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# Study of the Quality of Biogeotextile Materials as Semi-Organic Mulch on Saline Land

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## ABSTRACT

Degraded land affects almost all ecosystems and can harm the progress and quality of human life, so it needs attention. Saline soil is a land degradation with high salt content that causes toxic effects, increases root osmotic pressure, and inhibits plant growth. One solution is using organic mulch processed into biogeotextiles because it can provide solutions for erosion control and soil stabilization while minimizing negative impacts on the ecosystem. This research was conducted from May to August 2023 in the experimental garden of the Faculty of Agriculture UPN 'Veteran' East Java. This study used a group randomized design with one factor, the type of geotextile material consisting of reed grass (RG), straw (ST), pandanus odorifer (PO), and sugarcane bagasse (SB). This research was conducted with a litterbox of 20x20 cm filled with 100 g of biogeotextile material. The results obtained show that pandanus odorifer biogeotextile material is the best biogeotextile material because it can last a long time on the soil surface, but can still be adequately mineralized, according to the results obtained, reducing the C/N ratio and C-Organic but increasing total nitrogen. Decomposition is closely related to the materials' quality rather than external factors. The quality of the material, namely lignin, organic carbon, C/N ratio, and nitrogen, influences the decomposition process. Furthermore, this technology can be applied to improve soil productivity and to keep soil healthy.

***Keywords***: Biogeotextile, degradation, saline, soil

## INTRODUCTION

Degraded land affects nearly all terrestrial ecosystems, endangering human progress and quality of life. As a result, it has gained significant international attention as a major environmental issue (Zhao et al., 2023). Soil erosion, alkalinization, salinization, water logging, soil contamination, and desertification are examples of land degradation (Lestariningsih et al., 2018). Land conditions that experience a decrease in the land's ability to support plant growth. Land degradation is defined as a reduction in the ability of land to produce benefits and profits from certain land uses that receive special treatment from land management. Land damage usually indicates a decrease in land production capacity, either temporary or permanent (Osok et al., 2018). Saline soil is also a form of land degradation with high salt levels due to the high concentration of salt ions. Saline soil is one of the land types that has not been extensively utilised for plant cultivation, primarily due to the toxic effects and increased root osmotic pressure, which impede plant growth. According to Karolinoerita & Annisa (2020), high salinity impairs plant growth due to the reduction in osmotic pressure, thereby hindering the uptake of nutrients by roots.

New environmentally friendly agricultural techniques are needed for sustainable food production. Mulching can be beneficial by reducing soil evaporation, maintaining moisture, regulating soil temperature, inhibiting weed development, and increasing microbial activity. In addition, mulch can also benefit agriculture and landscaping in terms of cost, aesthetics, and environment (Iqbal et al., 2020).

An effort that can be applied is using biogeotextiles on saline land, which has long-term benefits. Some of the benefits of biogeotextiles on saline land include restoring the microbial ecosystem in the soil, thus creating a better environment. Using biogeotextiles also supports sustainable agriculture because biogeotextiles can decompose naturally without polluting the environment. This type of ground cover is widely used for plant cultivation activities. Utilizing weeds is an effort to suppress weed growth, temperature, and soil moisture. Farmers use both organic and inorganic mulch widely. However, inorganic mulch is more common and is used more by farmers. Utilizing organic mulch, which is rarely used, positively impacts soil and plants. Organic mulch is another effort that can be made to increase land fertility.

Ground cover types are widely used for crop cultivation activities. Weed utilization is one effort to suppress weed growth, temperature, and soil moisture. Farmers have widely used mulch, both organic and inorganic. However, inorganic mulch is often found and more widely used by farmers. Organic mulch, which is still rarely used, positively impacts soil and plants. Organic mulching is another measure that can be taken to improve soil fertility. The provision of organic material has a good impact, such as increasing the availability of macro nutrients and micro nutrients in the soil as well as providing energy for the activity of soil microorganisms (Biswas & Kole, 2017; Dhaliwal et al., 2019; Timsina, 2018). Numerous essential nutrients are lost while rice or stubble is burned, especially 25% of nitrogen and phosphate, 75% of potassium, and almost 50% of sulphur (Bains et al., 2021).

