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Research Article

The Production of Organic Matter From *Rhizophora mucronata* and *Sonneratia alba* at The Kajhu and Meunasah Mesjid Villages, Aceh Besar

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ABSTRACT

Production and decomposition of mangrove littercould contribute organic matter and nutrients to the coastal waters. This study was to estimate the extent to which the rehabilitated mangrove of *Rhizophora mucronata* and *Sonneratia alba* contribute organic matter. Litter traps were used to collectthe litter production and litter bags to measure decomposition rates. The results showed that the average of litter production for *S. alba* and *R. mucronata* was 4,38 g.m^{-2}.day^{-1}and 3,61 g.m^{-2}.day^{-1}, respectively. However, *S.alba* apparently showed higher decay rates compare with *R. mucronata*. Nutrients element (N and P) released were 321,2 kg.ha^{-1}.years^{-1}and 47,45 kg.ha^{-1}.years^{-1}for *S. alba*; and 131,4 kg.ha^{-1}.years^{-1} and 13,14 kg.ha^{-1}.years^{-1}for *R. mucronata*. Overall, this study indicated thatthe mangrove rehabilitation in the area study were contributed to organic matter production and nutrients to the coastal waters.

Keywords: *decomposition, litterfall, nutrients*

1. Introduction

Mangrove ecosystem is a unique habitat with a variety of functions, both ecologically and socio-economically. This coastal ecosystem has a very important role in supporting the fishery resources, such as the breeding, nursery and feeding grounds, and the protection of the diversity of aquatic biota (Bengen, 2004; Kumar et al., 2011). Several studies have shown a high number of fish species from 70 to more than 100 species found in this ecosystem (Kawaroe, 2001; Sukardjo, 2004). In addition, one hectare of mangrove is able to contributein fish production up to 672 kg/year (Mahmudi, 2010).

High production of litters (leaves, stems, fruit, twigs, etc.) from mangrove vegetation play an important role leading to be a basic components of the food web as a source of organic matter (Bengen, 2004). The litter seem to be the largest contributor of essential nutrients for their own growth as well as supporting both marine and estuarine biota life.

Substantially, litters produced by mangrove contains nutrients of C, N and P. Mahmudi (2010) reported that mangrove ecosystem in the area of reforestation in Pasuruan contributed to 129.58 to 184.69 kg.ha^{-1}.years^{-1} of nitrogen and 6.57-9.13 kg.ha^{-1}.years^{-1} of phosphorus. In addition, those organic materialscan bedirectly consumed by microorganisms and bacterially decomposed to enrich their energy systems (Aida *et al*. 2014). The accumulation of organic matter deriving from those litters is controlled by both production and decomposition processes (Triadiati et al., 2011), and so plant species, plant age, climate and environmental characteristics (Zamroni and Rohyani, 2008; Aida et al., 2014). The organic matter which is separated from the process of decomposition accumulate in sediments.

Tsunami, on December 24, 2004 in Aceh had caused the damage to the 174,590 ha of mangrove ecosystem in the province of Aceh (BRR, 2005). Since 2005, many rehabilitation activities have been made to restore the functions of those mangrove ecosystems by both government and non-government organizations.

Rehabilitation may restore the function of mangrove ecosystems that have been damaged. This research is to reveal whether *Rhizophora mucronata* and *Sonneratia alba* is able to support the fertility and productivity of the coastal waters. This contribution can be estimated from the rate of production and decomposition, the nutrients release of leaf litter and analyzing of organic matter on the sediment.

2. Materials and methods

Study area

The study was conducted from November 2015 to January 2016 in the rehabilitated mangrove area of Kajhu Village, Baitussalam Subdistrict and Meunasah Mesjid Village, Leupung Subdistrict, Aceh Besar District, Aceh Province (Figure 1). Mangrove species planted in Kajhu Village *are dominated by R. mucronata,* with approximately 25 Ha (Muhammad, 2009). In Meunasah Mesjid Village, mangrove species are dominated by *S. alba*, with approximately 15 ha. There are three site each location (village) and every site has three plot sampling. Laboratory analysis was conducted at the Laboratory of Services and Study, Assessment Institute for Agricultural Technology (BPTP) Aceh.

Litter production

Litter production (leaves, twigs and reproductive parts include inflorescence and fruits) was estimated by collection in 1x1 m^2 litter-traps nets (Brown, 1984). Litter-traps were placed at every site to seaward from landward underneath the canopy of mangroves, but about 1-1,5 m above the soil to prevent inundation. The samples were carried out every seven days for three weeks. The materials were sorted into their parts and oven-dried at 105°C to constant weight (Ashton etal.,1999), then analyzed for concentration of organic carbon, nitrogen and phosphorus.

