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Fisheries Journal, 15 (2), 808-820 (2025)
http://doi.org/10.29303/jp.v15i2.1457

ESTIMATION OF LEAF-LITTER DECOMPOSITION RATE *Avicennia* sp. ON THE NUTRIENTS CONTENT IN WONOREJO MANGROVE AREA, SURABAYA

Estimasi Laju Dekomposisi Serasah Mangrove *Avicennia* sp. Terhadap Kandungan Nutrien di Kawasan Mangrove Wonorejo, Surabaya

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(Received March 9th 2025; Accepted April 27th 2025)

ABSTRACT

The ecosystems of mangrove are one of the unique coastal ecosystems which have ecological and socio-economic functions. Mangroves have a significant role in supporting fisheries resources. Leaf-litter is a nutrient contributor released to the sea water and is functioned by aquatic biota both in the marine and estuary. The method used in this study is purposive random sampling method which refer to the category based on mangrove density. The average production of mangrove litter Avicennia sp, for 30 days at station I was 1.04 g/m^2/ day, station II was 1.20 g/m^2/day, station III was 0.75 g/m^2/day. The leaf-litter decomposition rate at station I, experienced a decomposition process of 65%, at station II at 62.33%, and station III at 69.42%. The content of nitrogen (N) and fosfor (P) nutrients at station I is an average of N 0.74% and P 0.07%, station II is N 0.76% and P 0.05%, station III is N 0.74% and P 0 , 07%. The total amount of nutrients released in the Mangrove Information Center forest area, Wonorejo - Surabaya is nitrogen (N) 443.81 kg/m^2/year and phosphor (P) 34.103 kg/m^2/year.

Keywords: Leaf-Litter Production, Mangrove, Nutrien, The Rate of Decomposition, The Release of Nutriet

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BAB 1

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(P) pada stasiun I rata-rata sebesar N 0,74% dan P 0,07%, stasiun II sebesar N 0,76% dan P 0,05%, stasiun III sebesar N 0,74% dan P 0,07%. Jumlah total nutrien yang terlepas di kawasan hutan Mangrove Information Center Wonorejo Surabaya sebesar nitrogen (N) 443,81 kg/m²/tahun dan fosfor (P) 34,103 kg/m²/tahun.

Kata Kunci: Laju Dekomposisi, Mangrove, Nutrien, Pelepasan Nutrien, Produksi Serasah

INTRODUCTION

Mangrove ecosystem is one of the unique coastal ecosystems, has ecological and socio-economic functions. Mangroves have an important role in supporting fishery resources. Litter is a contributor of nutrients that are released into the waters and utilized by aquatic biota in marine and estuary ecosystems.

Litter is organic plant residue that comes from fallen leaves, stems, fruits, twigs, and so on. According to Sopana *et al*., (2009), the average total production of Wonorejo mangrove litter on the east coast of Surabaya is 4.5 ± 0.50 tons/ha/year with a total average component of mangrove litter in leaves of 4.0 tons/ha/year (89.9%), twigs of 0.4 tons/ha/year (8.08%), fruits and flowers of 0.1 tons/ha/year (2.02%).

The decomposition process of mangrove litter begins with the destruction carried out by macrobenthos then the litter will be cut into smaller sizes. Decomposition is continued with a biological process carried out by bacteria and fungi as decomposers to decompose organic particles by releasing enzymes so that they can decompose organic matter into protein (Andrianto *et al*., 2015; Jingchun *et al*., 2021; Pingping *et al*., 2021; Truong *et al*., 2020).

Utilization of decomposition results is not only as a source of nutrients for soil fertility, plants and phytoplankton but also a food source for fish and invertebrates, because mangrove litter contains high levels of N (Nitrogen) and P (Phosphorus). The purpose of this study was to measure the estimated rate of decomposition of *Avicennia* sp. litter in the Wonorejo Mangrove Information Center Area, Surabaya, East Java Province and to determine the content of nitrogen (N) and phosphorus (P) nutrients in Avicennia sp mangrove litter released during the decomposition process.

