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Morphometric studies on the leaves of *Bruguiera gymnorrhiza* and *Rhizophora stylosa in* relation to the numerical litter decomposition process

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Abstract : Morphometric and volumetric measurements of eleven items in the leaves of *Bruguiera gymnorrhiza* and *Rhizophora stylosa* were done by materials collected from the Nagura lagoon, Ishigaki Island, southwest Japan. Using the results, the number of decomposed silt-size particles for a leaf was calculated as 3,716,581 in *Bruguiera gymnorrhiza* and 3,185,641 in *Rhizophora stylosa* respectively. The object to obtain these values was to estimate the quantitative output of organic particles decomposed from leaves of mangrove to estuarine waters as a food resources of the benthic animal community, particularly of filter-feeders. The particle number of a leaf obtained is, therefore, a basement of the further step of the study.

Key words : morphometry, mangrove leaves, decomposed organic particles, Ishigaki Island

Introduction

In a previous paper, the author estimated the litter productivity of mangroves in a mixed forest of *Bruguiera gymnorrhiza* and *Rhizophora stylosa* by counting the leaves of living trees (Kuwabara and Shiroma, 1996). The objective was to obtain the quantitative output of organic particles decomposed from leaves of mangrove trees to estuarine waters as a food source of the benthic community, particularly of filter-feeders. This process has been suggested by Odum and Heald (1975) as a part of the process of primary production replacing phytoplankton in an estuarine ecosystem. If the number of decomposed leaf particles is known, the supply to a productive zone of benthic organisms can be estimated from the number of trees in a measured area of mangrove forest at any given time by assuming their transport by estuarine water flow and the turbidity. For the purpose of completing the process, the author needs to know how many particles can be produced from a mangrove tree leaf. As the number of leaves per tree can be estimated from the tree height (Kuwabara and Shiroma, 1996), the next step involved a study of the material flow.

The volume of a dried mangrove leaf can be used as a base to calculate the amount of particles decomposed from it. However, the volume of dried leaves is very difficult to investigate due to irregular shrinkage during oven-drying. Hence, the volume was measured indirectly from the difference between green leaf volume and the water content available from the drying. The study does not actually trace the transfer of produced organic particles in the energy flow. It presents the estimated level at an optimum supply through calculations. As a supplementary work to the previous report (Kuwabara and Shiroma, 1996), the study involved morphological analyses on leaves of two mangrove species, *Bruguiera gymnorrhiza* and *Rhizophora stylosa*.

Materials and Methods

The materials were randomly collected from several trees of *Bruguiera gymnorrhiza* and *Rhizophora stylosa* in a mixed mangrove forest in Nagura estuary (24° 24′ N, 124° 8′ 30″ E), Ishigaki Island, southwest Japan on August 27, 1996. Eighty leaves of each species were examined for morphometric and volumetric characteristics. Morphometric characteristics included leaf length, leaf breadth, petiole length, the ratio of leaf breadth to leaf length, and the ratio of leaf length to the petiole length (Fig.1, I). Volumetric measurements included green leaf weight (wet w.), dry weight, wet volume, dry volume, surface area, and water content for calculation of dry volume.

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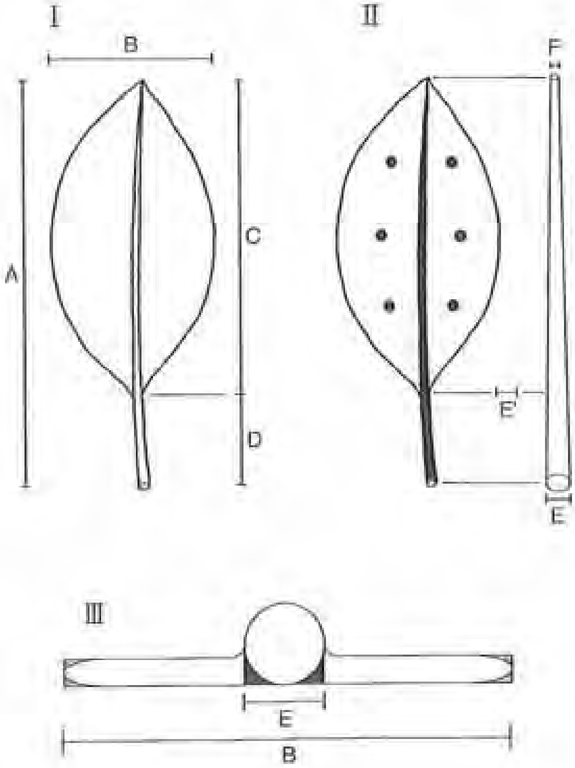

