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Litter decomposition of *Rhizophora stylosa* in Sabang-Weh Island, Aceh, Indonesia; evidence from mass loss and nutrients

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ABSTRACT

Dewiyanti I (2010) Litter decomposition of Rhizophora stylosa *in Sabang-Weh Island, Aceh, Indonesia; evidence from mass loss and nutrients. Biodiversitas 11: 139-144.* Mangrove is an essential coastal ecosystem that provides nutrients to estuarine and its surrounding environments through its litter decomposition. This vegetation can be considered as an important ecosystem in food web along the coast. The research was conducted in mangrove forest in Sabang-Weh Island, Aceh. *Rhizophora stylosa* was dominant species of mangrove in the study area that still remains after tsunami catastrophe in 2004. This study was conducted from February to April 2008, and the purposes were to obtain the decomposition rate of senescent leaves and to measure mass loss, and nutrient contents of decomposing leaves under different inundation regime. Three plots were established in each site. Decomposition of *R. stylosa* leaves were studied by using litter bag technique. They were made of synthetic nylon which had size 20x30 cm and mesh size was 1x1.25 mm^2. Senescent leaves were used because they present major leaves on the forest floor and started to decay. Remaining leaves decreased during experiment period because decomposition process had been taking place in the study area. Time required for decomposing a half of the initial material (t_{50}) was 67 days and 63 days for site next to the land and site next to the sea, respectively. The decay rate can be expressed by the decay coefficient (K) and the results of K were 0.010 and 0.011 (d^{-1}). The value of carbon (C), nitrogen (N), C: N ratio and phosphorous (P) during decomposition periods were no significant difference in sites but significant difference in time. The C: N ratio of decomposing leaves decreased in both sites. Low C: N ratio in the last of observation indicated that *R. stylosa* leaves were decomposed easier at the end of observation than that in the beginning of observation.

Key words: *Rhizophora stylosa*, leaves litter, mass loss, nutrients, Aceh.

INTRODUCTION

Mangrove defined as primary natural features which have characteristic littoral plant formation and they grow in tropical and subtropical regions (Hutchings and Saenger, 1987; Aksornkoae, 1993). Mangrove forest is a unique and productive ecosystem along coastal zone that spread from Western part of Sabang to Eastern part of Merauke, Indonesia. It has significant role in ecological, environmental and socioeconomical sector (Lacerda 2002). As primary sources, this ecosystem providing organic matter that supports not only the mangrove ecosystem itself but also other related ecosystems (Aksornkoae 1993; Jonathan 1999). Mangrove leaves are the biggest part of the primary litter production and they become available to consumers and had a significant contribution towards the coastal food chain by following senescent and death leaves (Ananda et al. 2007; Berg and McClaugherty 2008). Breakdown of leaf is defined as weight loss due to some physical-chemical properties caused by environmental conditions such as temperature, moisture, and nutrient availability (Graça et al. 2005), animal feeding, microbial activity and leaching (Steward and Davies 1989). Berg and McClaugherty (2008) mentioned that chemical composition of decaying litter changes during decay process; it can be characterized by the rate of mass loss and the nutrient immobilization. If nutrients are leached from leaves into the water, so they are available to organisms that live in mangrove ecosystem (Kao et al. 2002). Decomposers play an important role in the cycling of material and the flow of energy through an ecosystem (Holmer and Olsen 2002; Kuers and Simmons 2006). Besides fungi and bacteria as decomposer, protozoan, diatoms, nematodes, and polychaetes presence in the surface of senescent and decomposing leaves (Fell et al. 1984) and also on the soil surface and in the soil (Kuers and Simmons 2006). Crabs are also responsible for decomposition broken down litter into small pieces in order to be more easily decomposed by fungi and bacteria. Tidal flush and tidal current also give assistance in breaking down the litter to small pieces (Aksornkoae 1993). The amount of litter production and decomposition rate is very important to the nutrient cycle, main production, structure, and function of the ecosystem. Nitrogen (N) and Phosphorus (P) are important nutrients determining the quality of plant litter and their decomposition rates (Flindt and Lillebo 2005). The nutrient cycling and energy flow in mangrove ecosystem are quite complex, when mangrove plants receive sunlight for photosynthesis then they produce organic substances (Saenger and Snedaker 1993). Comparison between the value of carbon content and nitrogen content is called C: N ratio, this ratio estimate degradability ofthe organic material. Lower C: N ratio in one material indicates that the material is easier to be decomposed (Patrianingsih 2000).