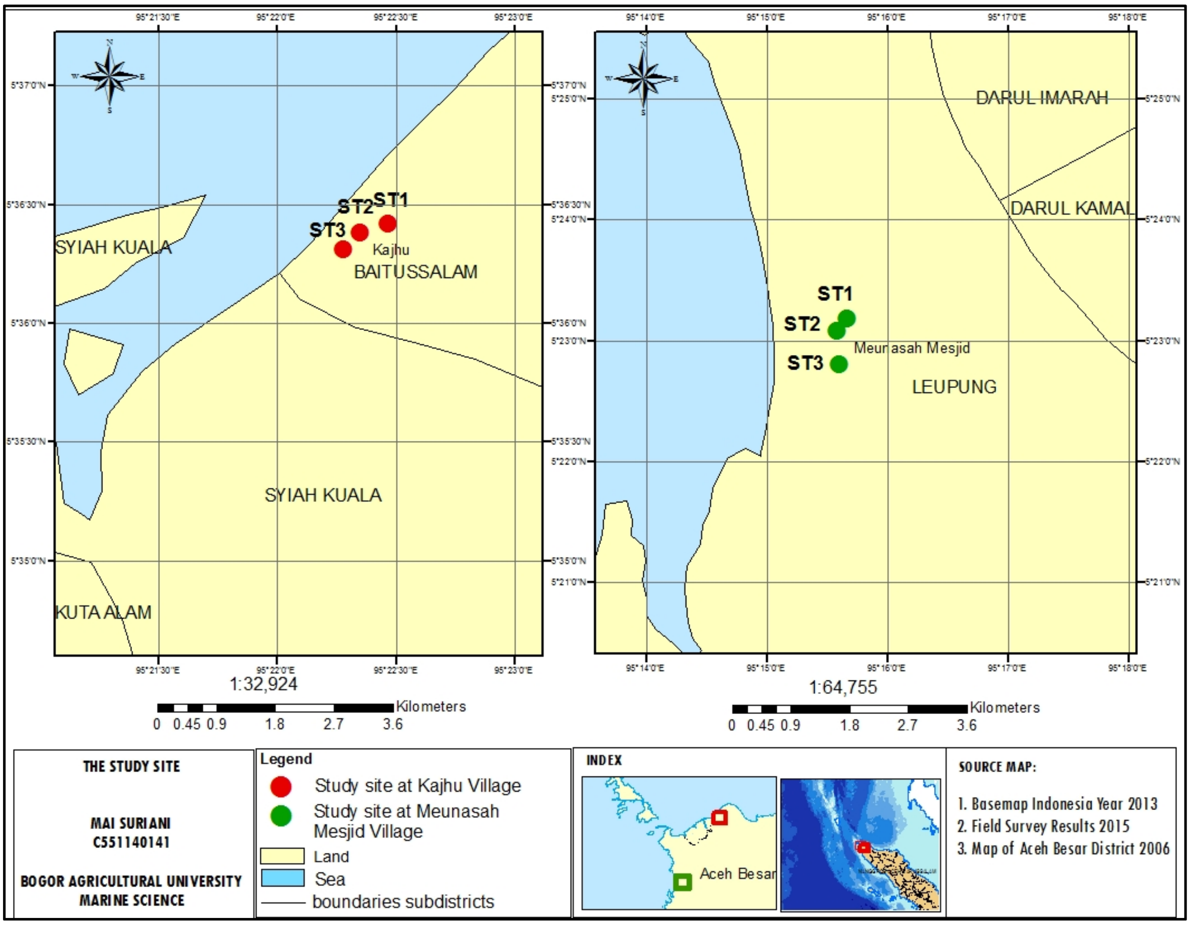


Figure 1. Study site in Kajhu and Meunasah Mesjid vilaages, Aceh Besar District

Litter decomposition

Leaf decomposition rates were estimated by placing about 10 g dry weight of leaf samples into 30 cm x 30 cm litter-bags with a mesh size of 1 mm^2 (Pribadi, 1998; Ashton et al.,1999). Litter bags were securely tied to the roots of the mangrove to prevent inundation, and were retrieved from each site at intervals: 10, 20 and 30 days. Residual leaf fragments were carefully washed to remove mud and then oven-dried at 105°C until constant weight (Ashton etal.,1999) to allow for the analyses of organic carbon, nitrogen and phosphorus concentration.