METHODS

Time and Place

The research was conducted in April - May 2020 in the Wonorejo Mangrove Area, Surabaya, East Java Province, Fisheries Laboratory, Nutrition Laboratory, Faculty of Agriculture - Animal Husbandry, UMM, and the East Java Agricultural Technology Assessment Center.

Tools and Materials

The tools used in this study were Litter trab 3 x 3 m², Litter bag 30 x 30 cm (mesh size 2 mm), roll meter, plot 10 x 10 m², sub plot 3 x 3 x 1 m², UN 55 memmert oven, tray, thermometer, refractometer, DO meter, analytical scales, blender, sewing needle. The materials used in this study were mangrove litter, distilled water, HCl, label paper, raffia rope, fishing line, universal pH.

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Figure 1. Research Location in the Mangrove Information Center Area, Wonorejo, Surabaya, East Java Province

Research Procedure
Description of Sampling Station

Determination of research stations using purposive random sampling method with reference to categories based on mangrove density. The 3 sampling areas consist of 3 locations/stations (Figure 1) representing low, medium, and high mangrove density levels where each density is taken 3 transects/plots with a plot size of 10 x 10 m². In addition, each
1 plot is taken using 3 x 3 m² Litter trabs, 30 x 30 cm Litter bags (mesh size 2 mm).

Mangrove *Avicennia* sp. Litter Sampling

Litter sampling in the mangrove ecosystem by installing 10 x 10 m² Litter trabs. Litter
7 trabs are placed on each plot at a height of 1.5 m above ground level to avoid sea water at high tide. Litter sampling is carried out for 1 month with intervals of 10, 20, and 30 days. This is intended to obtain accurate results or data and data diversity.

The collected litter is weighed to obtain a wet weight value. The litter is then put into a plastic clip and labeled to be ovened at a temperature of 80ºC for 24 hours until the weight is constant and then weighed for dry weight.

7 To determine the litter production per period and daily is calculated using the equation, (Rudiansyah *et al*., 2013).

$$Xj = \frac{\sum Xi}{n}$$

Description:
Xj = Litter production per period (grams of dry weight/m²/10 days)
7 Xi = Dry weight of mangrove leaves (grams of dry weight)
N = Litter-trap area (m²)

Mangrove Litter Decomposition Rate

The measurement of the decomposition rate begins with taking a sample of 10 grams of dry litter and putting it into a Litter bag with a mesh size of 2 mm as many as 9 bags at each station and placed under the tree touching the ground surface and tied tightly so that when the litter bag is installed it is not carried away by the current.

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The measurement of the decomposition rate is carried out by taking Litter bags from each plot with a time span of 10 days once for 3 times in 1 month. The litter is then removed and the litter bag is cleaned of mud and dirt. The litter is then dried in an oven at a temperature of 80ºC until constant weight and weighed.

The calculation of the percentage of the mangrove decomposition rate per period uses the formula (Indriani, 2008):

$$Y = \frac{BA - BK}{BA} \times 100$$

Description:
Y = Percentage of leaf litter that undergoes decomposition (%)
BA = Weight at initial drying (grams)
BK = Weight at final drying (grams)

To obtain the percentage value of leaf litter decomposition rate per day.

$$X = \frac{Y}{D}$$

Description:
X = Percentage of leaf litter that undergoes decomposition (%)
Y = Percentage of litter decomposition rate per day (%)
D = Length of observation per day (10 days)

Nitrogen and Phosphorus Nutrients

The dried litter was then measured for N and P nutrient content. Analysis of N content used the distillation method and analysis of P used the wet ashing method.

