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The Effect of Mixing Concentrations of Raw Materials: Coconut Fibre, Banana Fronds, and Water Hyacinth on the Content of Carbon, Nitrogen, Phospor, and Potassium (CPNK) and Biodegradation in Organic Mulch Sheet Planting Media

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Abstract

This study investigates the potential of agricultural biomass waste, including coconut fibre, banana fronds, and water hyacinth, to produce organic sheet mulch with optimal Carbon, Nitrogen, Phosphorus, and Potassium (CPNK) content and biodegradation properties. By evaluating the effect of mixing concentrations of raw materials, this research aims to develop a sustainable and eco-friendly planting medium that supports sustainable agriculture. **:** This study used a Randomised Group Design (RCD) with nine treatment variations and three replications to investigate the effects of mixing raw material concentrations on the properties of organic mulch sheets. Experimental data were analysed using the SPSS 16 Two-Way Analysis of Variance method and Duncan's Multiple Range Test (DMRT) to determine significant differences in organic mulch sheet parameters. The properties of the organic mulch sheets, including moisture content, ash content, biodegradability. In addition, the CPNK test was conducted to further characterise the organic mulch sheets. The optimal treatment will be identified using the Zeleny method. The results showed that the biodegradability ranged from 26.68% to 50.38%, C- organic at 57.8%, N-total at 0.355%, Phospor at 0.531%, Potassium at 0.8355%. The organic sheet mulch developed in this study is a promising eco-friendly planting medium that supports sustainable agriculture. The findings provide a foundation for future research on biodegradable mulch materials.

Keywords: Banana Fronds, Coconut Fiber, Organic Sheet Mulch, and Water Hyacinth

Introduction

The in an effort to support sustainable agricultural practices, biodegradable organic mulch emerges as a promising alternative as an environmentally friendly planting medium. The growing awareness of climate change and the negative impacts of plastic use in agriculture drives the urgent need to develop more ecological solutions. Organic mulch not only functions as a weed controller but also improves soil quality by enhancing its structure, fertility, and moisture retention. Recent research indicates that the use of organic mulch can reduce carbon footprint and negative impacts of chemical use (Karsinah et al., 2023). Additionally, the use of biodegradable mulch can also serve as an effective solution to reduce plastic pollution and enhance ecological functions of

soil (Deng et al., 2019; Velandia et al., 2019). Thus, the development of biodegradable organic mulch can be a strategic step in enhancing agricultural sustainability and mitigating environmental impacts.

The development of organic mulch as an environmentally friendly alternative in agriculture has become an increasingly attractive topic. Organic materials such as coconut coir, banana leaves, and water hyacinth (Eichhornia crassipes) have great potential as organic mulch that can improve soil fertility and health. Coconut coir, as a waste product of coconut production, has a varying air content between 16-23% and organic matter content of 3.57-13.13% (Abidin & Novika, 2024). Rich in cellulose, hemicellulose, and lignin, coconut coir can be used as an effective liquid organic fertilizer (Pangaribuan et al., 2022). The high potassium (K) content in coconut coir can also support photosynthesis, osmoregulation, and cell strengthening in plants (Nugraha et al., 2023). Thus, coconut coir can be an ideal material for improving soil fertility and physical structure.

Banana fronds and water hyacinth have characteristics that support their use as organic mulch materials. Research by Iriany et al. (2022) shows that a mixture of 40% water hyacinth and 40% banana fronds can improve plant growth. Banana fronds are rich in nutrients such as nitrogen, phosphorus, and potassium that are essential for plant growth. When decomposed, banana fronds can provide the necessary nutrients for plants, thereby improving soil health. Water hyacinth also has great potential as a mulch material due to its ability to absorb nutrients from the air and heavy metals from the soil (Suryaningsih, 2017). Additionally, water hyacinth can improve soil quality and serve as a good air quality indicator (Karnelasatri et al., 2020). The use of these materials in organic mulch production can improve soil fertility, plant growth, and reduce environmental problems by converting waste into useful products. The combination of coconut coir, banana fronds, and water hyacinth in organic mulch can provide a practical solution for sustainable and environmentally friendly agriculture.