Estimation of litter decomposition rate was calculated using the formula proposed by Ashton et al. (1999):

$$X_t = X_0\, e^{-kt} \;\ldots\ldots\ldots\; (1)$$

where, X_t is the litter dry weight at time t (days), X_0 the initial litter dry weight and k is a decay constant.

The nutrient contents analyzed were nitrogen (N) and phosphorus (P). The release of nutrients was calculated based on the following formula (Nga et al., 2004):

$$N_t = (W_0 \times N_0) - (W_1 \times N_1) \;\ldots\ldots\; (2)$$

Where N_t is nutrient release at t time; W_0 is the initial litter dry weight; W_1 is the dry weight of the remaining litter after time t; N_0 is the nutrient concentration in the remaining litter.

Sediment concentration in the initial litter; N_1 is the nutrient *sampling*

Sediment samples were collected using the pipe inserted into the soil at a depth of 30 cm. Those samples were analyzed at the Laboratory of Services and Study, Assessment Institute for Agricultural Technology (BPTP) Aceh to determine the content of C- organic, N and P as well as the fraction of the sediment.

The influence of mangrove species on the distribution of sediment organic matter were analyzed using Factorial Discriminant Analysis (FDA) using software of SPSS version 22 and Microsoft Excel 2007.

3. Results and Discussion

Litterfalll production

Mangrove litter production for 3 weeks showed that leaf, twig and flower/fruit were deposited on each litter-trap. Most litter found was leaf litter, from either the *R. Mucronata* or *S. Alba* stands. The percentages of leaf litter in both species were relatively similar, 76% and 73%, respectively (Figure 2). Ulqodry (2008) reported that the leaf was the largest litter component in the range of 66.10 to 82.23%, followed by twig and flower/fruit.

The difference production of leaf, twig and flower/fruitwas probably related to the biological characteristics of each organs of different litter, including their physical properties and the number of each component produced (Ulqodry, 2008). Biologically, the regeneration of leaves was faster and more continuous than that of the other organs. The leaves also tended to be more easily broken by the wind and the rain (Zamroni and Rohyani, 2008).

The production of twig and flower/fruit litters in both mangrove species varied. On *R. mucronata* stand, percentage of flower/fruit litter was higher than that of twig. On the other hand, on the stands of *S. alba*, percentage of twig and flower/fruit litters was in significantly different. This may be due to the interference of the primates during observation.