Determination of total Nitrogen content was carried out using the Kjelldahl method (Mukhlis, 2007):

$$\text{N content in leaves (\%)} = \frac{A \times 0{,}02 \times 14}{B}$$

Description:
A = Volume difference (ml)
B = Weight of dry material in 0.1 gr of leaf flour
0.02 = HCl normality (previously standardized to determine the correct normal value)

While the determination of the Phosphorus element is carried out by wet destruction (Mukhlis, 2007):

$$\text{P leaves (\%)} = \text{P solution} \times \frac{50}{0{,}25} \times \frac{50}{0{,}25} \times 10^{-4}$$
$$= \text{P solution} \times 0{,}2$$

Nutrient Release

The nutrient content analyzed was nitrogen and phosphorus. Nutrient release was calculated based on the formula (Nga *et al.*, 2004):

$$Nt = (W0 \text{ x } N0) - (W1 \text{ x } N1)$$

Description:
Nt = Released nutrient content (g/period)
W0 = Initial dry litter weight (g)

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W1 = Remaining dry litter weight after observation t (g)
N0 = Initial nutrient content (%)
N1 = Remaining nutrient content after observation t (%)
T = Incubation time (weeks)

RESULTS

Mangrove Litter Production *Avicennia* sp.

Total mangrove litter production for 1 month with a 10-day sampling period for 3 times found litter from various parts, namely leaf litter, twigs, and fruit/flowers. A direct relationship between mangrove density and litter production occurred at station II compared to other stations. According to Widhitama *et al*., (2016), the results of mangrove litter production are influenced by the level of tree density. Generally, in sparse areas, the litter production value is smaller than in dense areas, in these areas the litter that falls is influenced by the number of living trees. The value of mangrove litter production is presented in (Figure 2).

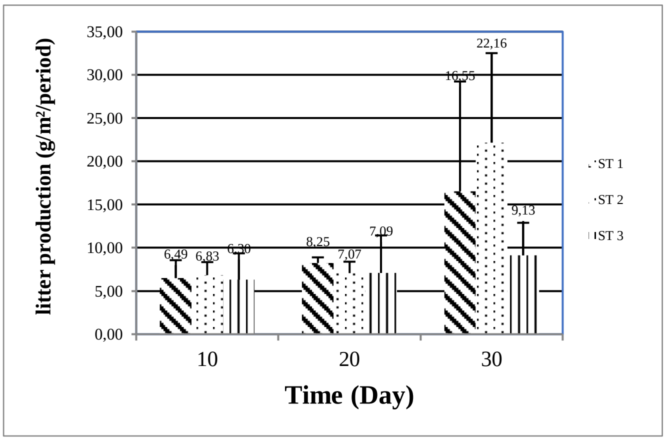

Figure 2. Mangrove Litter Production Per Period

Mangrove Litter Decomposition Rate

The decrease in wet weight of *Avicennia* sp. litter shows the remains of debris that gradually change shape into small particles during the observation period from day 10 to day 30. It is suspected that there is a role for organisms as biological decomposers, because Amphipoda were found in the litter bag, and in the physical process of litter erosion due to the movement of sea water currents during ebb and flow and wind. Physical changes in decomposed *Avicennia* sp. litter are presented in (Figure 3).