Biodegradable organic mulch offers various benefits for plant growth by improving soil properties and supporting root growth, thereby promoting better plant growth (Ni et al., 2016). Additionally, the use of organic mulch materials such as straw or agricultural waste can also increase soil moisture retention and reduce evaporation (Goud et al., 2021). In the context of sustainable agriculture, this study aims to explore the potential development of biodegradable organic mulch as an environmentally friendly planting medium that supports more sustainable agricultural practices. By positioning itself at the forefront of agricultural innovation, this research is expected to provide a foundation for further development that can strengthen food security and environmental conservation (Soylu, 2024). The results of this study are expected to provide insights and guidance for future research on more effective and economical biodegradable mulch materials (Cheruiyot et al., 2022; Mohebi et al., 2022).

Research Method

Method

This research was conducted from July 2024 to March 2025 at the Bioindustry Laboratory and Entrepreneurship Laboratory, Faculty of Agricultural Technology, Brawijaya University, Malang, Indonesia. The research design used was a nested randomized block design with 2 factors, namely type and biomass ratio, consisting of 9 treatment combinations with 3 replications, resulting in a total of 27 samples. The

treatment combinations included: coconut coir (M1) with ratios of 90%, 80%, and 70%; banana fronds (P1) with ratios of 10%, 20%, and 30%; and water hyacinth (E1) with ratios of 10%, 20%, and 30%. Additionally, there were control treatments with 100% coconut coir (M1), 100% banana fronds (P1), and 100% water hyacinth (E1). This study aimed to determine the effect of type and biomass ratio on the observed parameters.

Pre-treatment Procedure

The pre-treatment procedure was meticulously conducted in accordance with the methodology outlined by Kusuma (2022), which involved a series of carefully planned steps to ensure optimal preparation of the materials for subsequent treatment. The process commenced with the thorough preparation of materials and equipment for each treatment, followed by a size reduction process that yielded uniform particle sizes ranging from 0.5 to 1 cm. Subsequently, the materials underwent alkaline pre-treatment, a crucial step that aimed to enhance the efficacy of the subsequent treatment processes. By adhering to this established protocol, the pre-treatment procedure was able to achieve its intended objectives, thereby laying the groundwork for successful experimentation.

Analysis CPNK

The CPNK analysis procedure was conducted based on standard methods. The C test was performed using the ashing method, while the N test was conducted using the Kjeldahl method (SNI 19-7030-2004). The P and K tests were carried out according to SNI 2803-2010. The N, P, and K tests were conducted at the Biosain Laboratory, State Polytechnic of Jember.

Analysis Biodegradation

Biodegradation testing of organic mulch is a crucial process to evaluate the effectiveness of materials as environmentally friendly alternatives in agriculture. The burial method is used to assess the biodegradation rate by burying organic mulch samples in soil and observing changes over time. This procedure involves sample preparation, including measuring material proportions and cutting them into small sizes, sample burial at the test site, and monitoring and observing changes in the samples. Chemical and microbiological analyses are also conducted to understand how soil conditions affect biodegradation rates.

By following this procedure, research can provide a clear picture of the biodegradation rate of organic mulch mixtures involving natural materials such as coconut coir, banana fronds, and water hyacinth. The results obtained can be used to understand the effectiveness of material mixtures used as organic mulch and their contribution to sustainable agriculture. This research can also help reduce plastic use and improve soil quality in sustainable agricultural practices

Results and Discussion

Biodegradation

In this study, the biodegradability values of the organic mulch materials, which ranged from 26.68% to 50.38%, showed significant decomposition rates and gave an idea of the effectiveness of using a mixture of natural materials such as coconut fiber, banana fronds, and water hyacinth. This figure is important to assess in the context of poverty and the performance of organic mulches.