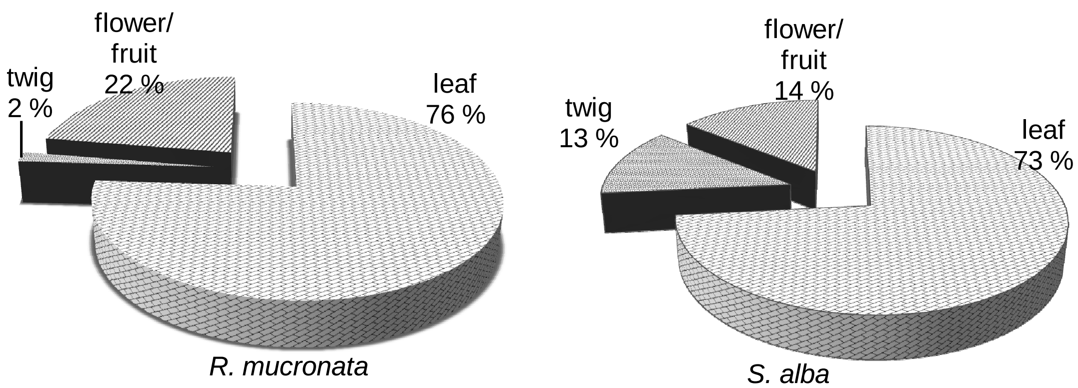


Figure 2. Proportion of litter component in study site

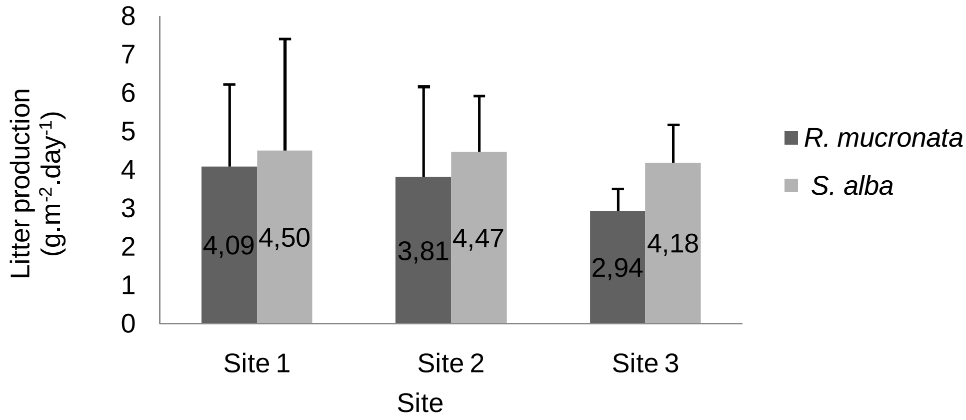


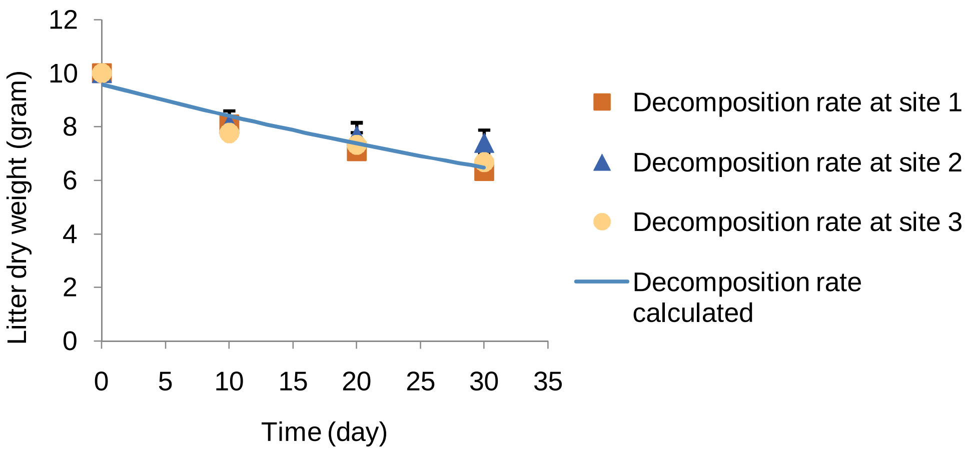
Figure 3. Average mangrove litter production of each site

Figure 3 shows the difference in litter production between the *R. Mucronata* and *S. alba* stands, and the differences of that morphology seemed to determine. *S. alba* showed larger fruits compared with *R. mucronata*. More over, the diameter or size of mangrove trees also affected the litter production (Kusmana et al., 2000). S. alba in this study site has a large individual size and canopy thicker than that of *R. mucronata*, the environmental conditions in this area are suitable for S. alba growing well.

Mangrove rehabilitation inthese study areas produced 3.99 $g.m^{-2}.day^{-1}$of litter. The results were still higher compared to those conducted by Mahmudi (2010) in the *Rhizophora* reforestation area of Pasuruan (2.18 $g.m^{-2}.day^{-1}$). However, it was insignificantly different from those in Tangerang, Banten on *A. marina*, *A. alba, R. mucronata* and *S. caseolaris* of 3.45 $g.m^{-2}.day^{-1}$(Aida et al., 2014). These differences could be possibly related to the geographical condition, vegetation condition and forest component structure (Sa'ban et al., 2013).

Mangrove leaf litter decomposition

The average weight loss of leaf litter of *S. alba* and *R. mucronata* were found to be the highest in the first 10^{th} day of decomposition, and subsequently decreased (Figure 4). This results showed that the length of the period of observation might affect the value of decay in gas it was indicated by declining the value of the decomposition rate until the end of the sampling period. Farooqi et al. (2014) also found that the leaf of *A. marina* and *R. mucronata* was a very rapid weight loss at initial observation and followed by the subsequent decrease of decay ratesuntil to the rest of the study period.



