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# Biomass and productivity of a *Rhizophora mucronata* Lamarck plantation in Tritih, Central Java, Indonesia

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ABSTRACT

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Perum Perhutani (The State Forestry Corporation) is establishing large-scale mangrove plantations for reforestation and/or afforestation, and the production of wood for fuel as well as other purposes in Java. The mangrove species used currently in Segara Anakan Cilacap is *Rhizophora mucronata* Lamarck. The above-ground biomass, litter production and litter accumulation in a 7-year-old stand in Tritih were studied. The mean diameter at breast height (DBH) or 30 cm above the highest prop root was 5.91 cm. The mean annual increment in DBH of individual trees was 0.89 cm. The total above-ground biomass of the stand was 93.726 t $ha^{-1}$ of dry weight, consisting of 60.442 t of stem, 13.906 t of branch, 14.708 t of prop root and 4.670 t of leaf material. Litter production ranged from 7.058 to 10.395 t $ha^{-1}$ $year^{-1}$ of dry weight with leaf litter making up 73.29–84.30% of the total. Leaf litter accumulation amounted to 16.922–20.511 t $ha^{-1}$ $year^{-1}$ of dry weight and the turnover constant ($k$) of leaf litter was estimated at 0.2943–0.4082. The high productivity is discussed in relation to lower turnover ($k$) of litter.

## INTRODUCTION

Indonesia has an area of mangrove forests estimated to be about 4.25 million ha (Darsidi, 1987), and only about 10% have been exploited commercially for charcoal, poles, firewood and pulp. In Java, there are about 50 000 ha of mangrove forest (Sukardjo, 1990a) managed by Perum Perhutani (The State Forestry Corporation). Perum Perhutani has embarked on large-scale planting of a number of mangrove species (*Rhizophora* spp., *Bruguiera* spp., *Ceriops* spp., *Avicennia* spp.) since early to mid-1964. In Segara Anakan Cilacap, the remaining largest block of mangrove swamp in Java, they have es-

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tablished plantations to produce wood for pulp, charcoal and firewood since 1965, planting various species of Rhizophoraceae, as well as *Avicennia* spp. KRPH Rawa Timur Cilacap of the Perum Perhutani, meanwhile, has undertaken large-scale planting in an effort to reforest large areas of degraded mangrove forests in Segara Anakan Cilacap, and to relieve the possible shortage in firewood supply for local consumption.

Owing to the value of mangrove wood and coastal land, few mature mangrove plantations remain in Segara Anakan Cilacap. In fact the plot discussed in this paper may represent the best young mangrove plantation in the area.

In this paper we present data on the biomass of a 7-year-old stand of *Rhizophora mucronata* Lamarck in Tritih, as well as the litter-fall production, in order to determine the net above-ground productivity of the species.

## THE STUDY AREA

The study area is the Rawa Timur forest district located in Tritih, approximately 15 km north of Cilacap (Fig. 1). Sea water inundates the area during

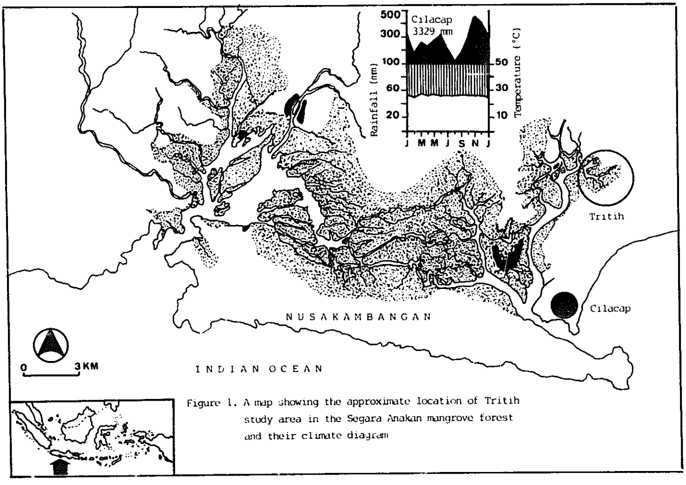


Fig. 1. A map showing the approximate location of the Tritih study area in the Segara Anakan mangrove forest with climate diagram.