Fig. 1 Recording length measurements of a mangrove leaf.
I : plane figure, II : positions for the thickness and the midrib diameter measurements, III: longitudinal section,
A: midrib length with petiole, B: leaf breadth, C: leaf length, D: length of petiole,
E: diameter of petiole at the base,
F: diameter of midrib at the tip.

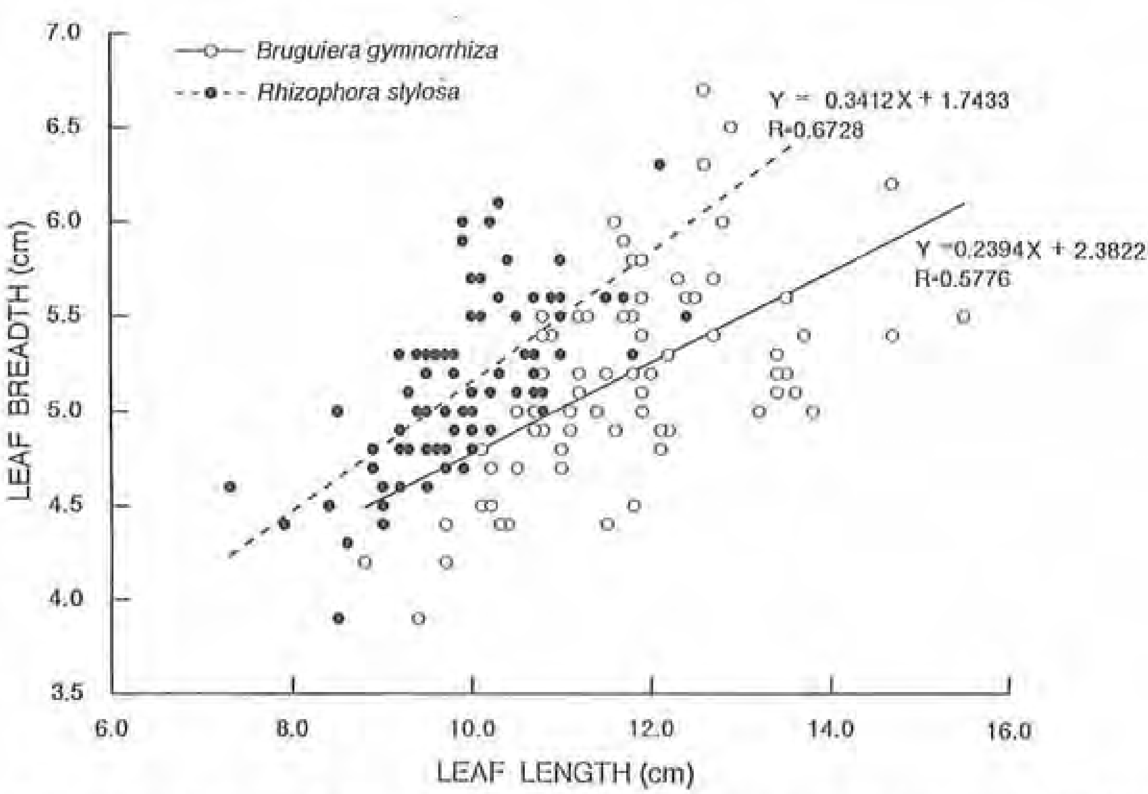

Fig. 2 Relationship between leaf length and leaf breadth in *Bruguiera gymnorrhiza and Rhizophora stylosa*

