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Potential Use of *Tithonia diversifolia* Plants to Improve Productivity of Marginal Land for Enhancing Growth and Yield of Agricultural Crops in West Kalimantan

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ABSTRACT

West Kalimantan has a total area of marginal land reaching 1,015,631 ha, which has the potential for agricultural use, but it requires appropriate land management techniques due to its naturally low fertility. This research aimed at assessing the potential of *Tithonia diversifolia* fertilizer as soil fertility enhancer for marginal land. The study was conducted from January 2019 to February 2020. It involved three stages: stage 1 was the planting of *T. diversifolia* in former gold mining soil, stage 2 was the planting of eggplants in red-yellow podzolic soil and stage 3 was the planting of spinach in alluvial soil. The research utilized a randomized block design using polybags. The results indicated that the application of *T. diversifolia* fertilizer improved the growth and yield of eggplants in red-yellow podzolic soil and spinach in alluvial soil. Moreover, *T. diversifolia* was also effective in soil reclamation on former gold mining sites, as evidenced by a mercury content reduction up to 45.61%.

Key words: Marginal soils, soil fertility, *Tithonia diversifolia*, West Kalimantan

INTRODUCTION

The world's growing population and increased demand for food have led farmers to use marginal lands for agriculture, such as acid sulphate soils and alluvial soils found in the tropics, because more and more fertile land is being converted to other uses like urbanization and industrial production (Panhwar *et al.*, 2020). Marginal land is a nutrient-poor terrestrial ecosystem, and its use is not optimal because of its minimal soil organic matter content (Wan *et al.*, 2021). However, the optimization of marginal land use is relatively unknown to many people because of unfavourable soil conditions, namely, dry and poor nutrients, which make the land less fertile and unfavourable for agriculture. Marginal soil fertility is relatively low, as indicated by the reaction of acidic soil, low nutrient reserves, alkaline exchange capacity, and low base saturation, while high to very high aluminium saturation (Mutammimah *et al.*, 2020).

There are 1,015,631 ha of critical or marginal land in West Kalimantan, which has the potential to be used for agriculture but requires the proper land management methods due to its inherently poor fertility (BPS, 2018). It is well recognized that organic materials can be used to amend soil and increase soil fertility. It has been discovered that adding organic materials to soil can ensure nutrient availability while also maintaining the organic matter content of the soil (Dayo-Olagbende *et al.*, 2020).

Due of the comparatively high nutrient concentration, *T. diversifolia* has recently attracted research attention with a focus on food security, soil sustainability and the recycling of organic matter (Silva *et al.*, 2021). According to Dayo-Olagbende *et al.* (2020), *T. diversifolia* has enormous potential to boost food production. *T. diversifolia* organic fertilizer can raise cauliflower yield and enhance the physical and chemical quality of Inceptisol soil, according to research by Hafifah *et al.* (2016). *T. diversifolia* organic fertilizer was found to increase the chemical quality of soil, nitrogen absorption and maize growth in deteriorated sandy soil in Malang, East Java, according to Farni *et al.* (2022). The application of *T. diversifolia* enhanced the quality of clay varied soils in Nigeria, according to Dayo-Olagbende *et al.* (2020). These researches demonstrate that organic fertilizer made from *T. diversifolia* can increase crop yield and soil quality in a variety of soil types.

The expected use of *T. diversifolia* as green manure can replace inorganic fertilizer to improve soil productivity and to increase crop yield is based on its role and function as a soil amendment to maintain and improve the physical, chemical, and biological properties of soil and increase the availability of nutrients in the soil (Adekiya *et al.*, 2022). This research aimed at evaluating the *T. diversifolia* fertilizer's potential as a soil fertility enhancer in West Kalimantan's marginal land.

MATERIALS AND METHODS

This experiment was carried out at the greenhouse of the Faculty of Agriculture, Panca Bhakti University, Pontianak, from January 2019 to February 2020. It involved three stages: stage 1 was the planting of *T. diversifolia* in former gold mining soil, stage 2 was the planting of eggplants in red-yellow podzolic soil and stage 3 was the planting of spinach in alluvial soil.

The research utilized a randomized block design using polybags. The parameters observed were the growth and yield of each crop in the three stages of the study. F test at a rate of 5% was used to see the effect of all treatments. The Tukey test was carried out at the level of 5% to see a real difference in each level of treatment. The materials used in this experiment were *T. diversifolia* organic fertilizer, eggplant seeds, spinach seeds, agricultural lime, polybags and organic pesticides. The equipment used in the experiment consisted of biomass enumerators, sickles, hoes, machetes, thermometers, hygrometers, meters, scales, measuring cups, plastic buckets, plastic tubs and office stationery.