TABLE 1

Physical and chemical properties of soil from the *Rhizophora mucronata* plantation in Tritih–Cilacap, Java, Indonesia

| Depth (cm) | Soil fraction (%) | | | Wet pH | C (%) | N (%) | C/N ratio | Available $P_2O_5$ (ppm) | Site plot |
|---|---|---|---|---|---|---|---|---|---|
| | Clay | Silt | Sand | | | | | | |
| 0–20 | 49.40 | 24.92 | 25.68 | 6.47 | 3.889 | 0.252 | 15.433 | 1.6 | I |
| 0–20 | 54.68 | 19.86 | 25.46 | 6.13 | 3.551 | 0.250 | 14.204 | 1.40 | II |
| 0–20 | 54.68 | 21.86 | 23.46 | 5.55 | 2.722 | 0.228 | 11.939 | 1.10 | III |
| 0–20 | 61.40 | 17.92 | 20.68 | 5.88 | 2.875 | 0.235 | 12.247 | 1.30 | IV |
| 0–20 | 64.40 | 17.92 | 17.68 | 6.60 | 3.967 | 0.225 | 17.631 | 1.75 | V |

high tides twice daily for a period of less than 2 h. The area is covered by a young *R. mucronata* plantation, with numerous *R. mucronata* seedlings and grasses on the forest floor.

Mean monthly temperatures average between 24.7 and 30.35°C, while the annual rainfall approximates 3174 mm, with high rainfall (over 250 mm month$^{-1}$) in October–January and March–June. The climatological parameters for the meteorological station at Cilacap are presented in Fig. 1.

The soil of Tritih has a black clay texture with little horizontal differentiation. Fine roots (less than 2 mm diameter) are concentrated in the top 20 cm, but we found apparently healthy roots of *R. mucronata* 100 cm below the ground surface. Basic data on soil physical and chemical properties are presented in Table 1.

## METHODS

Stands representing five *R. mucronata* types were selected for sampling at KRPH Rawa Timur, near Tritih village. Representative 50 m×50 m plots (0.25 ha) were established permanently at each of the sites. Following the classification in terms of management of the Perum Perhutani, there were two sites of medium *R. mucronata* stand (Sites I and IV, 4.25–6.45 m height), one of tall with dense *R. mucronata* stand (Site V, 5.7–7.2 m height) and two sites of small *R. mucronata* stand (Sites II and III, 4.1–6.1 m height).

The 50 m×50 m plots were divided into 25 subplots each 10 m×10 m. All living trees within the plots were marked, their height and diameter at breast height (DBH) or 30 cm above the highest prop root were recorded.

In January 1985 ten sample trees were cut near ground level from the five study plots for estimation of biomass. Trees for the biomass study were selected so that the entire range of DBH sizes obtained within the study plots were represented. The trees were cut and processed as in Suzuki and Tagawa (1983).

Litter production was monitored from January 1985 to December 1985 by collection in litter-fall traps (Newbould, 1967). Thirteen litter-fall traps 1 m×1 m×0.2 m in size and having a 1 mm nylon mesh base were systematically suspended diagonally by nylon rope between trees in every 10 m×10 m subplot with 10 m intervals at a height of 2 m above the ground beyond the reach of high tides. Litter was collected every week, oven dried at 105°C for at least 5 days, sorted into various components, and then weighed. The total amounts for each subplot were converted to daily figures with no correction made for either leaching or losses. Litter accumulation was also assessed using 1 m×1 m quadrat.