Biogeotextiles are a specialized type of geotextile material designed to promote vegetation growth and control erosion in various environmental applications. These textiles are typically made from natural fibers or biodegradable materials that are environmentally friendly and can degrade over time without causing harm to the ecosystem. Geotextiles are materials with excellent potential to biodegrade, are environmentally friendly, and are useful for soil conservation (Prambauer et al., 2019; Tanasă et al., 2022). The findings demonstrated that applying water hyacinth mulch helps raise temperature, increase maize output, and improve soil water conditions (D. Xu et al., 2017).

Biogeotextiles are commonly used in landscaping, agriculture, and civil engineering projects to stabilize soil, prevent erosion, and promote vegetation growth. They provide a protective barrier that helps (Kusmana & Yentiana, 2021) retain moisture in the soil, encourages seed germination, and supports the establishment of plant roots. One of the key advantages of biogeotextiles is their ability to integrate with the surrounding environment, unlike synthetic materials, which may pose long-term environmental risks. Using natural or biodegradable fibers, biogeotextiles offer a sustainable solution for erosion control and soil stabilization while minimizing negative impacts on ecosystems.

Applying biogeotextiles is one of the implementations of a conservation agricultural system. This agricultural system implements a system so the land is always covered and cultivated with minimal tillage, following conservation agriculture principles. It is hoped that soil that is always covered can maintain soil fertility levels, reducing nutrient loss due to surface runoff. Semi-organic mulch represents a promising and eco-friendly approach to combating salinity in agricultural lands. By suppressing evaporation, promoting beneficial soil microbes, and improving soil health, this technique paves the way for the rehabilitation of saline soils. While further research is needed to optimise its application, semi-organic mulch holds immense potential for unlocking the agricultural potential of vast saline areas across the globe. This research aims to assess the suitability of materials for use as ingredients in semi-organic mulch and biogeotextiles.

## MATERIALS AND METHODS

This research was conducted from May to August 2023 at the Experimental Garden of the Faculty of Agriculture UPN 'Veteran' East Java. This study used the Randomized Group Design (RGD) method. The study involved the construction of a 20 × 20 cm litter box, which was then filled with 100 g of Biogeotextile Material (Table 1) and repeated three times in each plot. One experimental plot was replicated four times and then sampled at two-week intervals, with one plot allocated for chemical and biological analysis (Table 2).

Observation variables related to each material's decomposition rate were analyzed chemically and biologically, in the form of pH, Total-N, C-Organic, C/N Ratio, and Biomass (Table 2).

The data obtained during the study were compiled using the Microsoft Excel program. They were then tested for normality to determine the distribution of the data. Furthermore, the ANOVA test was used to analyze variance to determine the effect of the treatment applied. If there is a significant effect at the 5% level, the Tukey test is

Table 1. Material of biogeotextile.

| No | Biogeotextile Material | Code |
|---|---|---|
| 1. | Reed grass | RG |
| 2. | Straw | ST |
| 3. | *Pandanus odorifer* | PO |
| 4. | Sugarcane Bagasse | SB |

Table 2. Variables of observation.

| No | Parameter | Satuan | Metode | Keterangan |
|---|---|---|---|---|
| 1. | Soil acidity (pH) | - | Konduktrimetri | Balittanah, 2009 |
| 2. | Total N | % | *Kjeldhal* | Balittanah, 2009 |
| 3. | C-Organic | % | *Walkley and Black* | Balittanah, 2009 |
| 4. | C/N Rasio | - | - | Balittanah, 2009 |
| 5. | Biomass | % | Calculation | - |

carried out. Statistical analysis was carried out using the SPSS program.

## RESULTS AND DISCUSSION

### Decomposition rate of biogeotextile against pH value

The level of acidity (pH) of each biogeotextile material has a different value and shows significantly different results at the first, third, and fourth measurement intervals. Each biogeotextile material has a pH ranging from 5.21 to 7.56 (acid-neutral). The more mature the biogeotextile material, the more neutral the pH of the material is. The further decomposed biogeotextile material can increase and stabilize the pH (Haribowo et al., 2022; Yang et al., 2016). The pH value at each interval is presented in Table 3.

