5-10	138	-	138	23.8[b]
10-15	236	21	257	44.4[a]
15-20	81	49	130	22.5[b]
20-25	22	22	22	3.8[c]
Total	487	92	579	
Relative density (%)	84.1[a]	15.9[b]		

Different superscripts within each row or column indicate significant differences between the relative density values.

Table 6 summarizes the growth attributes of melaleuca at Abel-kiri during the study periods. Melaleuca produced about 12% double leaders and suffered from wind throw (about 7%) due to its shallow rooting depth (70 cm). The crown diameter and diameter of root spread values of melaleuca were closely related, being 4.6 m and 5.4 m respectively. The crown diameter: diameter of root spread ratin (%) in 1993 was 85.2. Melaleuca had total basal area of 11.3994 m^2 ha^{-1} and volume value of 49.7014m^3 ha^{-1} as well natural regeneration (10.8%) via root suckers in 1993. No significant differences existed between the 1991 and 1993 results of the various attributes studied in the melaleuca plantation.

Table 6: Growth characteristics of melaleuca plantation at Abel-kiri, Nigeria.

	Mean values per plant*	
Attributes	1991	1993
Sample size (trees ha-1	593	579
Survival (%)	71.2	69.5
Total height (m)	10.1 ± 0.2	10.9 ± 0.3
Dbh (over bark) (cm)	12.3 ± 0.2	13.1 ± 0.2
Bark thickness (cm)	1.8	1.9
Basal area (over bark) (m2 ha-1)	9.5787	11.3994
Volume (over bark) (m3 ha-1)	38.6979	49.7014
Double stems per plant (%)	11.3	12.2
Wind thrown plants (%)	6.5	7.4
Rooting depth (cm)	70.0	70.0
Crown diameter (m)	4.1 ± 0.3	4.6 ± 0.5
Diameter of root spread (m)	4.9 ± 0.5	5.4 ± 0.7
Crown diameter: diameter if root spread (%)	83.7	85.2
Root suckers (%)	9.6	10.8

* Mean values are on per plant basis except for sample size, basal area, volume and percentages of survival, wind-thrown plants and root suckers calculated on per ha basis

DISCUSSION

Mangrove formations are constantly controlled by marine and terrestrial factors such as the distance from the sea, frequency and duration of inundation, tidal dynamics, soil aeration and salinity (Benessala, 1988). Such environmental factors largely govern the distribution of species and their succession. The low relative densities of trees of *R. racemosa and A. germina*, the two dominant invading species within the melaleuca plantation (Table 1), indicate that both species are slow growing, especially in terms of height and diameter classes, basal areas and volumes (Table 2 and 4) after 28 years (in 1993). The slow growth rates might be due to the shading effect of melaleuca in the melaleuca plantation and also competition with *A. aureum*. Sukardjo (1984) reported a similar trend in growth. The abundant natural regenerations/invasions of *R. racemosa and A. germina* within the melaleuca plantation also indicate the potentials of the species for plantation establishment to increase the timber and other multiple uses, eg. fodder, fuelwood, of the species.

The high relative densities of seedlings and saplings of the commercial mangrove species (*R. racemosa and A. germina)* in the furrows might be due to drainage which in turn is related to the degree of sedimentation and salinity (Sukardjo et al., 1984). The soft mud within the furrows is richer in soil nutrients and salinity and, therefore, better for the mangrove species' regeneration than the highly enmeshed, thick and hard, fibrous "chikoko" soil on which melaleuca grows. The furrows are also more easily flooded at high or low tide than the more elevated "chikoko: soil.

Although high mangrove species diversity at Abel-kiri was found mainly in furrows and on the edges of dykes within the melaleuca plantation, the various mangrove species, including *R. acemosa and A. germina,* had different habitats and regeneration patterns with different densities and importance values. Shade tolerance and dispersal characteristics of the various mangrove species within the melaleuca plantation might also influence the distribution and cover values of the mangrove species, at Abel-kiri. The crown diameter of melaleuca in the plantation probably cast some shade on the invading mangrove species and adversely affected the growth rates of the invading mangrove species. Sukardjo (1987) also noted that commercial mangrove species, eg. *A. germina,* are intolerant of shade.