## RESULTS AND DISCUSSION

### *Stand characteristics*

The stand characteristics of the *R. mucronata* plantation for January 1985 are presented in Tables 2, 3 and 4. At 7 years of age, individual DBH values

TABLE 2

Stand characteristics of the *Rhizophora mucronata* plantation in January 1985

| Attribute | Site | | | | |
|---|---|---|---|---|---|
| | I | II | III | IV | V |
| Age (years) | 7 | 7 | 7 | 7 | 7 |
| Height range (m) | 4.25–6.45 | 4.25–6.20 | 4.10–6.10 | 4.25–6.45 | 5.70–7.20 |
| MDH[1] (m) | 5.84 | 5.40 | 5.20 | 6.10 | 7.10 |
| Canopy (%) | 87.75 | 85.20 | 80.95 | 82.25 | 90.50 |
| Basal Area ($m^2$ $ha^{-1}$) | 14.789 | 13.574 | 8.491 | 9.054 | 17.661 |
| Density $ha^{-1}$ | 3250 | 3200 | 3200 | 3300 | 3400 |
| DBH range (cm) | 3.55–7.25 | 3.20–7.15 | 2.26–6.70 | 4.30–6.95 | 3.50–7.95 |

[1]MDH (Mean Dominant Height) is the mean height of the five tallest trees per plot.

TABLE 3

Number of trees according to the diameter classes (DBH) in the *Rhizophora mucronata* plantation

| Diameter class (cm) | Site | | | | | Total | % Total |
|---|---|---|---|---|---|---|---|
| | I | II | III | IV | V | | |
| 2.00–4.00 | 163 | 175 | 600 | 638 | 50 | 1626 | 39.75 |
| 4.01–6.00 | 638 | 615 | 193 | 178 | 463 | 2087 | 51.01 |
| 6.01–8.00 | 13 | 10 | 7 | 10 | 338 | 378 | 9.24 |
| Total | 814 | 800 | 800 | 826 | 851 | 4091 | - |
| % Total | 19.90 | 19.56 | 19.56 | 20.19 | 20.79 | - | - |

TABLE 4

Structural characteristics of the *Rhizophora mucronata* stand according to diameter (DBH) and height classes in January 1985

| Diameter class (cm) | Height class (m) | | | | | |
|---|---|---|---|---|---|---|
| | 4.00–5.00 | 5.01–6.00 | 6.01–7.00 | 7.01–8.00 | Total | % Total |
| 2.00–4.00 | 271 | 533 | 578 | 244 | 1626 | 39.75 |
| 4.01–6.00 | 314 | 685 | 743 | 345 | 2087 | 51.01 |
| 6.01–8.00 | 53 | 115 | 125 | 85 | 378 | 9.24 |
| Total | 638 | 1333 | 1446 | 674 | 4091 | - |
| % Total | 15.59 | 32.58 | 35.35 | 16.48 | - | - |

ranged from 2.26 to 7.95 cm, and the mean DBH was 5.91 cm. Thus the mean annual increment of the stand was 0.89 cm. The basal area (BA) and height of stands in Site V up to January 1985 was higher than the BA and height in Sites I, II, III and IV. This apparent difference in growth rate could be owing to soil fertility (Table 1). Moreover, no thinning was conducted in the study area. Using Bunt's method (Bunt et al., 1979) the forest canopy was estimated to be about 80.95–90.50% (Table 2). The canopy closure in Site V (90.50%) is relatively high in comparison with other sites. The stand characteristic of *R. mucronata* is typified by height and diameter classes of 6–7 m and 4–6 cm, respectively, with the individual number amounting to 743 trees or 18.16% of the total population (Table 4). Proportions of individual trees in terms of their diameter and height vary considerably from site to site. The *R. mucronata* stand of the Tritih area shows ecological preferences and tends to grow in areas subject to daily tidal flooding. Together with the fact that the area can be considered to belong to the Watson's inundation Class III (see Watson, 1928), the reason for DBH and height variability is probably caused by deep flooding coupled with soil fertility in a particular site. It is clear, however, that this young growth *R. mucronata* plantation is extremely dynamic. Hence, site characteristics affect the growing rate of *R. mucronata*.