Rhizophora stylosa is dominant species of mangrove vegetation in Sabang- Weh Island, Aceh and it is growing naturally. Some of communities in this island entrust their life as fishermen and they commonly use mangrove area for fishpond land in order to increase their income besides tourism sector. Significantly, the most important indirect role is the fertilization of the estuary and coastal area. Nowadays, the area of mangrove forest in study area is starting to decrease with increasing the population and finally this condition will result in low mangrove production in this area. Deterioration of coastal ecosystem and mangrove vegetation will led to decrease of organic material productivity and decline of biological productivity in coastal area, owing to litter fall of mangrove is food, energy and material resources of and coastal ecosystem.. Therefore, the present study aims (1) to measure mass loss, the changing of carbon and nutrient content during decomposition period, (2) to obtain the decomposition rate of senescent leaves of mangrove (*R. stylosa*), and (3) to determine the correlation between decomposition rate and physical-chemical characteristics of water.

MATERIALS AND METHODS

Study area

The research had been conducted in Sabang-Weh Island, Aceh, Indonesia since February-April 2008. It is located in 05^{o}46'28"-05^{o}54'28" N and in 95^{o}13'02"-95^{o}22'36" E. The climate is dominated by rainy and dry season. The location was conducted in two sub-village of Iboih-Sabang affected by tsunami. Mangrove in research location is dominated by *Rhizophora stylosa.* Totally, 6 plots were selected of two sites which has different inundation regime. The 1st site consists of plot 1, 3 and 5 located next to the land (low inundation), and then the 2nd site consists of plot 2, 4 and 6 situated next to the sea (high inundation).

Sampling of environmental parameters and sediment

Environmental parameters were carried out in order to support analyses of decomposition process such as water temperature, salinity, and pH. Measuring of these parameters was done *in situ*. Sampling of sediment was taken by using shovel as depth as 10 cm from soil surface. Sample of sediment was transported to the laboratory in order to analyze textures, C, N and P of mangrove sediment. Analyses of sediment were done in Soil Laboratory, University of Syiah Kuala, Banda Aceh.

Leaf decomposition experiments

Leaf litter decomposition is commonly measured by using the litter bag technique (Ashton et al.1999). This technique is simple and effective to assess decomposition rate of leaf litter (Fell et al. 1984). Decomposition rate is usually investigated by enclosing an exact amount of mangrove leaves in litter's bags, and regularly measuring the loss of leaf weight (Kuers and Simmons 2006). The litter bags were made of synthetic material and had size 20 x 30 cm (Mackey et al. 1995) with mesh size 1 x 1.25 mm^2. Leaves as primary component were collected from senescent leaves. Collecting of senescent leaves was done manually by handpicked from the tree. Furthermore, collected leaves were oven dried at 60^{o}C for 24 hours in order to make no surface water remained in leaves (Strojan et al. 1987; Hegazy 1998). 20 g of leaves after oven dried was placed in each litter bag and every bag was tied up in the prop root. Collecting of litter bags was done at 1st, 3rd, and 5th days, then weekly for three weeks and biweekly for six weeks. 18 litter bags were needed in each observation. Totally for 9 observations in 10 weeks, dry leaves needed were 3240 gram and litter bag was 162 bags. 0 day was also measured for sample control before decomposition was started. After collecting sample, the bags were returned to laboratory where they were rinsed in a sieve to remove sediment, and then continue with oven dried to have a constant mass. The samples were oven dried at 60^{o}C for 2 days and weighed until constant and then final dry mass was recorded then continue with graining process to be a fine powder with mortar and pestle, finally leaves sample were taken ±5 gram to analyzed carbon, nitrogen, and phosphorous contents. Those analyses were done in Stable Isotope Laboratory, Goettingen University, Germany.