The dry weight of a green leaf was determined by drying it at 105°C for 4 hours in an oven. The wet volume of a green leaf was calculated from the measurements of its surface area, thickness, and midrib volume. The surface area was estimated by a paper weight method which calculates the ratio between the weight of paper cut off along the outline of the leaf and the weight of the same type of paper of which the surface area was known. The weight of the paper traced for each leaf was shown as the average of the measured values of six papers. The leaf thickness was measured at six points evenly distributed on the leaf (Fig.1, Ⅱ). The total average from 20 leaves of each species was 0.44㎜ in *B. gymnorrhiza* and 0.53㎜ in *R. stylosa* and along the estimated surface area were used to calculate the volume of a cube. The volume of the midrib with petiole was calculated separately as a frustum with the length of the midrib as the height (Fig.1, Ⅰ－A), the bottom area obtained from the diameter of the petiole at the base (Fig.1, Ⅱ－E), and the top area from the diameter of the midrib at the top (Fig.1, Ⅱ－F). The diameter at the top of the petiole (Fig.1, Ⅱ－E') was just on the side-line of the midrib's cast shadow and was deleted from the calculation. A hidden area was previously excluded from the surface area of the leaf during the calculation of the frustum volume (Fig.1, Ⅲ, black zones). The calculation was offset by inclusion of over-calculated zones at the fringe of the leaf (Fig.1, Ⅲ, oblique lines) against the surface area of the leaf cubically calculated. The calculations of each partial volume were finally combined with the volume of a wet leaf.

As the dry volume of the leaf could not be determined due to irregular shrinking during drying, it was obtained from the difference between the wet volume and the volume of water content as (wet weight-dry weight) × 1.002 being density of pure water at room temperature, for each leaf. The water content of the green leaf was obtained from the weight difference between wet and dried leaves.

Results and Discussion

1. Morphological description and morphometry

The results of morphometric and volumetric measurements of eleven items in the leaves of *Bruguiera gymnorrhiza* and *Rhizophora stylosa* were summarized in Table 1.As the samples were randomly collected from well-grown trees, the difference of values between two species would be characteristic of a leaf specific to species of the both.

Table 1 Morphometric measurements of leaves in two mangrove species

Items	*B. gymnorrhiza*	*R. stylosa*
Leaf length (cm)	11.68 ± 1.26	9.92 ± 0.91
Leaf breadth (cm)	5.17 ± 0.52	5.12 ± 0.45
Length of petiole (cm)	3.46 ± 0.63	2.04 ± 0.38
Leaf length : Leaf breadth	1 : 0.45 ± 0.04	1 : 0.52 ± 0.04
Length of petiole : Leaf length	1 : 3.45 ± 0.54	1 : 5.05 ± 1.32
Wet weight (g)	2.29 ± 0.64	2.76 ± 0.47
Dry weight (g)	0.67 ± 0.21	0.91 ± 0.18
Wet volume (cm³)	2.30 ± 0.45	2.46 ± 0.41
Dry volume (cm³)	0.70 ± 0.19	0.60 ± 0.18
Surface area (one side, with petiole, cm²)	43.22 ± 7.86	39.12 ± 6.04
Water content (%)**	70.68 ± 2.98	67.06 ± 4.56