Mounds were absent in the study area. Therefore, *R. mucronata* seedlings are plentiful on the forest floor and appear to be the major source of recruitment in canopy gaps. There are 12 undergrowth species recorded in the study area, and only *Acrostichum aureum* appears to grow rapidly in the canopy gaps. Consequently, competition by undergrowth species, smothering of regeneration by abundant growth of *A. aureum* and possibly crab damage to *R. mucronata* seedlings are likely to pose problems.

### *Stand biomass*

Table 5 summarizes the characteristics of sample trees for biomass estimates of *R. mucronata*. The least-squares line of best fit is described by Log

TABLE 5

Characteristics of sample trees ($n = 10$ trees)

| Attribute | Minimum | Maximum | Mean |
|---|---|---|---|
| DBH (cm) | 3.9 | 7.8 | 6.06 |
| Height (m) | 6.3 | 7.2 | 6.80 |
| Basal area ($cm^2$) | 11.95 | 47.78 | 30.12 |
| *Biomass (dry weight kg)* | | | |
| Leaves | 0.47 | 2.11 | 1.427 (4.98%) |
| Branch | 0.91 | 6.44 | 4.249 (14.84%) |
| Stem | 5.51 | 27.46 | 18.468 (64.49%) |
| Prop root | 0.65 | 6.91 | 4.494 (15.69%) |
| Whole tree | 7.54 | 42.92 | 28.638 |

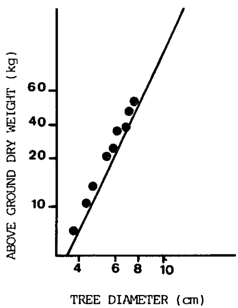


Fig. 2. Log of total above-ground dry weight (biomass) as a function of the log of the tree diameter (DBH) of *Rhizophora mucronata* in the Tritih mangrove plantation Cilacap Indonesia. The regression equation is: $\mathrm{Log_{10}Biomass} = 2.9499\ \mathrm{Log_{10}DBH} - 0.9036$ ($r = 0.943$).

Biomass $= A + B$ Log DBH, where $A$ and $B$ are constants. These equations were used with the DBH data in the five study plots to generate biomass estimates for the stands. Regressions of biomass of the components on DBH (using log–log transformed data) yielded equations that were highly significant (with regression coefficients, $r > 0.925$) (Fig. 2, Table 6). Table 6 summarizes the regression constants ($A$, $B$) and the correlation coefficient ($r$) of each component. Values of $r$ for leaves ($r = 0.933$) were lower than for the other components. Owing to seasonal variation, leaf data were more variable (Gill and Tomlinson, 1971; Christensen and Wium-Andersen, 1977; Duke et al., 1984; Sukardjo et al., 1987) and also more susceptible to losses from wind gusts. It also may be owing to the fact that the present *R. mucronata* plantation had a single sparsely layered canopy and the tall stand had the open and discontin-

TABLE 6

Allometric regression of above-ground biomass on DBH for *R. mucronata* stand. *A* and *B* are constants in the equation $\text{Log}_{10}\,\text{Biomass} = A + B\,\text{Log}_{10}\,\text{DBH}$. $n = 10$ is the number of trees sampled within the indicated DBH range (3.90–7.80 cm)

| Variable | *A* | *B* | *r* |
|---|---|---|---|
| Leaf | −1.9187 | 2.5968 | 0.9334 |
| Branch | −1.9962 | 3.2731 | 0.9460 |
| Stem | −0.9333 | 2.7527 | 0.9390 |
| Prop root | −2.4696 | 3.8795 | 0.9410 |
| Total | −0.9036 | 2.9499 | 0.9430 |

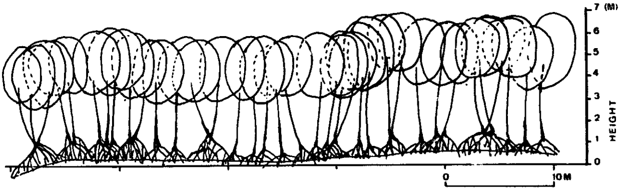


Fig. 3. A profile diagram of the *Rhizophora mucronata* plantation based on a 20 m × 50 m plot.