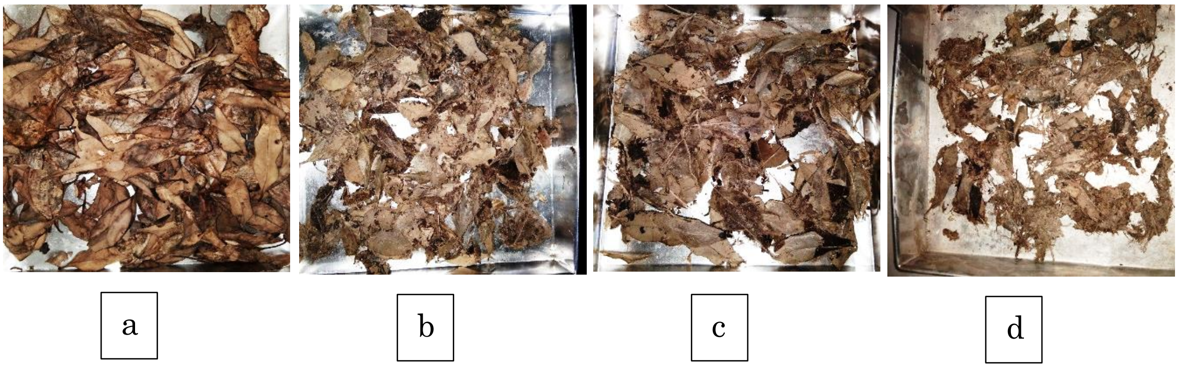

Figure 3. Observation of Mangrove Litter Decomposition Rate, Day 0 (a), Day 10 (b), Day 20 (c), Day 30 (d)

4 Based on the graph of changes in dry litter weight (Figure 4) during 30 days of observation at three different stations (ST 1, ST 2, and ST 3), it can be seen that all three treatments experienced a gradual decrease in litter weight over time. On the 10th day, the highest dry weight was recorded at ST 1 at 5.27 g, followed by ST 3 at 5.06 g, and ST 2 at 4.98 g. This difference is still relatively small and indicates that decomposition has not occurred significantly in the early stages. Entering the 20th day, there was a more significant decrease in weight, with ST 3 showing the highest value of 3.55 g, while ST 1 and ST 2 decreased to 3.12 g and 2.32 g, respectively. This indicates that the ST 3 treatment experienced a slowdown in decomposition compared to the other two stations.

However, on the 30th day, the pattern reversed. ST 3 showed the lowest dry weight of 1.79 g, indicating the most advanced decomposition process, while ST 1 and ST 2 reached 2.08 g and 2.77 g, respectively. These results indicate that although ST 3 was left behind on the 20th day, overall it showed the highest decomposition rate in the long term. This significant decrease in dry weight can be attributed to the effectiveness of ST 3 in facilitating the activity of decomposing microorganisms or increasing the availability of decomposition enzymes. In general, the trend of decreasing litter weight indicates that all three treatments are effective in supporting the decomposition process, but ST 3 showed the most optimal results in accelerating the decomposition of organic matter until the 30th day.

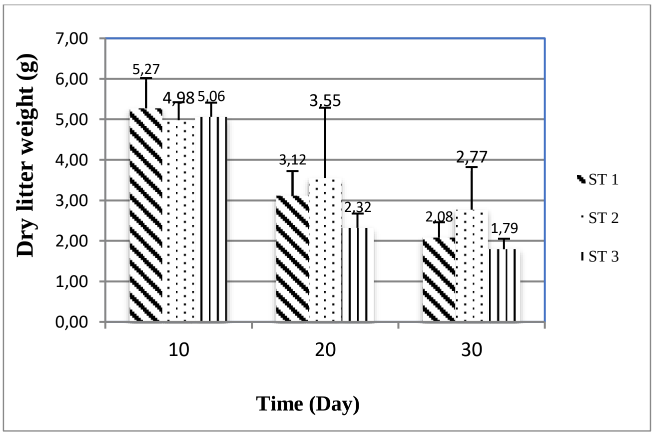

Figure 4. Dry Weight of Litter Decomposition Rate

4 The litter decomposition rate (%) for 30 days (Figure 5) at three different stations (ST 1, ST 2, and ST 3), in general, all stations showed an increase in decomposition rate over time, indicating that the organic matter degradation process was taking place progressively. On the 10th day, the three stations had relatively close decomposition rate values: ST 1 at 47.90%, ST 2 at 50.21%, and ST 3 at 49.39%. This shows that in the early phase, decomposition activity has not shown significant differences between stations. However, on the 20th day, differences began to appear where ST 3 showed the highest increase with a decomposition rate reaching 76.80%, followed by ST 1 (68.85%) and ST 2 (64.49%).