Table 3 shows that the pH of various geotextile materials can increase from the acidic category at interval 1 to neutral at interval 4. The treatment of reed grass biogeotextile material (RG) experienced an increase in pH of 1 class, namely 5.24 (acidic) to 6.30 (slightly acidic). Straw bio geotextile material (ST) has a fluctuating pH value at intervals 1 to 3, which has decreased but is still classified in the same pH class as mildly acidic (6.15 to 5.96). The fourth interval is an increase in pH, which is classified as a neutral class (7.56). *Pandanus odorifer* (PO) experienced an increase in pH from intervals 1 to 4. In the first and second intervals, 5.43 and 5.45 (acidic), respectively; in the third interval, the pH has a slightly acidic increase with a value of 5.56, while in the fourth interval, the pH is classified as a neutral class, namely 7.20. The treatment of sugarcane bagasse biogeotextile material (SB) also

Table 3. pH values of various biogeotextile materials.

| Materials of biogeotextile | Interval Observation | | | |
|---|---|---|---|---|
| | Interval 1 | Interval 2 | Interval 1 | Interval 4 |
| RG | 5.24 a | 5.23 | 5.21 a | 6.30 a |
| ST | 6.15 b | 5.76 | 5.95 b | 7.56 b |
| PO | 5.43 a | 5.45 | 5.56 ab | 7.20 ab |
| SB | 5.82 ab | 5.43 | 5.50 ab | 7.04 ab |
| significant 5% | 0.632 | ns | 0.58 | 0.82 |

Note: RG (Reed grass), ST (Straw), PO (*Pandanus odorifer*), SB (Sugarcane bagasse); ns: not signififant at 5% tukey test

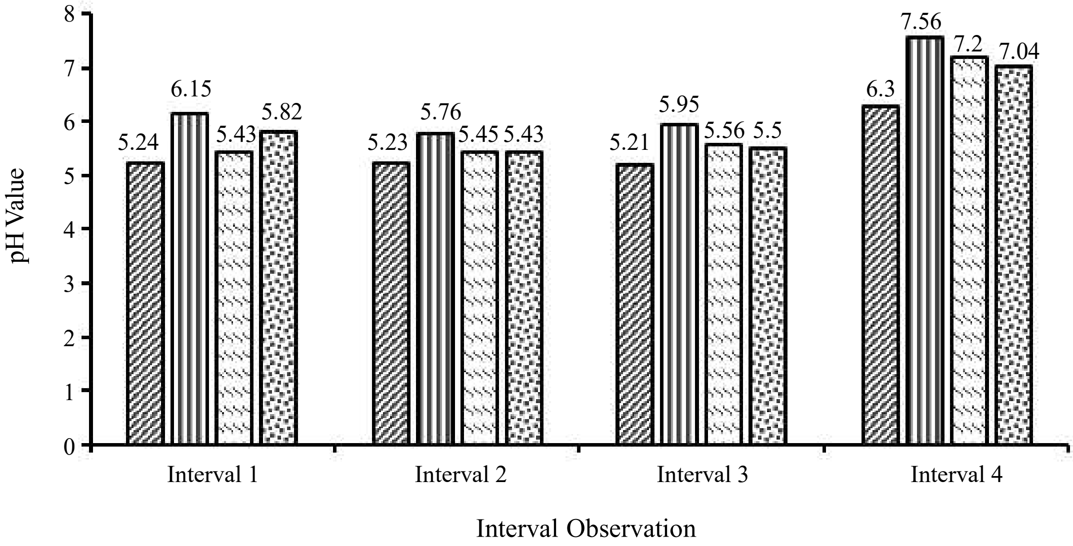


Figure 1. pH values of various biogeotextile materials. : AL, : JR, : PL, : AT.

experienced fluctuating changes in intervals 1 to 3 from slightly acidic (5.82) to acidic, with consecutive values of 5.43 and 5.55. Meanwhile, in the fourth interval, the pH increased to neutral (7.04).

The straw material (ST) found the highest pH increase, while the material with the lowest was reed grass (RG). Increasing soil pH with straw mulch can act as a pH buffer because straw helps create a more stable environment for microorganisms, which makes it more stable in increasing soil pH (Zhang et al., 2015; Zhou et al., 2021). The increase in geotextile pH at each interval is presented in Figure 1.

## Decomposition rate of biogeotextile to biomass weight

Decomposition is the destruction of organic matter carried out by biological agents, which will become mineral materials and humus. Hence, the decomposition process is also commonly called the mineralization process. In this process, microbes (decomposers) obtain energy for their reproduction (Andrianto et al., 2015). Decomposition of organic matter is the process of breaking down organic components from high molecular weight to lower molecular weight, which is carried out by microbes. The biomass of various biogeotextile materials is presented in Table 4.