*N = 60 for each species; **Weight percentage

The shape of a mangrove leaf can be oblong or narrowly oblong as in *B. gymnorrhiza* and elliptic as in *R. stylosa* (Nakamura and Fukuoka, 1990). Hence, there is no clear difference in shape for distinguishing between the species. But, the difference is easily recognizable in macroscopic observation, since the leaf of *R. stylosa* is broader than that of *B. gymnorrhiza*. As seen in Table 1, the leaf of *B. gymnorrhiza* is longer than *R. stylosa*, though the breadth is almost the same for both. This can be seen from the calculated ratio of the leaf length to the leaf breadth, showing 1 : 0.45 in *B. gymnorrhiza* and 1 : 0.52 in *R. stylosa*. Correlation analysis in present materials also indicated such differences (Fig.2). Bigger leaves tend to be broader as shown by differences in the slope of the regression lines. The petiole is relatively longer in *R. stylosa* than in *B. gymnorrhiza* as shown in it's ratio to leaf length being 1 : 0.52 in the former and 1 : 0.45 in the latter. Another difference between the species is the existence of brown dots on the ventral side of the leaf of *R. stylosa* while that of *B. gymnorrhiza* is plain.

As seen in the comparison of volumetric items of the leaves between the two species (Table 1), wet and dry weights and wet volume showed higher values in *R. stylosa* than in *B. gymnorrhiza*. On the other hand, dry volume, surface area and water content were higher in *B. gymnorrhiza* than *R. stylosa*.

2. Amount of particles decomposed from a leaf

In estimating the amount of decomposed particles from a leaf, the value of the dry volume (Table 1) was used as a cube, namely $0.70 = 0.8872^3$ ㎤ in *B. gymnorrhiza*, and $0.60 = 0.8446^3$ ㎤ in *R. stylosa*, showing the number of a cubic root. The number of particles present in a cube can be estimated as :

$$N = (\sqrt[3]{V} \times 10 / r)^3 = V \times 10^3 / r^3 \quad \text{———} (1)$$

where N : amount of particles
V : volume of cube (㎤)
r : diameter of particle (㎜)

and a side of a cube is $\sqrt[3]{V} \times 10$ (㎜). When the size of the particles is assumed to be uniform, the vacant space index of a cube is derived from the packing index $\sqrt{2}\,\pi / 6$ (Kittel, 1976), such that $1 - \sqrt{2}\,\pi / 6 = 0.26$. Then, an additional number of particles rearranged from the volume of the vacant space is

$$N' = 0.26V \times 10^3 / r^3 \quad \text{———} (2)$$

Because there are considerably less particles in vacant space than in packed space, twice the additions using rearranged cubes from the vacant space would be sufficient. Therefore, the final calculation is

$$N = (V + 0.26V + 0.26 \times 0.26V) \times 10^3 / r^3 \quad \text{———} (3)$$

The diameter of particle (r) must be specified from an actual condition. Photo 1 shows microscopic particles of suspended matter filtered from water of the Nagura river surrounded by a large mangrove forest (Photo 1, A) and detritus washed out from the bottom sand in a part of the mangrove covered (Photo 1, B). This indicates that decomposed particles attain a smaller size below 0.1㎜ diameter. Based on the classification of standard size grades of sedimentary particles (Briggs, 1977), it is assumed that particles having a diameter of 0.063㎜ are at the upper limit of coarse silt. This is generally considered a normal sized particle providing a moderate sinking speed does not easily allow particles to be supplied to estuarine bottoms for benthic production. Nor does it allow particles to further decompose to the finer grains needed for food for the benthos.

Using $r = 0.063$ and $V = 0.70$ in *B. gymnorrhiza* and 0.60 in *R. stylosa* to equation (3),

$N = 3{,}716{,}581$ and 3,185, 641 respectively, an average of $N = 3,\ 451{,}111$ is obtained. A mixed forest of the both species contains approximately $3,\ 451 \times 10^3$ silt-size particles per leaf.