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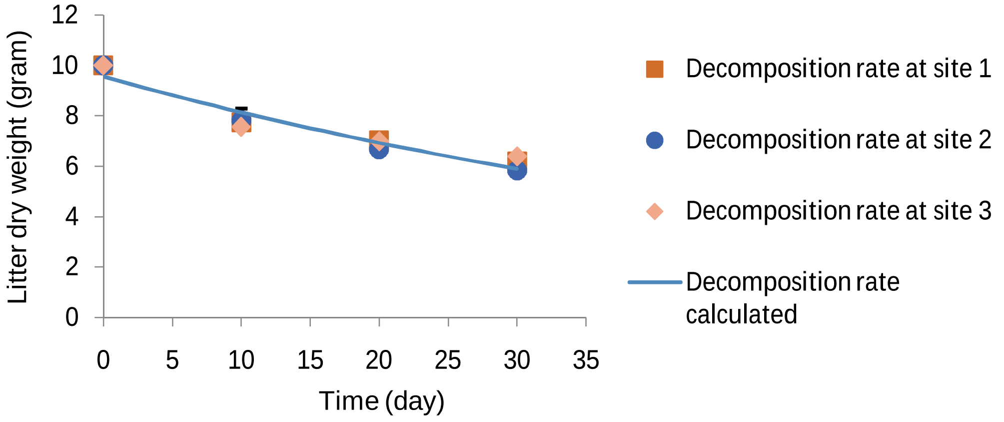


(b)

Figure 4. The decline in mangrove leaf litter weight at the study site, (a) *R. mucronata*; (b) *S. alba*

The leaf litter decomposition rate on *S. alba* was higher than that of *R. mucronata*. Bosire et al. (2005) reported that the results of the study conducted in the area of mangrove reforestation in Kenya showed faster decomposition of *S. alba* leaf litter than those of *R. mucronata*. The average value of decomposition rate constant (K) was also similar, where the value of the K constant on the stand of *S. alba* (0.016) was higher than thatof *R. mucronata* (0.013). It means that it is similar with the previous information showing higher decomposition rate of *S. alba* than that of *R. mucronata*. Pribadi (1998) sorted mangrove litter decomposition rate, i.e. *Sonneratia alba*>*Avicennia eucalyptifolia*> *Rhizophora apiculata*>*Bruguiera gymnorrhiza* >*Bruguiera parviflora*.

The higher rate of leaf litter decomposition of *S. alba* than *R. mucronata* was closely related to the level of sclerophylly and the composition of the leaves constituent of the mangrove (Hardiwinoto et al., 1994). Litter witha high N content preferentially decomposed because it is more easily digestible (Choong et al., 1992). C:N ratio could also contribute to decomposition rate, in which the low C:N ratio would generally produce the faster decomposition processes (Bosire et al., 2005). The C:N ratio of leaf litter of *S. alba* (24.9) was much lower than that of leaf litter *of R. mucronata* (63.76). In addition, the duration of inundation also greatly affected the decomposition rate of mangrove leaves for leaching, but litter decay was more effective for leaves wet (Mfilinge et al., 2002; Bosire et al., 2005). In this mangrove rehabilitation area, *R. mucronata* was planted in more suitable areas to sunlight exposure so that it could inhibitthe leaching and decay processes.

The constant value of K in this study was lower than those on the stand of *S. alba* (0.0204) reported Kusnita et al. (2014). In contrast, this constant value of K in this study was in significantly different compared with that of the result of the stand of *R. mucronata* ranging from 0.002 to 0.028 conducted by Fernando and Bandeira (2009). Temperature and geographical condition differences may be responsible for the differences in decomposition rate (Tam et al., 1998). In addition, Bosire et al. (2005) stated that in addition to litter quality and mangrove species, inundation of tides and seasons, management way also played an important role in determining the efficiency of ecological processes in the mangrove ecosystem.

Nutrient content of leaf litter during decomposition process

The content of C-organic tended to decrease with the time of decomposition, where as that N and P tended to increase (Figure 5). Similar results were also reported by Green way (1994) and Ulqodry (2008).

Multiple Regression Analysis of the content of C-organic showed that the value of R^2 was 0.390 (<0.5). It means that the decomposition and mangrove species was negatively correlated to the C-organic content, where C-organic content decreases until the end of sampling time. Multiple Regression of the content of N and P showed R^2 values of 0.546 and 0.629 (> 0.5), respective. It means, the roles of both decomposition time and mangrove species were quite significant on N and P contents. The decomposition time and mangrove species seemed positively to correlate to the contents of N and P, where the longer observation time of decomposition the higher production contents of N and P.

The increased nutrient content of nitrogen during decomposition was caused by several factors, i.e. the nature of insoluble nitrogen, and translocation of N (Melillo et al., 1982). The immobilization of nitrogen as a result of accumulation of biomass and product of microbial activity also affected the increased of nutrient contents (Bosire et al., 2005; Mfilinge et al., 2005). Steinke et al. (1983) suggested that the increased content of N was probably due to the involvement of nitrogen bacteria in leaf litter during N fixation. According to James and Olivares (1997), Some bacteria are able to conduct free N2 fixation and fixation results are transferred to the host plant. The increased nutrient content of P in leaf litter in the mangrove estuaries thought to be due to an increase in river sediments and the improvement of sediment phosphorus compounds carried away by the tidal currents of the river water retained in leaf litter (Chauvet, 1987).