Table 4 shows that the biomass values of various biogeotextile materials at intervals 1, 2, 3, and 4 are not significantly different. In general, the biomass value of each biogeotextile constituent material decreased. In reed grass (RG), the biomass decreased from 10.46 in interval 1 to 5.28 in interval 4. The straw material (ST) biomass decreased from 10.84 in interval 1 to 6.32 in interval 4. In the material of *Pandanus odorifer* (PO), the biomass decreased from 11.33 in interval 1 to 7.36 in interval 4. In the sugarcane bagasse material (SB), the biomass decreased from 13.46 in interval 1 to 5.57 in interval

Table 4. Biomass reduction on biogeotextile material.

| Materials biogeotextile | Interval Observation | | | |
|---|---|---|---|---|
| | Interval 1 | Interval 2 | Interval 3 | Interval 4 |
| RG | 10.46 | 7.26 | 5.33 | 5.28 |
| ST | 10.84 | 10.53 | 8.37 | 6.32 |
| PO | 11.33 | 11.21 | 9.89 | 7.36 |
| SB | 13.46 | 11.24 | 6.89 | 5.57 |
| significant 5% | ns | ns | ns | ns |

Note: RG (Reed grass), ST (Straw), PO (*Pandanus odorifer*), SB (Sugarcane bagasse; ns: not signififant at 5% tukey test.

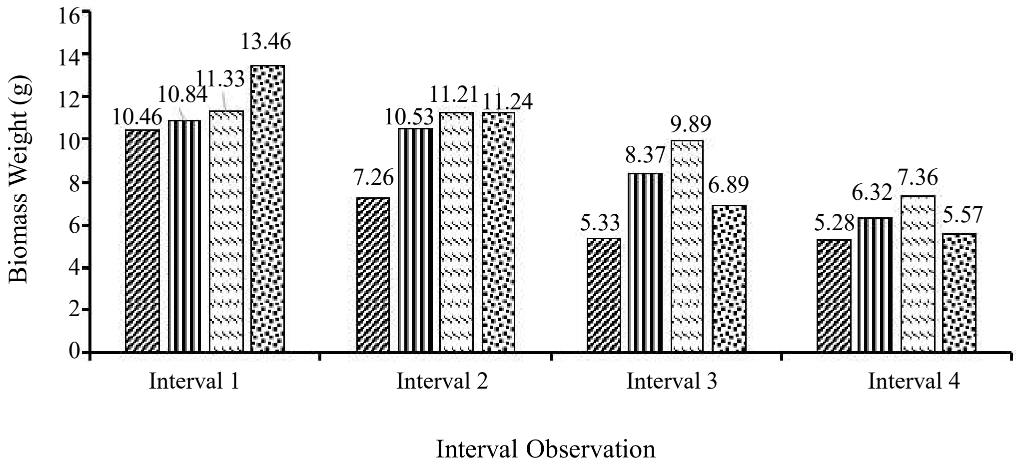


Figure 2. Biomass reduction of each biogeotextile material. ◪ : AL, ◫ : JR, ◻ : PL, ◼ : AT.

4. The weight loss of biomass of biogeotextile constituent materials is presented in Figure 2.

At the beginning of decomposition, the biogeotextile material has a similar weight, but over time, it has decreased by about 90% of the initial weight. Based on the results of observations, bagasse is the material that loses its mass the fastest at each observation interval. *Pandanus odorifer* experienced the least mass loss at each observation interval. It can be due to the content of materials that are difficult to decompose in sea pandanus, which has a higher percentage of 25.58% than others and has thicker fibres (Khaopakro et al., 2020; Teli & Jadhav, 2015). *Pandanus odorifer* is a prominent pandanus with a leaf length of 70-100 cm and a width of 3-5 cm. It has a fibrous leaf arrangement (Sahupala et al., 2021), so sea pandanus leaves have the potential to be used as textile materials and a mixture of other materials (Nasim et al., 2021).

The decrease in biomass weight occurs because microorganisms in the soil use carbon for decomposition. Microorganism activity can affect the rate of biomass decomposition, as microbial activity leads to carbon sequestration (Baldrian, 2017; Yan et al., 2018). Litter lignin and cellulose degradation, soil pH, and C-degrading enzymes have been identified as direct factors affecting soil organic carbon fraction during plant biomass decomposition (Xu et al., 2023).