Statistical analysis

Litter (leaf) which was already decomposed and percentage of leaves decomposed were calculated by using formula:

$$D\ (\%) = \frac{B1 - B2}{B1}\ x\ 100\%$$

D is litter decomposed, B1 is dry weight before decomposition; B2 is dry weight after decomposition. The percentage of initial dry mass remaining in the litter bags were determined by using two sample t-Tests in STATISTICA 6.0 software. It was carried out to investigate the effect of site and time. The t-test method was based on the assumption that the variances in two groups are the same and this method was used to evaluate the differences mean between groups (Anonymous 2000).

The relationship between percentage dry mass remaining in litter bags and sampling time at all sites best fitted in a negative single exponential model (Ashton et al. 1999). The formula is $Xt = Xoe^{-Kt}$.Where *Xt* is percentage of the initial material, Xo is remaining after time t (days) and K is a decay coefficient (d^{-1}). The times required for decomposition of half the initial material (t_{50}) were determined by using the formula: $t_{50} = \ln 2 / K$

RESULTS AND DISCUSSION

Stand characteristics

The composition of *Rhizophora stylosa* in the site next to the land had 76 stems/0.04 ha and in the site next to the sea had 78 stems/0.04 ha. However, the differences between number of stems/ha found in both sites were not statistically significant (t-test, P=0.835). In average, diameter of *R. stylosa* was 11.15 cm and height was 7.56 m. For site next to the land, *R. stylosa* had 8.16 cm in diameter and 6.36 m in height. Furthermore, t-test showed that the differences between diameter and height found in both sites were not statistically significant (P diameter= 0.13, P height=0.14). *R. stylosa* had big value of basal area was found in the site next to the sea. It was covered about 121.51 cm^2 of the area given of land that is occupied by the cross-section of tree trunks and stems at their base. Site next to the land had basal area of this species about 74.74 cm^2. Besides *R. stylosa*, another species of mangrove found was *Avicennia marina*. *A. marina* found out in plot 1 was 4 stems/0.04 ha and it had big diameter. The basal area of this species achieved 1097.06 cm^2. Mangrove vegetation in the study area was categorized low biodiversity because the presence of species detected was less than five species. *R. stylosa* is growing well in the study area which was dominated by sandy loam soil containing nutrient.

Environmental parameter and sediment

Average of temperature, salinity and pH were 28.72 ^{0}C, 36 ‰, and 8, respectively. Temperature was influenced by light penetration and forest cover. Salinity was high in both sites because directly influenced by the sea, and high salinity value was affected by evaporation and tide. Range of pH was the same in all plots, and close to sea water pH. They were not significantly difference between site (P>0.05), and did not show big fluctuation. The observation was done in the same season (dry season), so the characteristics of all plot were assumed uniform. In average, chemical and physical of surrounding water at mangrove vegetation was similar in site next to the land and next to the sea. It was presumed because the distance between two sites was not quite far due to the limitation of width (vertical) of study area; the distance was approximately 40 m.

Texture of soil was analyzed according to percentage of sand, silt and clay fraction. Soil was dominated by sand fraction in both sites, due to the study area directly receives water from the sea and sand fraction was brought from the sea. Sand which is heavier than silt will settle on the soil surface. In the study area, sand was mainly deposited indicating that there was no strong current, tidal water and waves. For site next to the land, fraction of sand, silt, and clay were 59%, 19% and 21%, and site next to the sea were 62%, 25% and 13%, respectively (Table 1). These percentage was not statistically different between sites (P>0.05). Soil texture in study area was sandy loam and *R. stylosa* was growing well in the study area because it grows in appropriate sediment. The surface layers of 10 cm depth of mangrove forest were high in C content, ranging from 6.81% to 10.54%. The range of N was 0.23%-0.27% and C: N ratios ranged from 29.61 to 42.42. High organic matter in mangrove floor was presumed mostly come from fallen litter of mangrove leaves which was contributing significantly to the higher organic matter in sediment.