The physical and chemical characteristics of mulch materials play a crucial role in the biodegradation process. Coconut fiber, banana fronds, and water hyacinth have high cellulose, hemicellulose, and oligomer content, which can be broken down by microorganisms in the soil. The chemical structure of the material also affects biodegradability, where more easily decomposable compounds tend to have higher biodegradability rates. Therefore, understanding the physical and chemical characteristics of mulch materials is essential to determine their effectiveness as environmentally friendly alternatives in agriculture.

Environmental factors such as temperature, humidity, and the presence of microorganisms in the soil play a crucial role in determining the efficiency of the biodegradation process. Research by Thompson et al. shows that ideal environmental conditions, such as sufficient humidity and warm temperatures, can increase the rate of biodegradation (Thompson et al., 2019). Thus, the biodegradation results obtained can be influenced by the environmental conditions during the biodegradation process.

The success of biodegradation is highly dependent on the activity of microbes in the soil. Microbes that can break down cellulose and lignin components in mulch materials are key to achieving higher biodegradation rates (Rose et al., 2019; Westlake et al., 2023). The presence of a healthy microbial community in the soil enables the decomposition of organic matter to occur more quickly and efficiently. Therefore, it is essential to understand the role of microbes in the biodegradation process.

Other studies have shown that biodegradability values are similar for organic-based materials. For example, research by Wortman et al. shows that biodegradation of degradable plastic mulch can be in a similar range depending on composition and environmental conditions (Wortman et al., 2016). This suggests that the values of 26.68% to 50.38% are consistent with existing research, indicating the validity of the measurement.

By comparing the biodegradation results with other studies, it can be concluded that the biodegradation measurement conducted has high validity. The biodegradation values obtained are consistent with other research, indicating that the measurement method used is effective in determining the rate of biodegradation. Therefore, the results of this study can be used as a reference to understand the biodegradation process of organic mulch materials.