P content in the leaf litter of both *R. mucronata* and *S. alba* was quite low compared with the other elements. This is because the element of P is very easily moving (mobile) from the branch tissue to other plant parts, when the shortage of P in a plant tissue occurs, P on the old tissue will be allocated to the other active tissue, and thereby the content of P in the older tissue (such as litter) will be relatively lower compared to those active (Rodriguez et al., 2011).

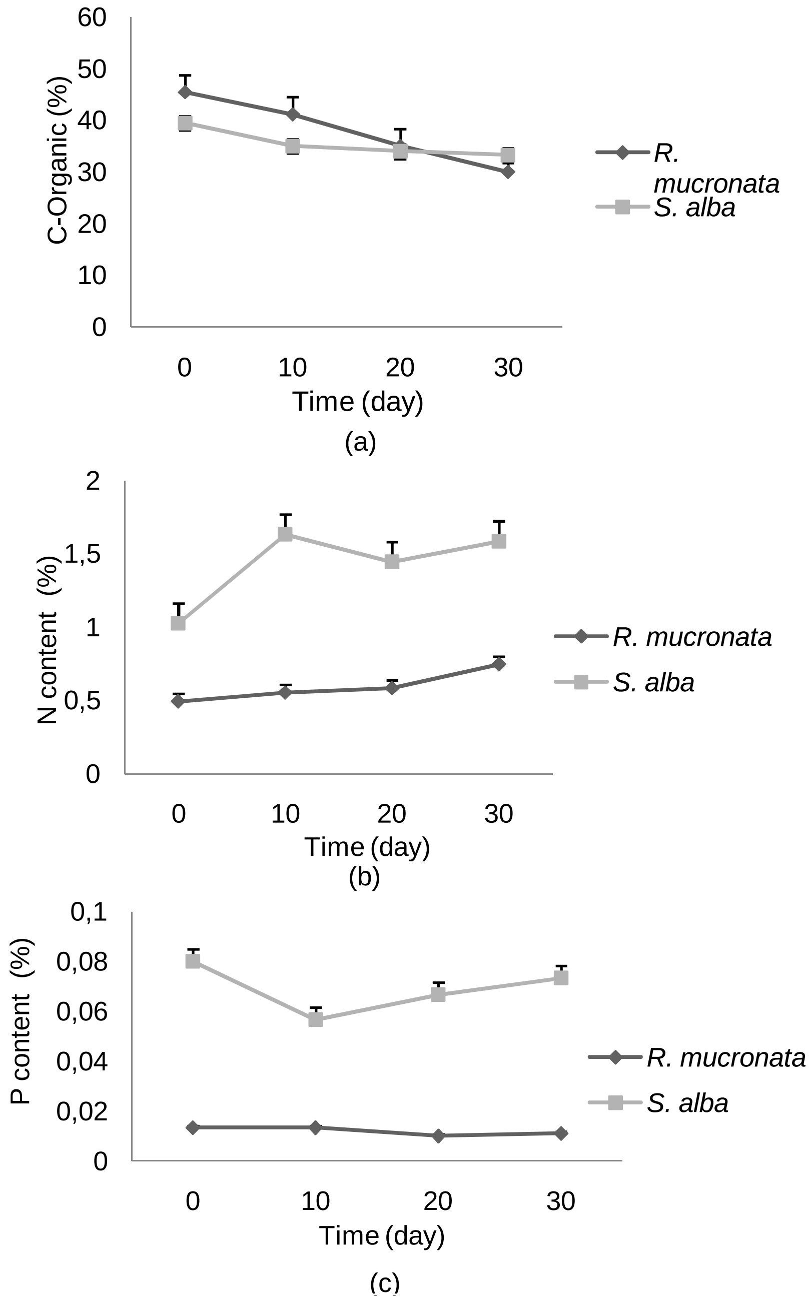


Figure 5. The content of: (a) C-organic, (b) N and (c) P in leaf litter of *R. mucronata* and *S. alba* during decomposition

Nutrients release

The average of nutrients (N and P) released from leaves of *R. mucronata* and *S. alba* were 0.01 g N.g DW of litter^{-1}.day^{-1} and 0.001 g P.g DW of litter^{-1}.day^{-1} and 0.02 g N.g DW of litter^{-1}.day^{-1} and 0.003 g P.g DW of litter^{-1}.day^{-1}, respectively (Figure 6).