Table. 1. General characteristics of sediment in study area

Site	Plot	Fraction			Textures
		Sand (%)	Silt (%)	Clay (%)	
Next to the land	1	68	13	19	Sandy loam
	3	53	20	27	Sandy clay loam
	5	57	25	18	Sandy loam
	Average	59	19	21	
Next to the sea	2	61	26	13	Sandy loam
	4	62	19	19	Sandy loam
	6	62	30	8	Sandy loam
	Average	62	25	13	

Mass loss

Mass loss was observed in the 1st, 3rd, 5th, 12th, 19th, 26th, 40th, 54th and 68th day; in order to gain information about changing of mass loss not only in daily but also in weekly and biweekly. During the experiment period, the mass loss of mangrove leaves was changed significantly in both sites. The comparison between both sites at the end of observation showed that the percentage of decomposed litter was 56.68% ± 0.67 in site next to the land and it was 59.30% ± 1.81 in site next to the sea. In the first day of observation the percentage (%) of remaining litter was 92.38 ± 0.94 and 91.46 ± 1.62 in site next to the land and site next to the sea, respectively and then decreased until 43.32 ± 0.67 in site next to land and 40.71 ± 1.81 in site next to the sea at the end of observation (68th days) (Figure 1). The result explained that mass loss in site next to the sea was slightly higher than site next to the land where leaves remaining less in this site and both sites had similarity of the response to decomposition time; a longer time of decomposition results in a less remaining litter per period. This condition was caused because site next to the sea received bigger influence of physical tide process from sea water directly impacted fragmentation of leaves. Robertson (1988) and Ashton et al. (1999) explained that increasing decomposition rates because of water soaking caused leaching of labile material and high inundation caused more litter will be decomposed. Another reason the mass loss result from the abundant invertebrate such as juvenile of shrimps and crabs in the litter bag during experiment period, they entered as juveniles and then unable to escape after feeding. Decomposition rate is influenced by environmental factors such as temperature, nutrient content, sediment deposition rate, and densities of leaf-shredding invertebrates and soil moisture (Meyer and Johnson 1983). Mesh size of litter bag was enough to allow small invertebrates and microorganism as decomposer and feeder access to the leaves. Lambertini et al. (2000) mentioned that the abundance of bacteria, microorganisms and invertebrates enormously accelerates the decomposition process of the organic material produced by mangrove forest.

Leaves decomposition rate were high in the beginning and at the end of degradation process and they were fluctuated during experiment period. Fell et al. (1984) stated that decomposition initially rapid than slow. This mode was suspected due to quality and quantity of the litter, element content acting as food for the soil microbe. It was also suspected that some materials of litter were easily dissolve or leaching in the beginning. After two weeks, leaves had lost 27.72% in site next to the land and 32.11% of site next to the sea; Davis et al. (2003) found that total leaf mass may be lost because of leaching up to 33% during an initial phase of a few days to weeks. Mass loss obtained by Ananda et al. (2007) after one week showed a rapid initial mass loss indicated by dried leaves had lost 38.3% owing to leaching in a mangrove of Southwest India.

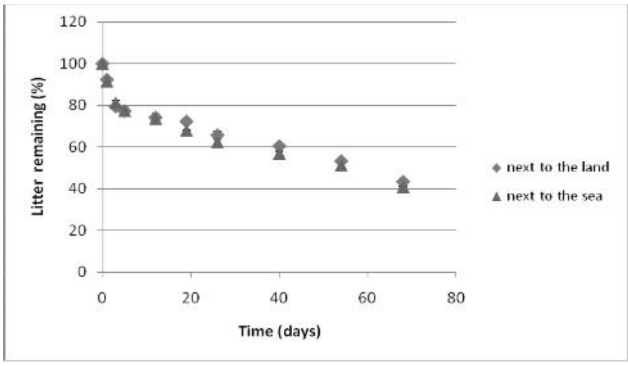

Figure 1. Percentage of litter remaining in site next to the land and in site next to the sea during experiment period