TABLE 7

Distribution of above-ground biomass for *R. mucronata* stand according to their diameter class. Values are percentages ± SD

| Diameter class (cm) | Leaf | Branch | Prop root | Stem |
|---|---|---|---|---|
| 2.00–4.00 | 6.20 ± 1.55 | 12.09 ± 1.75 | 8.62 ± 4.35 | 73.09 ± 5.15 |
| 4.01–5.00 | 5.10 ± 1.45 | 15.50 ± 3.10 | 16.30 ± 2.75 | 63.10 ± 4.90 |
| 6.01–8.00 | 4.90 ± 1.75 | 14.10 ± 4.70 | 15.95 ± 3.10 | 65.05 ± 4.15 |

uous layer (canopy was 80.95–90.50%) (Fig. 3). However, leaf biomass represents less than 10% of the above-ground biomass for *R. mucronata* stand with DBH less than 10 cm (Tables 5 and 7), so that variation in leaf biomass did not significantly affect the regressions for total above-ground biomass. The allometric relationship obtained in this study for total above-ground biomass of the *R. mucronata* agrees well with those obtained by Ong et al. (1985), Putz and Chan (1986) and Clough and Scott (1989) for *Rhizophora apiculata* in mangrove forests at Matang in Malaysia and at northern Queensland in Australia (Table 8). The total biomass of the 7-year-old stand for *R. mucronata* was 93.726 t $\text{ha}^{-1}$ of dry weight and was made up of 60.442 t of stem,

TABLE 8

Comparative estimates of total above-ground biomass for trees of *Rhizophora* spp. derived from different sources

| Species | DBH (cm) | Total dry weight (kg) | Location | Source |
|---|---|---|---|---|
| *R. mucronata* | 5 | 10.2 | Tritih, Indonesia | This study |
| | 7.8 | 42.9 | Tritih, Indonesia | This study |
| *R. apiculata* | 5 | 8 | Queensland, Australia | Clough and Scott (1989) |
| | 10 | 51 | Queensland, Australia | Clough and Scott (1989) |
| *R. apiculata* | 5 | 11 | Matang, Malaysia | Ong et al. (1985) |
| | 10 | 58 | Matang, Malaysia | Ong et al. (1985) |
| *R. apiculata* | 5 | 10 | Matang, Malaysia | Putz and Chan (1986) |
| | 10 | 56 | Matang, Malaysia | Putz and Chan (1986) |

TABLE 9

Estimated above-ground dry weight for mangrove forests around the world

| Location | Age (years) | Above-ground dry weight ($t\ ha^{-1}$) | Source |
|---|---|---|---|
| Indonesia | 7 | 93.726 | This study |
| Peninsular Malaysia | 5 | 16 | Ong et al. (1981) |
| | 15 | 257 | Ong et al. (1981) |
| | 28 | 287 | Ong et al. (1981) |
| | 80 | 270–460 | Putz and Chan (1986) |
| | 80 | 237–474 | Putz and Chan (1987) |
| Thailand | 6 | 50 | Aksornkoe (1975) |
| | 9 | 93 | Aksornkoe (1975) |
| | 11 | 116 | Aksornkoe (1975) |
| | 12 | 149 | Aksornkoe (1975) |
| | 13 | 167 | Aksornkoe (1975) |
| | 14 | 188 | Aksornkoe (1975) |
| | 15 | 159 | Christensen (1978) |
| Philippines | Virgin | 590 | Brown and Fisher (1918) |
| Japan | Virgin | 94.8 | Suzuki and Tagawa (1983) |
| Florida | unknown | 98–173 | Lugo and Snedaker (1974) |
| Panama | Old | 279 | Golley et al. (1975) |

13.906 t of branch, 14.708 t of prop root and 4.670 t of leaf material. The value of above-ground dry weight observed in Tritih–Cilacap Indonesia (93.726 $t\ ha^{-1}$ of dry weight) is the highest of the reported range for young mangrove forests (6–9 years of age) in Peninsular Malaysia and Thailand reported by Ong et al. (1981) and Aksornkoe (1975), respectively (Table 9).