The overall mean crown diameter and diameter of root spread values for *A. germina,* at Abel-kiri might indicate utilizable, initial spacing treatment for these species in plantations. Closer spacing might result to crowding and steadily decreasing growth rates for mangrove timber species. Understanding the natural dynamics of the mangrove species may, thus, lead to the development of new and improved silvicultural techniques (Putz and Chen, 1986). The study has shown that *R. racemosa and A. germina,* can be interplanted in furrows within a non-halophytic tree (eg. melaleuca) plantation in a transitional zone in the mangrove ecosystem.

Melaleuca, which may be useful for reclaiming swampy land, has good ornamental, commercial timber and fuelwood values (Morton, 1966). The species strongly dominates a site and drastically reduces habitat diversity once it is established (Crowder, 1974; Austin, 1978). Melaleuca was the main surviving non-halophytic tree species growing on the dykes. The growth of melaleuca in a transitional environment within the mangrove ecosystem may also be dependent on the degree of salinity, soil nutrient status, tidal/inundation level, etc. Melaleuca, as observed in this study (Table 6), can produce large amounts of roots and develops this dense root mass as a mechanism of aeration in flooded sites (Di Stefano and Fisher, 1983). These features which can also give the species competitive advantages over native species in nutrient an d moisture uptake (Di Stefano and Fisher, 1983) might also explain the shallow rooting depth and the large mean diameter of root spread shown in Table 6.

Melaleuca also has the problem of autotoxicity. The species produces and releases some allelochemicals which profoundly inhibit or suppress the germination and growth of plant species and compete vigorously with other already established vegetation (Di Stefano, and Fisher, 1983). Allelopathy can negatively influence succession, dominance, vegetation dynamics and community structure (Del Morah and Muller, 1970; Rice, 1979). This allelopathic feature of melaleuca might be responsible for the absence of melaleuca wildlings and the extremely poor survival ($< 6\%$) and growth (< 2 m height) rates of casuarina intercropped with melaleuca. The performance of melaleuca in the transitional environment within the mangrove ecosystem is quite encouraging. The growth rate of melaleuca (Table 6-eg. Total height: 10.9 m; basal area: 11.4 m2 ha-1, volume: 49.7m3 ha-1) after 28 years is comparatively greater than that of the invading mangrove timber within the same site.

CONCLUSION AND RECOMMENDATIONS

The study has shown the vigorous natural regeneration/invasion potentials of halophytic (mangrove) species in a non-halophytic (melaleuca) plantation within a transitional environment in the mangrove ecosystem at Abel-kiri, Nigeria. *Rhizophora racemosa* had significantly higher relative density and relative dominance than *A. germinans*. Simpson's and Shannon-Weiner's diversity indices showed a high mangrove species diversity at the study site. Melaleuca's natural regeneration method at Abel-kiri was mainly via root suckers. The results, therefore, highlight the potential for plantation establishment of *R. racemosa and A. germinans* at Abel-kiri and other parts of the Niger Delta region in Nigeria.

Further research is required to examine the alleleopathic influence of commercial mangrove species, e.g *R. racemosa and A. germinans.* It may also be necessary to evaluate the potential benefits of utilizing melaleuca to control invading weedy, mangrove species, eg. *A. aureum and N fruticans,* in naturally or artificially regenerating mangrove forests containing usefulmangrove timber species in the Niger Delta or elsewhere in the tropics. Studies may be undertaken on the agroforestry potentials of melaleuca in sylvoaquaculture within the transitional zone of the mangrove ecosystem. The performance of some arable crops on lands reclaimed with melaleuca may also be evaluated. The possibilities of growing some arable crops and rearing some livestock in a hitherto uncultivable land reclaimed with melaleuaca and/or any other non-halophytic tree species will hold tremendous potentials for food production in the Niger Delta region.

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