K (d^{-1}) is decay coefficient that can determine the rate of decomposition. Average of K in site next to the land was 0.010 d^{-1} ± 0.000577 and in site next to the sea was 0.011 d^{-1} ± 0.001. There was not significantly different between K next to the land and next to the sea (at $P > 0.05$) by using 95% confidence interval (α=0.05). T-test result informed that the mean of K was equal in both sites; implying that there was not significantly different decomposition rate of *R. stylosa* leaves in both sites. Ananda et al. (2007) stated that mass loss as function of time by using exponential decay model can be categorized into tree categorizes those are fast (K>0.01), medium (K= 0.005-0.01), and slow (K<0.005). Decay coefficient in both sites indicating that rate of decomposition in this study area was medium.

A t_{50} is time required for the decomposition of half the initial material, average of t_{50} were 67 days and 63 days for site next to the land and site next to the sea, respectively (Table. 2). The value showed that time to decompose a half the initial material in site next to the sea decompose slightly fewer than at the site next to the land. This value was correlated with mass loss where at the end of observation site next to the sea had less percentage of litter remaining (40.70%) than site next to the land (43.32%). Ashton et al. (1999) found that t_{50} in *Rhizophora apiculata* was 76 day (in cleared site) and 43 day (in Virgin Jungle Forest Reserve) of mangrove forest in Peninsular Malaysia. Some factors presumed influence high leaves decomposed in this site were inundation factor, environmental factors, and decomposer.

Carbon (C), nitrogen (N), C: N ratio and phosphorous (P) content

The changing of C, N, C: N ratio and P during decomposition is showed in the Figure2. *R. stylosa* leaves contained high C and N content compared to P as nutrient during the decomposition period. Between sites, *R. stylosa* had similar values of C contained in decomposing leaves during observation. C content in site next to the land ranged from 42.33% ± 1.00 to 46.91% ± 1.88 and in site next to the sea it ranged from 42.41% ± 1.07 to 46.41% ± 1.10. The lowest C content was found in the first day of observation. Figure below also shows that site next to the land had the highest C content at the last observation (the 68^{th} day) and at the 54^{th} day for site next to the sea. Based on this figure, C contained in decomposed leaves increased during observation but sometimes it was fluctuated during observation in both sites. Increasing C was presumed because the rising concentrations of structural carbohydrates as a result of the loss of sugars and starches in detritus and decreasing carbon content was indicated by dry weight loss caused rapid release of total nonstructural carbohydrates which is easily used by microbes. Mfilinge et al. (2002) found that C an initial decreased and then increased during decomposition a subtropical mangrove forest at Oura Bay, Okinawa, Japan. Fell and Master (1980) mentioned that in dry weight of senescent *Rhizophora mangle* leaves, carbon represents 45% and about half of this carbon is leached and then half becomes particulates detritus.

Nitrogen (N) increased slowly with increasing duration of decomposition periods in both sites. It was presumed because of microbial N immobilization as a result of accumulation of microbial biomass and products of microbial activity. Comparison of both sites showed that increasing N content was slightly higher in site next to the land than site next to the sea which ranged from 0.53% ± 0.01 to 1.03% ± 0.07. In site next to the sea, N ranged from 0.53% ± 0.01 to 0.99% ± 0.05. The lowest N was gained in the first observation and this value was the same in both sites of observation. Fell and Newell (1981) and also Holguin et al. (2001) found that total N in decomposing leaves increased from time because of N immobilization and decomposer activity (Rice 1982). Fell and Master (1980) found that N was initially 0.2-0.4% of the dry weight and then increasing to 0.5 % because of microbial N immobilization.