*Annual litter fall*

The annual litter production in the *R. mucronata* plantation was 7.058–10.395 t ha$^{-1}$ year$^{-1}$ of dry weight (Table 10). This value is relatively high in comparison with values from several natural mangrove forests dominated by *Rhizophora mangle* in Florida, which generally range from 5.00 t ha$^{-1}$ year$^{-1}$ (Golley et al., 1962) to 9.00 t ha$^{-1}$ year$^{-1}$ of dry weight (Heald and Odum, 1970; Twilley, 1982). The values from Tritih–Cilacap can be compared with those values from the Malaysian region (Table 11). Sasekumar and Loi (1983) observed a small litter-fall rate in a mixed stand of *R. apiculata* and *R. mucronata* in Selangor Malaysia of 15.8 t ha$^{-1}$ year$^{-1}$ of dry weight. The lowest values of litter-fall production in a mixed stand of *R. apiculata* and *R. mucronata* forest are found in Muara Angke-Jakarta Indonesia of 4.9 t ha$^{-1}$ year$^{-1}$ of dry weight (Sukardjo, 1989). Litter production at Tritih–Cilacap agrees with reported values for three *R. apiculata* dominated forests in Australia, which generally range from 6 to 11.4 t ha$^{-1}$ year$^{-1}$ of dry weight (Duke et al., 1981). Thus, even though the *R. mucronata* at Tritih–Cilacap was a young plantation (Tables 2, 3 and 4), the rate of litter production is high. It is apparent that in Tritih–Cilacap, after even only 1 year of study, there is considerable spatial variability in litter production within a *R. mucronata* plantation (Table 10). Furthermore, long-term studies of litter

TABLE 10

Litter production (t ha$^{-1}$ year$^{-1}$ of dry weight) and accumulation (t ha$^{-1}$ year$^{-1}$ of dry weight) in the *Rhizophora mucronata* stand

| Item | Site | Total | Leaf | Twig | Flower, fruit, bud | Other debris |
|---|---|---|---|---|---|---|
| Litter production | I | 8.193 | 6.907 | 1.105 | 0.181 | - |
| | II | 7.369 | 6.133 | 0.969 | 0.267 | - |
| | III | 7.058 | 5.730 | 1.009 | 0.319 | - |
| | IV | 8.236 | 6.036 | 0.989 | 1.212 | - |
| | V | 10.395 | 8.194 | 1.494 | 0.707 | - |
| Accumulation | I | 51.376 | 16.922 | 14.679 | 13.078 | 6.697 |
| | II | 50.908 | 16.973 | 14.905 | 11.704 | 7.326 |
| | III | 48.568 | 16.758 | 13.482 | 13.802 | 4.526 |
| | IV | 51.896 | 20.511 | 11.388 | 15.080 | 4.917 |
| | V | 47.424 | 20.393 | 11.232 | 12.073 | 3.726 |
| Turnover ($k$) | I | 0.1595 | 0.4082 | 0.075 | 0.014 | - |
| | II | 0.1448 | 0.3613 | 0.065 | 0.023 | - |
| | III | 0.1453 | 0.3419 | 0.075 | 0.023 | - |
| | IV | 0.1587 | 0.2943 | 0.087 | 0.080 | - |
| | V | 0.2192 | 0.4018 | 0.133 | 0.059 | - |