This increase continued until the 30th day, where ST 3 still showed the best performance with a decomposition rate of 82.06%, higher than ST 1 (79.16%) and ST 2 (72.29%). These results indicate that ST 3 consistently produced the highest decomposition rate during the observation period. The effectiveness of ST 3 is most likely due to the content of microorganisms or bioactivators that are more active in breaking down organic matter. Meanwhile, although ST 1 and ST 2 also showed significant increases, their performance was slightly lower than ST 3. Overall, these data strengthen the suspicion that ST 3 is the most potential station to accelerate the litter decomposition process.

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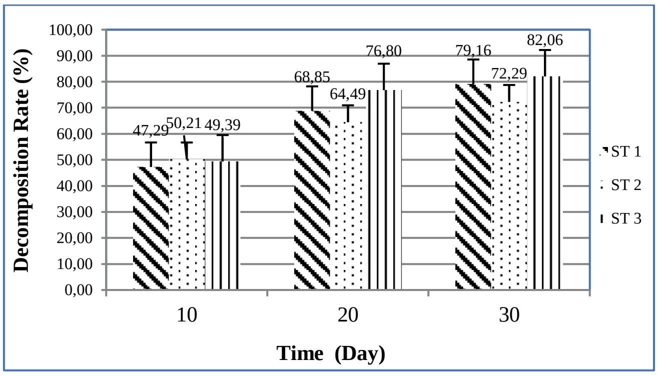

Figure 5. Percentage of Litter Decomposition Rate

Litter Nutrient Content During the Decomposition Process

Nutrients are elements that function in the life processes of organisms (Parsons et al., 1984). The nutrient content of mangrove litter during the decomposition process obtained analysis results showing that the N nutrient value was higher than the P nutrient, both tended to increase on the 10th day and then tended to be stable after more than 20 days.

The graph in Figure 6 shows the dynamics of nitrogen (N) content in litter during 30 days of observation at three different stations (ST 1, ST 2, and ST 3). In general, nitrogen levels at the three stations fluctuated during the decomposition process. On day 0, the initial N content ranged from 0.6–0.9%, with ST 1 showing the highest value. Until the 10th and 20th days, the three stations showed a relatively stable pattern without drastic changes, with the N content range still below 1%.

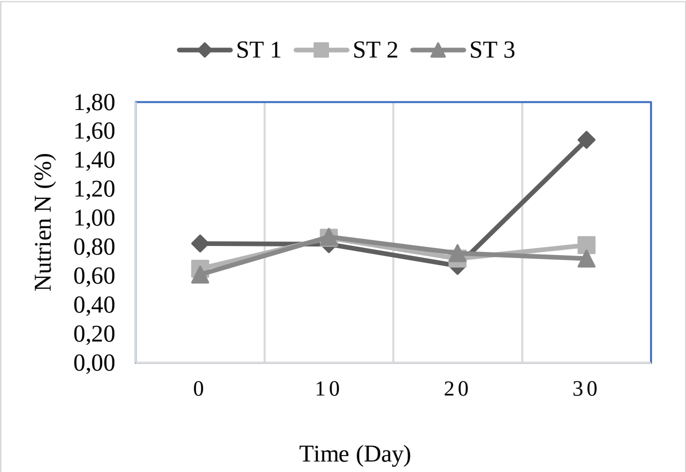

Figure 6. Nitrogen (N) Content During Litter Decomposition Process

However, significant differences began to appear on the 30th day, where ST 1 experienced a sharp spike in nitrogen content reaching around 1.6%, far exceeding ST 2 and ST 3 which remained in the range of 0.7–0.8%. The significant increase in N levels in ST 1 may indicate more intensive nitrogen mineralization activity at the end of the decomposition period, or the possibility of nitrogen addition through biological fixation or the activity of certain microorganisms that are dominant in the treatment. Meanwhile, the stability of nitrogen levels in ST 2 and ST 3 indicates that the process of releasing nitrogen from organic matter to available forms may be slower or more stable. These results indicate that although ST 3 is superior in terms of decomposition rate, ST 1 has the potential to be higher in enriching nitrogen content at the end of the process.