Table 2. Value of decay coefficient (K) from litter remaining (%) and t_{50}

Site	Plot	Equation	K (d^{-1})	R^2	t_{50} (days)
Next to the land	1	$y = 0.8742e^{-0.01x}$	0.01	$R^2 = 0.9321$	69
	3	$y = 0.8758e^{-0.011x}$	0.011	$R^2 = 0.919$	63
	5	$y = 0.8892e^{-0.01x}$	0.01	$R^2 = 0.9294$	69
	Average		0.010 ± 0.00056	0.927	67
Next to the sea	2	$y = 0.8861e^{-0.012x}$	0.012	$R^2 = 0.9439$	57
	4	$y = 0.867e^{-0.01x}$	0.01	$R^2 = 0.9168$	69
	6	$y = 0.8762e^{-0.011x}$	0.011	$R^2 = 0.938$	63
	Average		0.011 ± 0.001	0.933	63

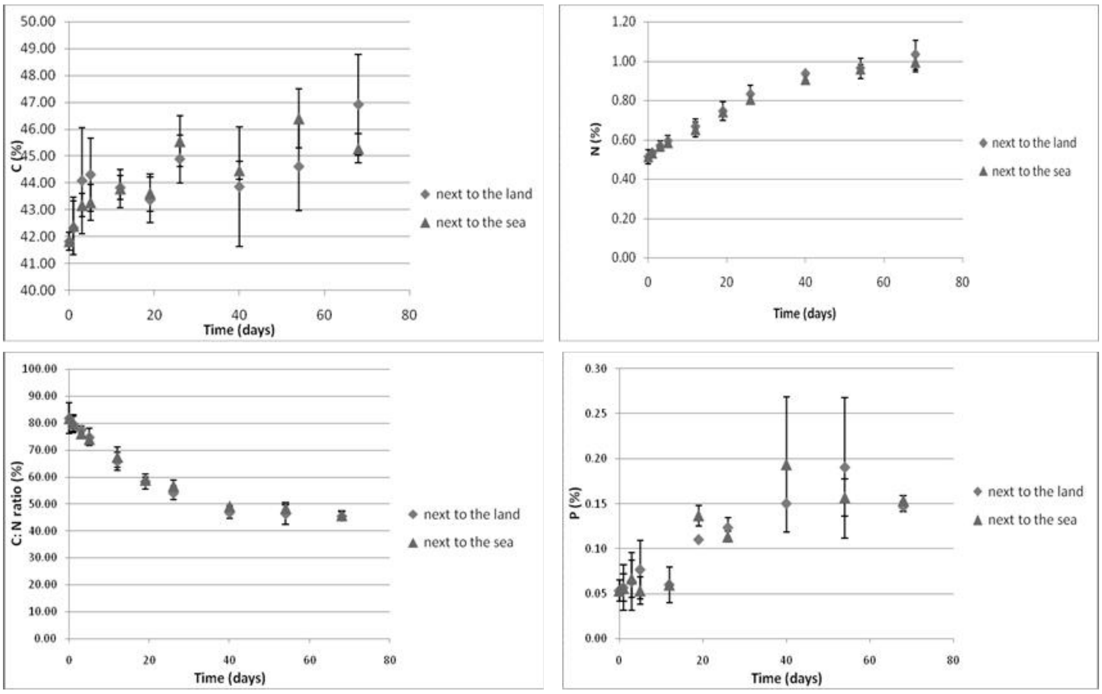

Figure 2. Changes in C, N, C: N ratio, and P Content from both sites during decomposition.

Furthermore, increasing N was related to the decreasing C: N ratio. The initial of C: N ratio was 81.81 and it decreased during the decomposition period in both site. The study found that C: N ratio ranged from 79.61 ± 2.76 in the beginning of observation to 45.52 ± 1.54 at the end of observation in site next to the land and from 79.76 ± 3.27 to 45.58 ± 1.76 in site next to the sea. Leaves of *R. stylosa* decompose faster at the end of observation than in the beginning of observation which was indicated by low of C: N ratio at the end of observation. Mfilinge et al. (2002) mentioned that high N concentration or low C: N ratio enhanced rapid microbial colonization and low C: N ratio will have relatively low recalcitrant and will decompose fast. Fell et al. (1984) found that C: N ratio decreased during the decomposition from 120 in senescent leaves to 43 in partially decomposed leaves observed from nutritive enrichment of *Rhizophora mangle* in South Florida because loss in carbon content and increase in final nitrogen.