TABLE 11

Regional comparison of litter production in the *Rhizophora* spp. dominated forests

| Forest type | Yield (dry t $ha^{-1}$ $year^{-1}$) | Location | Source |
|---|---|---|---|
| *R. mucronata* plantation | 7.058–10.395 | Tritih–Cilacap | This study |
| *R. apiculata* forest | 4.944 | Muara Angke | Sukardjo (1989) |
| *R. apiculata* forest | 12.905 | Tiris Indramayu | Sukardjo (1988) |
| *R. apiculata* forest | 21.098 | East Kalimantan | Sukardjo (1990b) |
| *R. apiculata* forest | 20.498 | East Kalimantan | Sukardjo (1990b) |
| *Rhizophora stylosa* forest | 14.30 | PNG | Leach and Burgin (1985) |
| *Rhizophora* (Merbok) | 10.07 | Malaysia | Ong et al. (1981) |
| *Rhizophora* (Matang) | 23.40 | Malaysia | Ong et al. (1982) |
| *Rhizophora* forest | 15.73 | Malaysia | Sasekumar and Loi (1983) |
| *R. apiculata* forest | 6.7 (leaf only) | Thailand | Christensen (1978) |
| *R. apiculata* forest | 6–11.4 | Australia | Duke et al. (1981) |

fall beneath mangroves have generally indicated little variation in total production from one year to another (Bunt, 1982; Ong et al., 1985; Twilley et al., 1986). Tritih study areas belong to the Watson's inundation Class III, hence, the relatively high values in Tritih plantation are consistent with the conclusions of Pool et al. (1975), who suggested a relationship between productivity and freshwater turnover (freshwater input divided by receiving water body volume) for the different forest types of Lugo and Snedaker (1974). One year observations indicate that the litter fall in the Tritih plantation is seasonal, with greatest fall in the rainy season (Fig. 4). The proportional composition of litter fall is very interesting, being not only associated with high rainfall, but also with other climatic variables in the region.

The totals of the various components of the litter are shown in Table 10 for the five sites. Clearly there was significant difference between sites in overall output of any of the litter fractions ($r=0.955$, $P<0.01$). During the 1 year monitoring, leaf litter formed 73.29–84.30% of the total weight, woody litter 12.01–14.37% and reproductive materials 2.21–14.70%. Of the reproductive materials, 25.91–48.58% by weight consisted of fruits, the rest being made up of flowers and buds fragments. Leaf litter accounts for over 70% of the total litter production. This reflects the higher turnover of leaves in the canopy as well as the relatively lower fall of twigs and other support components, indicative perhaps of the building phase of growth of the *R. mucronata* stand as a young forest plantation (7 years old).

The accumulation of litter of 47.424–51.376 t $ha^{-1}$ $year^{-1}$ of dry weight is relatively high compared with that in natural old mangrove forests dominated by *R. apiculata* in the Apar nature reserve (Table 10), East Kalimantan (Sukardjo, 1990b). Our observations suggest that the build-up of the litter layer on the floor may still continue. One likely reason for the high accumu-

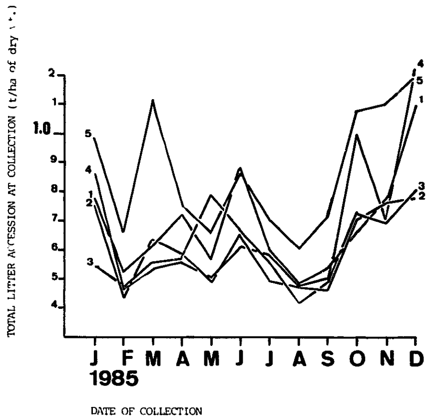


Fig. 4. The monthly litter accession measured on the five sites (1–5) over the study period 1985–1986.

lation may be the slower decomposition rate of *R. mucronata* leaves. The presence of sesarmid crabs herbivory and gastropods in the forest floor probably would have contributed, either directly or indirectly, to a more rapid breakdown of *R. mucronata* leaf litter. Interestingly Heald and Odum (1970) found that the animals in an estuarine system in southern Florida were dependent on an input of energy in the form of vascular plant detritus from mangrove leaves. Thus this *R. mucronata* plantation may contribute in a similar way to the animal populations of its associated estuarine system in the Segara Anakan areas.