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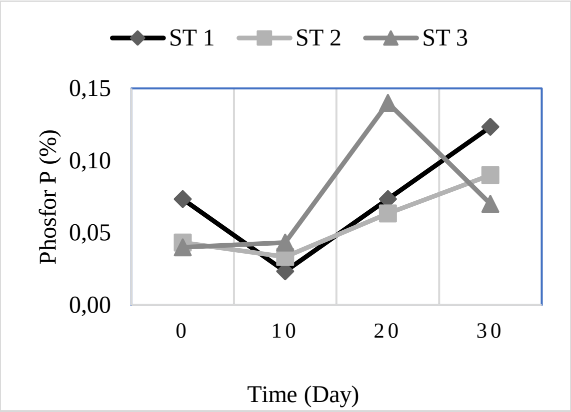

Figure 7. Phosphorus (P) Content During Litter Decomposition Process

The P nutrient content in mangrove litter at the three stations was quite low compared to the N nutrient presented in (Figure 7), this is because the nature of P nutrients can be directly decomposed in the sediment. At all three stations there was an increase after 10 days of observation until the 30th day, this is suspected to be due to the presence of decomposer bacteria attached to the litter that was also analyzed.

4 The graph shows changes in phosphorus (P) content in litter during 30 days of observation at three different stations (ST 1, ST 2, and ST 3). At the beginning of observation (day 0), all three stations showed relatively low and uniform P content, ranging from 0.04% to 0.07%. Interestingly, on the 10th day, ST 1 experienced a sharp decrease in P content, while ST 2 and ST 3 showed a slight increase. Then, on the 20th day, there was a significant spike in ST 3, which reached the highest value of around 0.14%, far exceeding ST 1 and ST 2 which were below 0.08%. This indicates that the ST 3 treatment supports the release of phosphorus from organic matter more efficiently in the middle phase of decomposition. However, on the 30th day, there was a decrease in P content in ST 3, while ST 1 showed a consistent increase reaching around 0.12%, and ST 2 was stable at around 0.08%. This pattern shows that phosphorus release does not occur linearly, but is influenced by microbial dynamics and the availability of organic substrates during the decomposition process. The increase in phosphorus content in ST 1 at the end of the observation indicates that the mineralization process of P elements is slower but more stable than ST 3 which experiences rapid but fluctuating release. Meanwhile, ST 2 shows a more conservative phosphorus release pattern over time. Thus, ST 3 has the potential to accelerate P availability in the short term, while ST 1 is superior for gradual phosphorus release in the longer term.

Nutrient Release

10 The decomposition of mangrove litter contributes nutrients that are released in the form
10 of the development and growth of the mangrove itself, crabs, shrimp, fish and other
10 microorganisms in the mangrove forest. Nutrients released through the decomposition process of mangrove litter are potential energy for the growth of phytoplankton which is a food source for juvenile fish that use mangroves as a place to find food sources.