The organic fertilizer was derived from the leaves and branches of *T. diversifolia*, which were chopped into 1-2 cm pieces. The experiment in stage 1 used *T. diversifolia* as a phytoremediator and soil fertility enhancer in post-gold mining soil. The experiment was conducted from January 2019 to June 2019 on soil from post-gold mining soil in Mandor District, Landak Regency, West Kalimantan. Seeds of *T. diversifolia* were planted in polybags containing post-gold mining soil, and then given 15 t/ha of *T. diversifolia* fertilizer. The experiment was repeated three times, with two plants planted in each experiment. The parameters observed were plant growth, wet and dry weight and reduction of mercury content in the soil.

The experiment in stage 2 used *T. diversifolia* fertilizer on eggplant (*Solanum melongena*) plants in yellowish-red podzolic soil. Before use, the red-yellow podzolic soil was cleaned, air-dried and sifted so that the soil medium was more homogeneous. The liming process was carried out to reduce the level of acidification (increase the pH) of the soil. The lime used to reduce soil acidification was dolomite $[CaMg(Co_3)_2]$ at a 40 g/polybag dose. Liming was carried out two weeks before planting. Eggplant seeds were first sown for four weeks after which they were transferred into polybags. Each pot was filled with one seedling. The *T. diversifolia* fertilizer given at the time of planting consisted of three levels, namely, T_1 – 10 t/ha, T_2 – 15 t/ha, and T_3 – 20 t/ha. The experiment was repeated three times. The parameters observed were the growth and yield of eggplant.

The experiment in phase three used *T. diversifolia* fertilizer on spinach plants (*Amaranthus tricolor*) in alluvial soil. Before use, the alluvial soil was treated as yellowish-red podzolic soil. The *T. diversifolia* fertilizer given at the time of planting consisted of same three levels as in stage 2. Spinach seeds before planting in polybags were first sown for one week after which they were transferred into polybags. Each pot was filled with one seedling. The experiment was repeated three times. The parameters observed were the growth and yield of the spinach plants.

RESULTS AND DISCUSSION

The nutrient contents, including C, N, P, K, Ca and Mg in *T. diversifolia* were quite high with a low C/N ratio (Table 1). With such nutrient contents, it enabled the biomass of these plants to become a highly potential source of organic material that can improve the chemical properties of the soil by enhancing the availability of nutrients in the soil.

The soil fertility status and mercury metal content of post-gold mining soils were taken in a composite manner from several points considering factors such as distance from the

Table 1. The nutrient content of *Tithonia diversifolia* biomass

Nutrient content	*Tithonia diversifolia*
C - Organic (%)	24.2
N (%)	2.23
P (%)	0.48
K (%)	3.31
Ca (%)	2.60
Mg (%)	0.61
C/N	10.85

river, road, land physiography and soil sampling depth (Table 2). It indicated that the soil pH was 3.82, categorizing it as acidic. The organic carbon content was only 0.104%, classifying as very low. Similarly, nitrogen content was also very low. The levels of several other nutrient elements such as phosphorus, potassium, sodium, calcium and magnesium were very low with high hydrogen and low aluminium. Similarly, both Cation Exchange Capacity (CEC) and Base Saturation (BS) were categorized as low. CEC is a chemical property closely related to soil fertility. Soils with high CEC (ranging from 25-40 cmol (+)/kg) are capable of absorbing and providing nutrients better than soils with low CEC. Soils with high organic matter or high clay content typically have higher CEC values than soils with low organic matter or sandy soils (Soinne *et al.*, 2021). Meanwhile, base saturation indicates the soil's ability to provide nutrients, especially basic cations. Fertile soils tend to have high base saturation values.

The texture of post-gold mining soil was classified as sandy. This soil was predominantly composed of sand, accounting for 89.90%, followed by silt at only 2.70%, and a dust content of 7.05%. Soils with a sandy texture, due to their larger particle size, had a smaller surface area per unit weight, making it difficult to retain water and nutrients. Under these conditions, plants growing in such soil often exhibited symptoms of nutrient deficiency and tended to grow stunted and thin. *T. diversifolia* plants were able to grow well and produce very high growth (Table 3). This indicated that *T. diversifolia* had the ability to adapt to very low soil fertility levels and high mercury concentrations above normal levels (Table 4). Laboratory analysis results of heavy metal mercury (Hg) content showed that the Hg content was 0.403 ppm which was quite high and exceeded the normal threshold level of 0.01-0.3 ppm, while the critical concentration threshold is 0.3-0.5 ppm. From the analysis, it can be seen that there was a reduction in mercury content in the soil after remediation using *T. diversifolia*.