## *Total above-ground net primary production (NPP)*

Even though we collected the litter-fall data prior to the stem-growth study, we have combined the two sets of data (litter-fall and woody biomass) to obtain estimates of net primary productivity of 20.804–25.000 t $ha^{-1}$ $year^{-1}$ at Tritih–Cilacap (Table 12). This places the *R. mucronata* among the productive trees in the mangroves in terms of organic matter production. Generally, reported values of total above-ground NPP in mangrove forests range from a low of 3.8 t $ha^{-1}$ $year^{-1}$ (Teas, 1979) to 54.75 t $ha^{-1}$ $year^{-1}$ (Carter et al., 1973) in Florida. Our values for the Tritih plantation are comparable with production values in the mangrove forests at Laguna De Terminos Mexico reported by Day et al. (1987) (16.07–24.58 t $ha^{-1}$ $year^{-1}$). Moreover,

TABLE 12

Estimated above-ground net primary production (NPP) of the *Rhizophora mucronata* stand at Tritih ($t\ ha^{-1}\ year^{-1}$)

| Site | Component | | Annual above-ground NPP |
|---|---|---|---|
| | Total woody growth | Total litter fall | |
| I | 13.961 | 8.193 | 22.154 |
| II | 13.746 | 7.369 | 21.115 |
| III | 13.746 | 7.058 | 20.804 |
| IV | 14.176 | 8.236 | 22.412 |
| V | 14.604 | 10.395 | 25.000 |

the assumption that total above-ground NPP for mangroves is three times total litter fall (Teas, 1979) is not supported by our results, in which NPP was 2.4–2.9 times (means of 2.7, Table 12) total litter fall. These results suggest that the NPP/litter-fall ratio for mangroves should not be applied to other forest types.

The ratio of biomass of leaf in the canopy to that in the litter fall is a measure of the life span of the leaf on the tree. The ratio 0.570–0.815 (year) obtained in this study indicates that the *R. mucronata* leaves are on the trees for an average of about 7 months. This is a rather short life span for a leaf in the tropics. Ogawa (1978) estimated the mean life span for a leaf in a primary rainforest to be about 13 months. So, the short life span of *R. mucronata* leaves may be related to the high growth rate and provide some adaptive advantage. However, in such young stands, the productivity generally increases with age, as has been found by Ong et al. (1981) and Aksornkoe (1975) (Table 9). These trends offer interesting directions of research in order to achieve higher organic matter production in *Rhizophora* crops for both timber and fuel.

## CONCLUSION

Our studies indicate that *R. mucronata* in Tritih–Cilacap is a suitable mangrove tree to plant in Java, being fast growing and productive as well as being able to out-compete weeds, and to grow in degraded areas of mangrove forest. Where end-use requirements are not so critical, such as for firewood, *R. mucronata* should certainly merit prime consideration. The abundance of stand (743 trees) (Table 7) in high class 6–7 m and diameter class 4–6 cm indicates that a management system of small annual coupes, retention of seed bearers and natural regeneration may be successful if the Segara Anakan mangroves were to be exploited on a sustained yield basis. Furthermore, with respect to both diameter and height classes of *R. mucronata* stand (Table 4), attempts should be made to reclassify the mangrove areas in Segara Anakan (see Fig. 1) in accordance with Watson's (1928) and/or De Haan's (1931) inundation classes. However, it is possible that young plantations such as Tritih play an important role in the dynamics of the Segara Anakan lagoon, and/or the near-shore coastal ecosystems on the coast of Java. The productivity and export is high, this type of system is common, and the tropical ocean is very oligotrophic (Whittaker, 1975).These factors suggest that the Segara Anakan lagoon may be seasonally important in the organic budget of the close near-shore zone.

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