Assuming the litter production of 3.61 g.m^{-2}.day^{-1} and 4.38 g.m^{-2}.day^{-1} for those respective vegetation, the total N released in those area was equal to 0.036 g.m^{-2}.day^{-1} or 131.4 kg.ha^{-1}.years^{-1}for *R. mucronata* and at 0.088 g.m^{-2}.day^{-1} or 321.2 kg.ha^{-1}.years^{-1} for *S. alba* (Table 1). The total P released by *R. mucronata* was 0.0036 g.m^{-2}.day^{-1} or 13.14 kg.ha^{-1}.years^{-1} and *S. alba* was 0.013 g.m^{-2}.day^{-1} or 47.45 kg.ha^{-1}.years^{-1}. According to Polglase et al. (1992), N and P were primarily released through direct leaching and through microbial activity.

The difference of nutrients released for *R. mucronata* and *S. alba* stands was possibly related to the fact that leaf of *S. alba* containing more decomposable organic matter than that of *R. mucronata* containing a lot of tannins (Kumar et al., 2011).

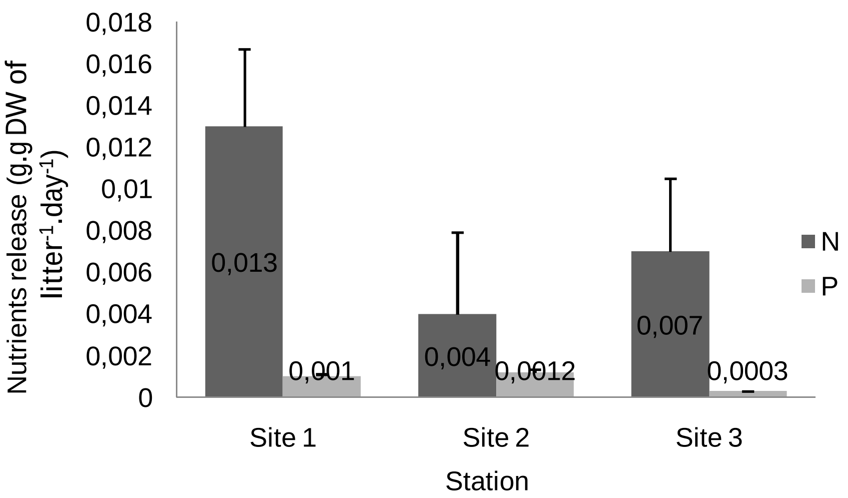
The analysis of nutrients release in this study was higher than that studied by Mahmudi (2010) in the mangrove reforestation area of Pasuruan where *Rhizophora* leaf litter contributed to nitrogen ranging 129.58 to 184.69 kg.ha^{-1}.years^{-1}, while phosphorus varying 6.57-9.13 kg.ha^{-1}.years^{-1}.

Above all, mangrove rehabilitation in this study does not only restore the physical ecosystem of mangrove, but it also improve its ecology function i.e. a contributor of nutrients. This finding was in line with Bosire et al. (2005) showing that rehabilitation did not only ensure seed availability for restocking the affected area, but also provided the sustainability of inherent ecological functions. Both, ecological and economic functions of that mangrove can indeed support its sustainable use.

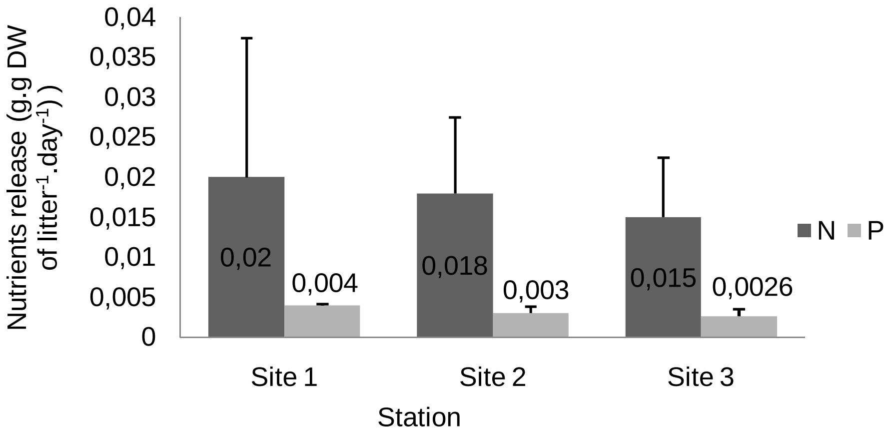
Table 1. The nutrients release

Mangrove Species	A		B	C	
	N	P		N	P
R. mucronata	0.01	0.001	3.61	0.0361	0.00361
S. alba	0.02	0.003	4.38	0.0876	0.01314