**Decomposition rate of biogeotextile to % C-Organic content**

Biomass decomposition is a process that plays a fundamental role in decomposing carbon. It is influenced by plant biomass, which is composed of many carbon groups. The carbon in plant biomass that microbes have decomposed will turn into C-Organic. C-Organic content in each biogeotextile material varies; this is determined by the type of base material used. The C-Organic content in each biogeotextile material is presented in Table 5.

Based on the data in Table 5, the C-Organic value of various biogeotextile materials at intervals 1 and 4 is significantly different, while at intervals 2

Table 5. C-Organic content (%) in each material of biogeotextile.

| Materials biogeotextile | Interval Observation | | | |
|---|---|---|---|---|
| | Interval 1 | Interval 2 | Interval 1 | Interval 4 |
| RG | 49.16 b | 47.95 | 44.83 | 40.84 b |
| ST | 36.88 a | 38.94 | 34.41 | 31.61 ab |
| PO | 45.54 b | 44.46 | 43.16 | 22.07 a |
| SB | 41.46 ab | 40.68 | 37.05 | 25.02 ab |
| Significant 5% | 7.23 | ns | ns | 14.69 |

Note: RG (Reed grass), ST (Straw), PO (*Pandanus odorifer*), SB (Sugarcane bagasse); ns: not signififant at 5% tukey test

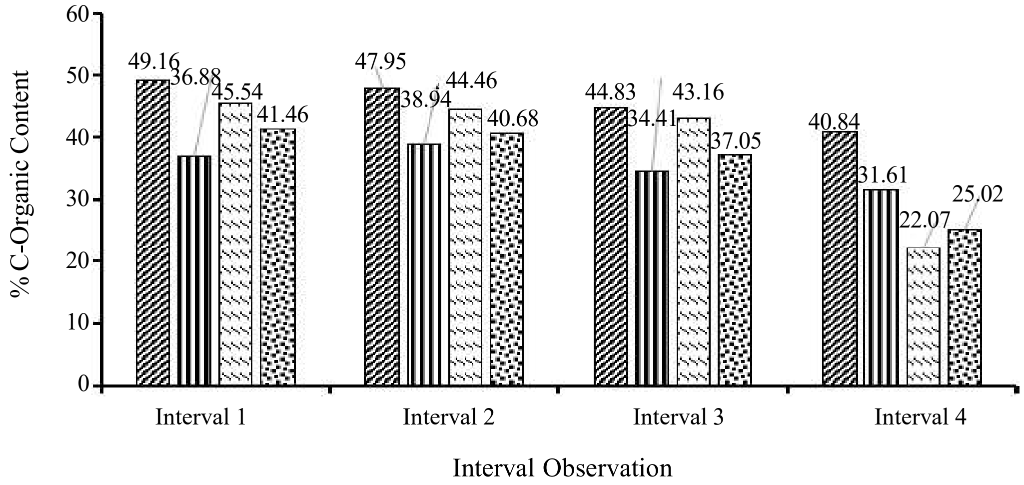


Figure 3. Reduction of % C-Organic content of each biogeotextile material. : AL, : JR, : PL, : AT.

and 3, it is not significantly different. All biogeotextile materials tested decreased in C-Organic value from interval 1 to interval 4. In reeds (RG), C-organic material decreased from 49.16 in interval 1 to 40.84 in interval 4. The straw material (ST) C-Organic decreased from 36.88 in interval 1 to 31.61 in interval 4. The material of pandanus odorifer (PO) C-Organic decreased from 45.54 in interval 1 to 22.07 in interval 4. In sugarcane bagasse material (SB), C-Organic decreased from 41.46 in interval 1 to 25.02 in interval 4. The decrease in C-organic content is presented in Figure 3.

Based on the observation results, it can be concluded that all materials experienced a decrease in organic C content at each observation interval. The organic carbon content will decrease during decomposition because microorganisms use it as an energy source to break down organic matter. The more C-Organic content, the higher the activity of biomass-degrading microbes. The characteristics of the decomposer community on the decomposition of biogeotextile material are influenced by species richness in each litter that can regulate chemical changes in biogeotextile material during the decomposition process, thus having an impact on changes in Carbon content in it (Pérez et al., 2021). The lower the organic carbon content in biogeotextile material, the better the decomposition process carried out by microorganisms. This study found the highest decrease in organic carbon levels in sea pandanus material.