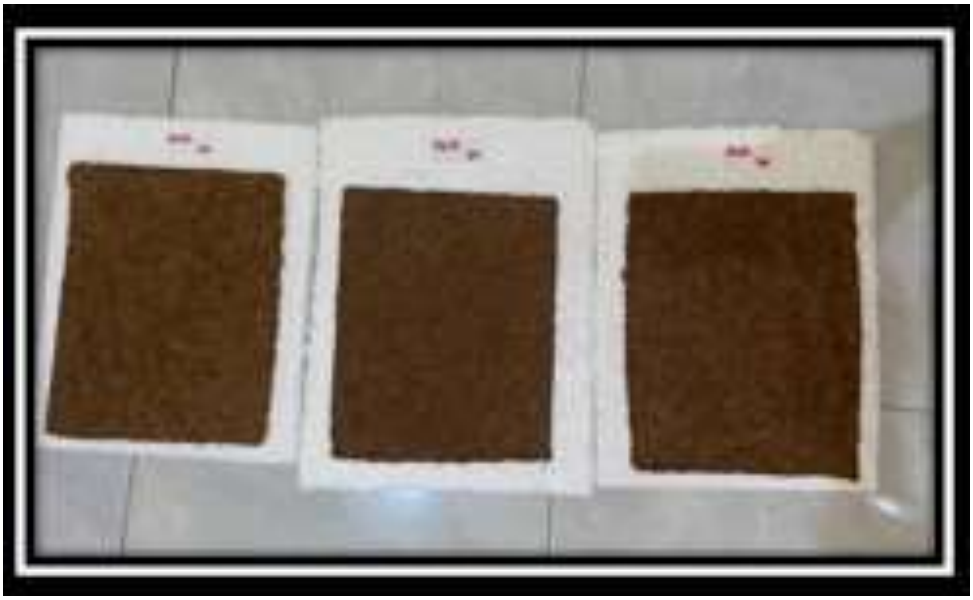

Figure 1. Organic Sheet Mulch

Analys C-PNK

- **Organic Carbon (C)**
  The high organic carbon content in organic mulch, which is 57.8%, indicates that this material is rich in organic matter that can increase carbon storage in the soil. Carbon is a key element in building good soil structure, increasing air retention capacity, and providing protection for soil microorganisms. Thus, biodegradable mulch rich in carbon can contribute to improving soil health and beneficial microbial activity, supporting sustainable agriculture.
- **Nitrogen (N)**
  The total nitrogen content of 0.355% in organic mulch indicates that this material can provide a source of nutrients for plants. Nitrogen is a crucial element in the formation of protein and chlorophyll, which directly impacts plant growth. The availability of nitrogen from organic mulch will depend on the biodegradation process and microbial activity in the soil, making it essential to understand the role of nitrogen in supporting healthy and productive plant growth.
- **Phosphorus (P)**
  The phosphorus content of 0.531% in organic mulch supports root development and increased crop yields. Phosphorus is an essential element for energy metabolism in plants and is particularly necessary during the early growth phase. Thus, phosphorus can increase plant resistance to environmental stress and improve nutrient use efficiency and overall plant quality. Therefore, the phosphorus content in organic mulch can provide significant benefits for plants.
- **Potassium (K)**
  The potassium content of 0.8355% in mulch indicates that this material is also rich in potassium, which plays a crucial role in photosynthesis, air regulation in plant tissues, and increasing resistance to pests. Potassium functions to regulate osmotic balance in plant cells, contributing to plant health and productivity. Thus, the availability of potassium in organic mulch can provide benefits in increasing crop yields and quality, as well as supporting sustainable agriculture.

Table 1. Parameters of Concentration Organic Sheet Mulch

Concentration	Water calcity	Dry Weight	Organic matter weig	Water Absorption	Tensile stren	Yield	Biodegradation	Density	C-Organik	N-Total	P	K
	min	max	max	max	max	max	max	max	max	max	max	max
M1	2,72	91,1	80	223	6,72	81,33	50,38	0,43	57,246	0,211	0,061	0,2563
P1	5,58	90,1	77	244	9,97	79,6	39,22	0,33	54,52	0,326	0,531	0,3469
E1	8,83	89,8	72	229	5,11	64,67	28,3	0,31	49,429	0,286	0,173	0,8355
M1E1	5,8	91,5	75	173	8,88	54	47,1	0,3	57,8	0,171	0,058	0,2105
M2E2	4,25	91,7	72	204	7,94	57,33	36,23	0,27	56,987	0,292	0,088	0,2297
M3E3	4,25	88,8	77	232	7,08	53,87	26,68	0,22	56,704	0,305	0,071	0,2236
M1P1	4,45	90,8	76	237	9,09	70,13	37,87	0,31	57,08	0,355	0,497	0,2524
M2P2	3,48	91,5	73	230	9,21	66,27	28,63	0,31	57,095	0,246	0,054	0,1847
M3P3	3,42	89,3	76	257	9,38	68,93	38,99	0,26	57,021	0,274	0,056	0,2034
Divisor	2,72	91,7	80	257	9,97	81,33	50,38	0,43	57,8	0,355	0,531	0,8355

Conclusion

The biodegradability of the organic mulch developed in this study ranged from 26.68% to 50.38%, indicating a promising potential for environmentally friendly applications. The chemical composition of the organic mulch also showed favorable results, with an organic carbon content of 57.8%, total nitrogen of 0.355%, phosphorus of 0.531%, and potassium of 0.8355%. The optimal treatment was achieved with a composition of 90% coconut coir and 10% banana pseudostem. The organic sheet mulch developed in this study is a promising eco-friendly planting medium that supports sustainable agriculture. These findings provide a foundation for future research on biodegradable mulch materials, which can be used as a more environmentally friendly alternative in agriculture. Thus, this study contributes to the development of sustainable agricultural technologies that are more environmentally friendly and can help reduce the environmental impact of agricultural practices

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