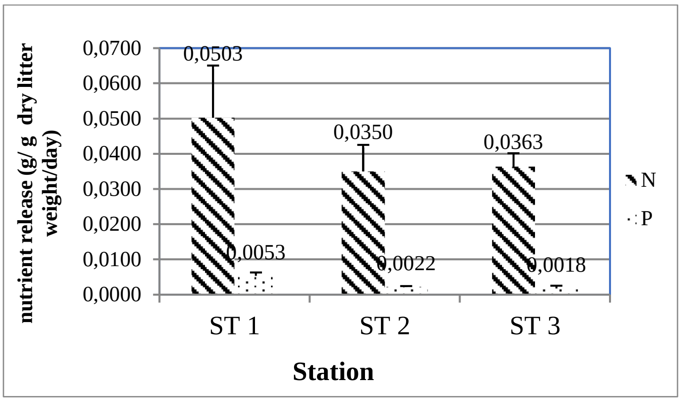

Figure 8. Average Release of N and P Nutrients

The average nutrients released from litter during the decomposition process of mangrove litter that can be utilized is highest at station I at 0.0503 g N/g dry weight of litter/day and 0.0053 g P/g dry weight of litter/day. Station II at 0.0350 g N/g dry weight of litter/day and 0.0022 g P/g dry weight of litter/day. Station III at 0.0363 g N/g dry weight of litter/day and 0.0018 g P/g dry weight of litter/day. The total amount of N nutrients released in the mangrove information center forest area is 0.121 g/m²/day or 443.81 kg/ha/year. The total amount of P nutrients released in the mangrove forest area of the information center is 0.009 g/m²/day or 34.103 kg/ha/year.

DISCUSSION

The value of mangrove litter production at station II was higher with a range of 6.83 g - 22.16 g dry / m² / period with daily litter production of 1.20 g dry / m² / day, while the lowest litter production was at station III with a range of 6.30 g - 9.13 g dry / m² / period with daily litter production of 0.75 g dry / m² / day. Station I found litter production of 6.49 - 16.55 g dry / m² / period with daily litter production of 1.04 g dry / m² / day. When compared with the research of Andrianto et al. (2015), found the highest mangrove litter production results with a value of 9.83 - 23.50 g / m² /10 days, with an average litter production of 16.73 g / m² / 10 days. According to Widhitama *et al*., (2016); Jingchun *et al*., (2021); Pingping *et al*., (2021); that the production of mangrove litter is influenced by the level of tree density. Environmental factors also affect the production of litter and the rate of decomposition, some of the factors that influence include temperature, rainfall, wind speed, pH, salinity, organic matter, and soil texture. High mangrove density will certainly also produce more litter fallout compared to low density areas. According to Aida *et al*., (2014) and Truong *et al*., (2020), in addition to the density factor, there are differences in tree diameter and mangrove types which are also thought to affect daily litter production.

The high loss of dry weight of the decomposition rate in the early stages is thought to be related to the loss of organic and inorganic materials that are easily dissolved and are also supported by the presence of microorganisms that play a role in several nutrients contained in mangrove litter. According to Affandi & Ni'matuzahroh (2000); Lang (2024); Jaehyun *et al*., (2021) that the micro and macro decomposer groups found in the mangrove litter decomposition process are Insecta (4 species with an abundance of 32.61%), Crustaceae (12 species with an abundance of 19.03%), Mollusca (16 species with an abundance of 19.03%), Polychaeta (25 species with an abundance of 16.69%), and Myriapoda (1 species with an abundance of 0.05%). The presence of fungi in this process at an early stage also has a very important role in the loss of organic and inorganic materials by leaching. According to Affandi & Ni'matuzahroh (2001), the types of fungi associated with the mangrove litter degradation process in the North Coast of Surabaya area are 30 strains represented by 7 genera, namely

Fisheries Journal, 15 (2), 808-820. http://doi.org/10.29303/jp.v15i2.1457
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Aspergillus (10 strains), Tricoderma (10 strains), Penicillium (4 strains), Paeocilomyces (2 strains), Gliocladium (2 strains), Gonatobotryum (1 strain) and Syncephalastrum (1 strain).

The rate of litter decomposition is characterized by a decrease in litter weight in each observation period. The average rate of decomposition process experienced the highest decrease in the early stages of decomposition, namely on the 10th observation day, then decreased over the observation period (Figure 4). Showing that the length of the observation period can affect the value of the decomposition rate which is characterized by a decrease in the value of the decomposition rate until the end of the period. The decrease in organic matter will continue to occur over time. According to Farooqi *et al*., (2014) that, the decomposition rate of *A. marina* showed a very fast weight at the beginning of the study and then the decomposition rate decreased until the remaining period of the study.

The highest decomposition rate of mangrove litter was at station III with a litter decomposition rate value of 69.42%, while at station I it was 65.10% and station II it was 62.33%, presented in (Figure 5), It can be concluded that the percentage of litter shrinkage is greater in the first 10 days. According to Farooqi *et al*., (2014) that, the decomposition rate of *A. marina* showed a very fast weight at the beginning of the study and then the decomposition rate decreased until the remaining period of the study.