This process involves the decomposition of plant litter by diverse enzymes from various microbes, releasing soil C into the atmosphere and impacting ecosystem diversity, structure, and function (Chen et al., 2023; X. Zhou et al., 2023). Litter decomposition not only affects the formation of soil organic matter but also influences the rate of nutrient release from sediments, thus underscoring the importance of litter in ecosystem function (Su et al., 2022). Therefore, the longer the decomposition rate, the C-Organic content decreases because the

Table 6. Total-N content in each biogeotextile material.

| Materials Biogeotekstil | Interval Observation | | | |
|---|---|---|---|---|
| | Interval 1 | Interval 2 | Interval 3 | Interval 4 |
| RG | 0.41 | 0.41 | 0.38 a | 0.79 a |
| ST | 1.12 | 0.52 | 1.27 b | 2.10 b |
| PO | 0.57 | 1.23 | 1.57 b | 2.08 b |
| SB | 0.88 | 0.40 | 0.39 a | 0.90 a |
| significant 5% | tn | tn | 0.33 | 0.46 |

Note: RG (Reed grass), ST (Straw), PO (*Pandanus odorifer*), SB (Sugarcane bagasse); ns: not signififant at 5% tukey test.

decomposed carbon groups are used for microbial metabolic processes to provide nutrients and accelerate the decomposition rate of each biogeotextile material.

**Decomposition rate of biogeotextile to Total-N content**

Decomposition or mineralization is the conversion of organic material into inorganic material, including nitrogen. This process is part of the degradation of nitrogen-rich materials by microbes. Inorganic nitrogen levels can increase in line with the mineralization process, so organic materials that are easily mineralized can be applied to increase nitrogen levels. Biogeotextiles and mulch are two options for increasing nitrogen levels. Nitrogen levels in various biogeotextile materials are presented in Table 6.

Table 6 shows that the nitrogen value of various biogeotextile materials at intervals 3 and 4 is significantly different, while at intervals 1 and 2, it is not significantly different. In general, all biogeotextile materials experienced an increase in N-Total value. The reed grass (RG) increased in N-Total from 0.41 in interval 1 to 0.79 in interval 4. Straw (ST) experienced an increase in N-Total from 1.12 in interval 1 to 2.10 in interval 4. Pandanus odorifer (PO) increased N-Total from 0.57 in interval 1 to 02.08 in interval 4. Sugarcane Bagasse (SB) increased N-Total from 0.88 at interval 1 to 0.90 at interval 4. The highest increase in interval 4 of biogeotextile constituent materials was straw material, while the lowest increase was reed material. The graph of the N-Total value is presented in Figure 4.

Nitrogen levels in various biogeotextile materials at intervals 3 and 4 are significantly different, while at intervals 1 and 2 are not significantly different. In general, all biogeotextile materials have increased N-Total values. The reed material (RG) experienced an increase in N-Total from 0.41 in interval 1 to 0.79 in interval 4. Straw (ST) experienced a rise in N-Total from 1.12 in interval 1 to 2.10 in interval 4. *Pandanus odorifer* (PO) increased N-Total from 0.57 in interval 1 to 02.08 in interval 4. Sugarcane bagasse (SB) increased N-Total from 0.88 at interval 1 to 0.90 at interval 4. The highest increase in interval 4 of biogeotextile constituent materials was straw material, while the lowest increase was reed material.

Nitrogen is an important nutrient in the decomposition process because it is the main component in the material as a constituent of protein and amino acids. Nitrogen levels in this study increased in all biogeotextile materials because of a mineralization process. N mineralization is a process in which microbial activity converts organic compounds into simpler inorganic compounds such as ammonium or nitrate ions (Kautsar et al., 2022). Various factors influence the mineralization process, one of the most important being the type of organic matter (Fang et al., 2011). The decomposition of biogeotextile materials is an important ecological process that returns nutrients from decayed plant biomass to the soil, impacting soil organic carbon stocks and terrestrial ecosystem carbon dynamics (M. Xu et al., 2023).