Phosphorous content ranged from 0.06% ± 0.03 to 0.19% ± 0.08 in both site. The highest content of P was in the 54th day in site next to the land and the 40th day in site next to the sea. In average, the P content in both sites had similar value. In Figure above is also showed that in the early step of decomposition process P did not show significantly. Content of P increased during the observation although occasionally in some period P declined, it increased because of P immobilization (Tam et al. 1990). The content of P in study area can be categorized height (0.05%-0.19%) if compared with result of the research done by D’Croz et al. (1989). They found that P increased from 0.04% to 0.13% of red mangrove (*Rhizophora mangle* L.) leaves in the bay Panama.

T-test result explained that, there was no significant difference in the loss of dry weight, C, N, C: N ratio, and P of decomposed *R. stylosa* leaves in the two sites of the field research at the P> 0.05. It means the mean value of those parameters during observation were equal in the both sites. On the other hand, there was significant difference in the loss of dry weight, C, N, C: N ratio, and P content based on time (at the beginning and at the end of observation) in all plots of study area at the P< 0.05. It means the mean values of those parameters during observation were not equal to the all plot observation and those variables were changed from time to time.

Correlation between physical and chemical characteristics of water and remaining litter

The correlation between physical and chemical characteristics of water and remaining litter gained in six plots during experiment period is shown in Table 3. They were analyzed in order to know the linear relationship between two variables. Correlation coefficient ranged from -1.00 to +1.00. There was significant correlation between temperature and remaining litter (P<0.05), the r value of correlation between temperature and remaining litter was -0.80, this value represents a significant correlation between temperature and proportion of remaining litter (P<0.05).

Table 3. Value of coefficient determination (r^2), correlation coefficient (r), P value and regression equation

Parameters	r^2	r	P value	Equation
Temperature	0.6400	-0.8000	0.0000*	y = 587.524785-18.3255229*x
Salinity	0.0133	-0.1153	0.4066	y = 174.045371 -2.9428318*x
pH	0.0458	-0.2141	0.1200	y = 324.8625-32.2706897*x

This means that the higher the temperature the less the remaining litter will be gained but there was no significant correlation between salinity, pH and remaining litter ($P>0.05$) because salinity and pH did not change during observation. Graca et al. (2005) mentioned that breakdown of the leave is defined as weight loss due to some physical-chemical properties caused by environmental conditions such as high temperature and also Kuers and Simmons (2006) found that the decomposition process increases in accordance with temperature.

CONCLUSION

Mangrove vegetation in Iboih village, Weh Island, Aceh, Indonesia is dominated by *Rhizophora stylosa* and this species is growing well in study area. Remaining leaves decreased during experiment period owing to decomposition was happened in the study area, which also implies that the percentage of decomposed mangrove litter increased by increasing the decomposition period. Rate of decomposition was not statistically different between site next to the land which had lower inundation than site next to the sea and remaining litter was significant different between time where dry weight of decomposed leaves was changed during the observation period. Time required for the decomposition of half the initial material (t_{50}) was 67 days in site next to the land and 63 days in site next to the sea. Remaining litter of *Rhizophora stylosa* was influenced by water temperature where higher the temperature would result in less remaining litter during experiment period, but pH and salinity did not have correlation with remaining litter. Carbon and nutrients contained in *Rhizophora stylosa* leaves changed during decomposition process but there was no significant difference in carbon, and nutrients between sites where the mean value of those was similar but significant difference was found in time. Leaves of *Rhizophora stylosa* decomposed faster at the end of observation than in the beginning of observation which was indicated by low of C: N ratio at the end of observation.

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