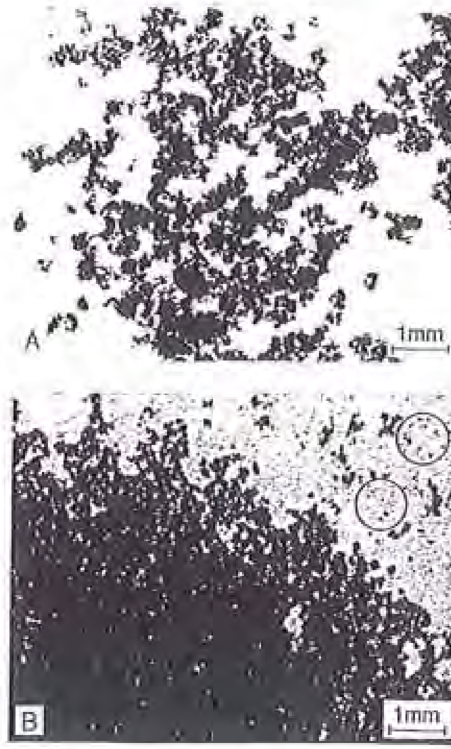

Photo. 1 Suspending matter in the river water (A) and detritus washed out from the bottom sand (B) of the Nagura lagoon, Ishigaki Island (Circle indicates particles of silt-clay size)

3. Amount of particles contained in turbid water

It is undeniable that the turbid river water flowing among mangrove forests supplies the decomposed particles of mangrove leaves, to the downstream and the estuarine area. It would be particular in the 'riverline forest' classified by Lugo and Snedaker (1974), which is suffered washing by tides and land surface drainage. On the assumption that the turbid substance is only the decomposed particles of mangrove leaves, an estimate of how much particles are contained in a known turbidity is necessary to understand the process of mangrove litter supply to estuarine ecosystems.

In general, turbidity is shown by NTU, equal to '㎎/l' which means some amount of dried substance per liter of water. Accordingly, using values of the dry weight in Table 1, one liter of water showing 10 NTU is equivalent to 1.5% and 100 NTU to 14.9% of a dried leaf of *B. gymnorrhiza*. Likewise, one liter of 10 NTU is equivalent to 1.1% and 100 NTU to 11.0% of a dried leaf of *R. stylosa*. If a flux of river water and the turbidity are known under the assumption that the turbid substance is derived from decomposed particles of mangrove litter, the supply of the particles to a domain of benthic community can be estimated as an energy flux for the ecosystem. These trial is only a step of the process of the decomposed litter supply to the estuarine ecosystem, for the future study.

Conclusion

The litter production of trees is generally expressed in an amount per hectare. Its flux into the ecosystem is often estimated on a macro-scale area. Nevertheless, the receiver is usually not uniform but variable within the area including semi-divisions geomorphologically and hydrologically. Therefore, for understanding the consideration of optional mangrove forest, the smallest available unit as the base of litter supply would be a leaf. As the author has already estimated the litter productivity of mangroves in a mixed forest of *Bruguiera gymnorrhiza* and *Rhizophora stylosa* at a riverine area of the Nagura lagoon (Kuwabara and Shiroma, 1996), how many leaves are possessed in a tree of mangroves is approximately known.

This study inestigated a part of the process of numerical litter decomposition focusing the estimation of the leaf amount. Although, even on a macro-scale analysis, each calculation flow contributed insights into subsystems for benthos as the consumer of litter-derived particles in the estuarine water still could not be confirmed. As the next step to complete the litter flow process, it is necessary to subdivide the lagoon area according to the distribution pattern of benthic communities.

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桑原　連*：オヒルギおよびヤエヤマヒルギ葉体形質の計測と落葉分解粒子量の推定

沖縄県石垣島名蔵ラグーン域で採集したオヒルギ及びヤエヤマヒルギの成長した葉体の各形質すなわち葉長・葉幅・葉柄長・それらの比率、並びに生重量・乾重量・生時の体積・乾燥体積・表面積・水分含有率を測定した。

一方、マングローブ落葉分解粒子が河川水で移送され濾過摂餌型ベントスなどの二次生産者に供給されるエネルギー収支を考えるとき、一枚の葉から生じる粒子数を基本とする必要がある。葉体各形質の測定値を用いて計算した粒子数は、オヒルギでは3,716,581粒、ヤエヤマヒルギでは3,185,641粒であった。

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