The highest nitrogen levels at interval four were found in the straw material and sea pandanus. However, in the straw material, the increase was

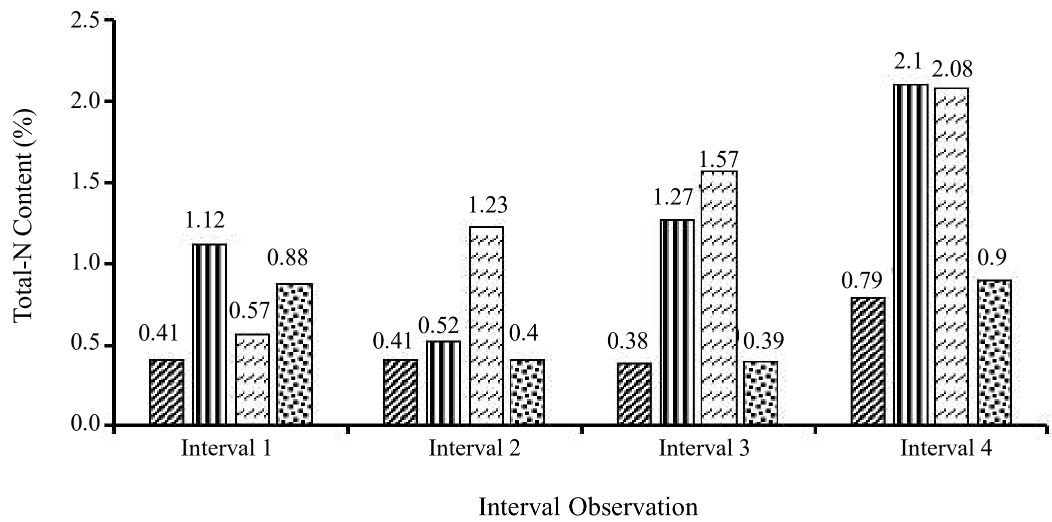


Figure 4. Increase in N-Total content of each biogeotextile material. ▨ : AL, ▥ : JR, ▤ : PL, ▩ : AT.

Table 7. C/N Rasio berbagai macam bahan biogeotekstil.

| Materials Biogeotekstil | Interval Observation | | | |
|---|---|---|---|---|
| | Interval 1 | Interval 2 | Interval 3 | Interval 4 |
| RG | 119.90 | 116.95 | 117.97 | 51.70 |
| ST | 32.93 | 74.88 | 27.09 | 15.06 |
| PO | 79.89 | 36.15 | 27.49 | 10.62 |
| SB | 47.11 | 101.70 | 95.00 | 27.42 |
| Significant 5% | ns | ns | 62.57 | 8.39 |

Note: RG (Reed grass), ST (Straw), PO (*Pandanus odorifer*), SB (Sugarcane bagasse); ns: not signififant at 5% tukey test.

not optimal because it experienced fluctuating changes, while in the sea pandanus material, nitrogen was constantly increasing, so it can be concluded that the mineralization process at each observation interval was most optimal in the sea pandanus material. Nitrogen mineralization is influenced by lignin content or the ratio of lignin to nitrogen, which is an effective index of nitrogen mineralization. Plant materials containing high lignin concentrations experience low nitrogen mineralization (Nakhone & Tabatabai, 2008). Straw has lignin levels ranging from 25-35%, and sea pandanus has lignin levels of 18-22%, which means the mineralization process is more optimal in sea pandanus materials. The quality of biogeotextile materials is essential in determining the decomposition rate, which includes nitrogen content, tannins, and water saturation capacity, which are significant predictors of decomposition rates (Ramos et al., 2021).

**Decomposition rate of biogeotextile to C/N ratio**

The C/N ratio is an important factor affecting a material's decomposition process. The C/N value affects the process between mineralization and immobilization. Table 7 presents the C/N ratio values of various geotextile materials at four observation intervals.