Other factors that affect the rate of decomposition are the length of the ebb and flow and the rainy season. In waters, the decomposition process is assisted by physical mechanisms, namely longer inundation by seawater and tidal current movements. According to Sa'ban *et al*., (2013); Novia *et al*., (2021); Harikrishna *et al*., (2023) the decomposition process in water areas is also assisted by physical mechanisms, namely tidal current movements and longer inundation by seawater. Pribadi (1998) and Lang (2024) that the rate of litter decomposition for mangroves is more accurately described as the rate of litter loss, due to the movement of litter components due to tidal currents.

The highest Nitrogen and Phosphorus content was found at station I compared to stations II and III, presented in (Figure 6) because litter production at station I was quite high, in addition, the high N nutrient content in *Avicennia* sp. mangroves is thought to be due to growing close to river mouths. According to Kushartono (2009) and Jaehyun *et al*., (2021), the high nutrient value at each observation station is due to the high production of litter. Meanwhile, according to Hutagalung & Rozak (1997) and Dietriech et al. (2018), the nitrogen value will increase towards the coast and the highest levels are usually found in estuary waters, because there is a source of nitrogen from land in the form of waste discharge.

The increase in nitrogen nutrients during the decomposition period is caused by several factors, namely the nature of nitrogen which is difficult to dissolve and the decomposition of nutrients into organic compounds. According to Melillo *et al*., (1982); Bosire *et al*., (2005); Novia *et al*., (2021); F. *et al*., (2023); Harikrishna *et al*., (2023); that nitrogen has the nature of being difficult to dissolve and N translocation and nitrogen immobilization as a result of accumulation of biomass and products of microbial activity. Meanwhile, Steinke *et al*., (1990), Mfilinge *et al*., *(*2002) and Pingping *et al*., (2021) that the increase in N content is due to the ability of nitrogen bacteria in mangrove litter to fix nitrogen.

According to Chauvet (1987); Jingchun *et al*., (2021); Truong *et al*., (2020); Pingping et al. (2021); that the increase in P nutrient content in mangrove leaf litter in the estuary area is thought to be due to an increase in river sediment and an increase in phosphorus sediment from compounds carried by the tidal currents of river water that are retained in the litter.

According to Polglace *et al*., (1992); Hui-Xing *et al*., (2023); Harikrishna *et al*., (2023) that the release of N and P elements is mainly through direct washing and through microbial activity. Kumar *et al*., (2011), that Avicennia contributes more nutrients than other types, namely nitrogen of 437.05 kg/ha/yr and phosphorus of 90.38 kg/ha/yr, this is because Avicennia has a higher nutrient content than other types, so that mangrove forests in coastal

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areas are more fertile than tropical forests when viewed from the contribution of nutrients from their litter.

CONCLUSION

5 The average production of mangrove litter production per period at station I was 10.43 g/m²/period, at station II was 12.02 g/m²/period and at station III was 7.51 g/m²/period. 5 Meanwhile, the average production of mangrove litter per day at station I was 1.04 g/m²/day, at station II was 1.20 g/m²/day, and at station III was 0.75 g/m²/day. At station III, a higher decomposition process occurred, namely 69.42%, while at station I it was 65.10% and station II was 62.33%. In the Wonorejo Surabaya mangrove forest area, the *Avicennia* sp. species has the potential to contribute nutrients released into the water amounting to 443.81 kg of nitrogen N/ha/year and 34.103 kg of phosphorus P/ha/year.

ACKNOWLEDGEMENT

We would like to thank the Faculty of Agriculture and Animal Husbandry, University of Muhammadiyah Malang for the full support that has been given during this research. We greatly appreciate the adequate laboratory facilities and assistance from the entire research support team who have contributed in various technical and analytical aspects. This support plays a major role in the smoothness and success of our research.

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