A: nutrients release (g/g DW of litter/day)
B :litter production (g/m^2/day)
C : nutrients release with assuming the litter production (g/m^2/day) --->> (C = A*B)



(a)



(b)

Figure 6. The average of nutrients (N and P) released from leaves in the study site, (a) *R. mucronata*; (b) *S. alba*

Difference of distribution of organic materials by mangrove species

The highest content of C-organic and N was found in *S. alba* stand which is high litter production, while the P content was in significantly different in both mangrove stands (Table 2). Kushartono (2009) also reported that the highest organic matter content was found in locations with high litter production. Part of litter produced by mangroves was deposited on the surface of the soil (Kusmana et al., 2000), and some of them would be remineralized (Brown 1984). The other part were probably accumulated in sediments (Odum, 1993).

C:N ratio in the sediments of both mangrove stands ranged from 14.8 to 56. This high range could indicate the terrestrial input. Bouillon et al. (2003) suggested that the organic material derived from terrestrial mangrove is characterized with a high C:N ratio (> 12). The sediment with a low C:N ratio (<8) could indicate autochthonous sources.

Table 2. Results of the analysis of texture and content of N, C-Organic and P in mangrove sediments in the study site

Species	**Site**	**Texture**			**N (%)**	**C-organic (%)**	**C:N**	**P (%)**	**Density (ind.100 m^{-1})**
		Sand	**Silt**	**Clay**					
R. mucronata	1	89.99	4.00	6.01	0.03	0.72	24	0.001	18
	2	75.90	16.07	8.03	0.02	0.42	21	0.0011	17
	3	94.00	4.00	2.00	0.01	0.56	56	0.0007	15
S. alba	1	87.50	6.25	6.25	0.1	2.34	23.4	0.00067	11
	2	77.43	10.26	12.31	0.1	1.48	14.8	0.00055	10
	3	87.64	6.18	6.18	0.07	1.68	24	0.0006	9

Table 3. Results of discriminant analysis of sediment organic matter distribution differences

Tests of Equality of Group Means

	Wilks' Lambda	F	df1	df2	Sig.
Sand	.965	.143	1	4	.724
Silt	.997	.012	1	4	.919
Clay	.776	1.157	1	4	.343
N	.098	36.750	1	4	.004
C	.158	21.386	1	4	.010
P	.224	13.894	1	4	.020
Density	.091	40.000	1	4	.003

Wilks' Lambda

Test of Function(s)	Wilks' Lambda	Chi-square	df	Sig.
1	.009	14.060	2	.001

Similarly, discriminant analysis showed a significant difference in the organic matter content of both species of mangrove sediments ($P<0.05$). The variables used to differentiate the two groups were the N content, followed by the density, contents of C-organic and P (Table 3). These, four variables were able to explain 91.2 % of difference/ variance while only 8.8 % were explained by other independent variables. The differentiate of N and C-organic contents due to the difference of the litter production and decomposition processes.

4. Conclusions

The average production of mangrove litter was 3.99 g.m^{-2}.day^{-1}, andmostlyin the form of leaves. The high production of litter (4.38 g.m^{-2}.day^{-1})was produced by *S. alba*. *S. alba* leaf decomposed faster than thatof *R. mucronata*.

Mangrove species of *S. alba* provided more nutrients than *R. mucronata*. *S. alba* was able to contribute to 321.2 kg.ha^{-1}.years^{-1} and 47.45 kg.ha^{-1}.years^{-1}, whereas *R. mucronata* was able to contribute to 131.4 kg.ha^{-1}.years^{-1}and 13.14 kg.ha^{-1}.years^{-1}. The content of Cand N organic found in sediments was high in *S. alba* stand ranging from 0.07 to 0.1% and from 1.48 to 2.34%, while the P content was high in *R. mucronata* stand ranging from 0.0007 to 0.0011%. This study indicate that the mangrove rehabilitation in the area study were contributed to organic matter production and nutrients to the coastal waters.

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