Table 7 shows that the C/N ratio values of various biogeotextile materials at intervals 3 and 4 are significantly different, while at intervals 1 and 2 are not significantly different. Generally, the C/N ratio value of biogeotextile constituent materials decreased until interval 4. The reed grass (RG) material decreased to the C/N level of 51.70. The straw (ST) material decreased to a C/N level of 15.06. The pandanus odorifer (PO) material decreased to a level of 10.62. The sugarcane bagasse (SB) material decreased to reach a level

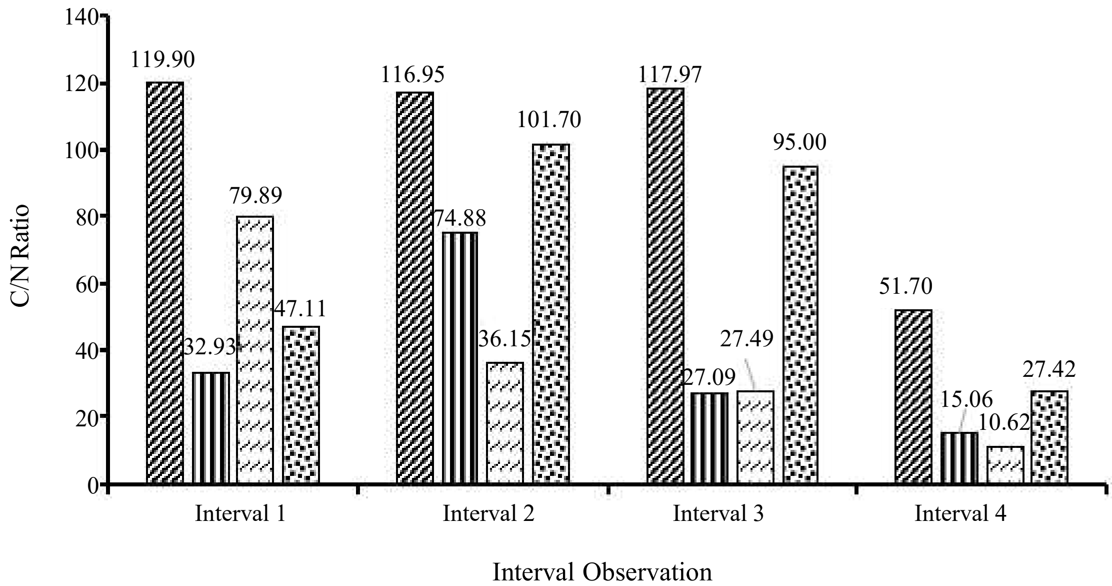


Figure 5. Reduction of the C/N ratio on biogeotextile material. ▨ : AL, ▥ : JR, ▤ : PL, ▦ : AT.

of 27.42. The decrease in the C/N ratio in each material is presented in Figure 5.

The C/N ratio is one of the main parameters used to determine the decomposition rate of a material. The ideal initial C/N ratio of a material used ranges from 25 to 30 (El-Mrini et al., 2022). In this study, the ideal material is straw. In the final decomposition results that are ideal for soil 15-25, this value is found in straw material, which means that the results of straw decomposition are ideal materials to increase soil fertility. Recent research shows that composting can be done effectively at a C/N ratio <15 (Azim et al., 2018). Therefore, based on the observation of the fourth interval, sea pandanus has the most optimal decomposition results in terms of its C/N ratio value.

In general, the decomposition of biogeotextile materials has its advantages. Materials with a relatively fast decomposition rate that can provide soil nutrients include straw. However, straw biomass is more easily decomposed, so it is more easily destroyed when used for mulch. Based on the study's results, the more appropriate material used for mulch is sea pandanus because the decline in plant biomass is slower than straw, bagasse, and reeds. The criteria for suitable materials for mulch are biogeotextile materials that are resistant to weathering so that they last longer and protect the soil surface. In addition, pandanus odorifer biomass also has a total nitrogen content similar to that of straw, so pandanus odorifer also has a good nutrient provision for the soil.

## CONCLUSIONS

The decomposition of several biogeotextile materials, such as reeds, straw, sea pandanus, and bagasse, observed at four observation intervals showed different results. The results showed that the pH parameters increased until the fourth interval, but the most significant was the sea pandanus material. In other parameters, such as biomass, sea pandanus is the highest biogeotextile material after decomposition. The parameters of organic carbon and C/N ratio show similar results, namely, sea pandanus has the lowest value, which means that the decomposition of sea pandanus runs optimally and is followed by an increase in nitrogen. So, sea pandanus is a good biogeotextile material for conservation and improving soil fertility. Decomposition is closely related to the quality of the materials used compared to external factors. The quality of materials, namely lignin, organic carbon, C / N ratio, and nitrogen, has an optimal effect on the quality of biogeotextile materials.

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