Table 2. Post-gold mining soil analysis

Parameters		Value	Criteria
pH H_2O	-	3.82	Acid
pH KCl	-	3.43	
C-Organic	%	0.104	Very low
Total nitrogen	%	0.07	Very low
P2O5	ppm	4.40	Very low
Kalium	cmol (+)/kg	0.25	Very low
Natrium	cmol (+)/kg	0.31	Very low
Calcium	cmol (+)/kg	0.20	Very low
Magnesium	cmol (+)/kg	0.44	Very low
CEC	cmol (+)/kg	15.74	Low
Base saturation	%	19.18	Very low
-Hidrogren	cmol (+)/kg	3.10	High
-Aluminium	cmol (+)/kg	0.78	Low
Texture			
-Sand	%	89.90	Sandy
-Silt	%	7.40	
-Clay	%	2.70	

Table 4. Reduction of mercury content in soil

Treatment	Before treatment (ppm)	After treatment (ppm)	Mercury reduction percentage
Tithonia diversifolia	0.403	0.2192	45.61

The texture of red-yellow podzolic soil was silty clay (Table 5). The penetration ability of plant roots and soil water retention are largely determined by soil texture. In addition, soil texture can also influence the chemical and biological properties of the soil (Pusparani, 2018). The soil pH in this study was 4.73, which was classified as acidic. Soil pH can influence the supply of plant nutrient levels due to chemical reactions in soil colloids which are regulated by the electrochemical properties of the soil. A number of nutrients will be less

Table 3. Growth of *Tithonia diversifolia* plants in post-gold mining soil

Treatment	Plant height (cm)	No. of leaves	No. of branches	Wet weight		Dry weight	
				Shoots	Roots	Shoots	Roots
Tithonia diversifolia	82.55	26.67	3.06	68.89	25.11	25.00	8.33

Table 5. Red-yellow podzolic soil analysis

Parameters		Value	Criteria
pH H_2O	-	4.73	Acidic
pH KCl	-	4.11	
C-Organic	%	2.09	Adequate
Total nitrogen	%	0.23	Adequate
Total P_2O_5	ppm	20.60	Very high
Calcium	cmol (+)/kg	0.25	Very low
Magnesium	cmol (+)/kg	0.10	Very low
Kalium	cmol (+)/kg	0.15	Low
Natrium	cmol (+)/kg	0.13	Low
CEC	cmol (+)/kg	9.18	Low
Base saturation	%	7.95	Very low
Aluminium	cmol (+)/kg	0.90	
Hidrogen	cmol (+)/kg	0.27	
Texture			
Sand	%	17.11	Silty clay
Silt	%	43.90	
Clay	%	38.99	

Table 7. Alluvial soil analysis

Parameters		Value	Criteria
pH H_2O	-	4.20	Highly acid
pH KCl	-	3.54	
C-Organic	%	2.39	Adequate
Total nitrogen	%	0.29	Adequate
P2O5	ppm	12.87	High
Calcium	cmol (+)/kg	1.22	Very low
Magnesium	cmol (+)/kg	1.12	Adequate
Kalium	cmol (+)/kg	0.14	Low
Natrium	cmol (+)/kg	0.25	Low
CEC	cmol (+)/kg	10.30	Low
Base saturation	%	26.50	Low
Aluminium	cmol (+)/kg	0.75	
Hidrogen	cmol (+)/kg	0.60	
Texture			Silty clay
Sand	%	1.24	
Silt	%	56.27	
Clay	%	42.49	

available in very acidic conditions. Iron phosphate which cannot dissolve at acid condition will fix the P element, causing the availability of P to be very limited (Manurung *et al.*, 2017). The C-Organic parameter showed a value of 2.09% (adequate). The C-Organic content is an important factor determining the quality of mineral soil, the higher the total C-Organic content, the better the soil quality. Base saturation and CEC values in the soil were also classified as very low and low. This implied that the availability of nutrients in the soil was low.

Analysis of variance for all parameters had a significant effect with the application of *T. diversifolia* fertilizer. The application of 20 t/ha of *T. diversifolia* (T_3) provided the best results for all observed parameters of growth and yield in eggplant (Table 6).

The soil texture of alluvial soil is silty clay (Table 7). The penetration ability of plant roots and soil water retention are largely determined by soil texture. In addition, soil texture can also influence the chemical and biological properties of the soil (Pusparani, 2018). The soil pH in this research was 4.20, which was classified as highly acidic. Soil pH can influence the supply of plant nutrient levels due to chemical reactions in soil colloids which are regulated by the electrochemical properties of the soil. Soil acidification occurs as a result of the presence of a layer of pyrite (FeS2) which undergoes oxidation (Khairullah and Noor, 2018). A number of nutrients will be less available in very acidic conditions. Iron phosphate which cannot dissolve at acid condition will fix the P element, causing the availability of P to be very limited (Manurung *et al.*, 2017). Apart from nutrient unavailability, plants can also experience Al and Fe poisoning as a result of the pyrite oxidation process, which can affect growth. Soil ameliorant such as organic materials, biochar and biomass ash is known to improve soil pH, reduce the toxicity of aluminium and iron, improve water content and soil permeability and increase nutrient availability. The C-Organic parameter showed a value of 2.39% (adequate). The C-Organic content is an important factor determining the quality of mineral soil, the higher the total C-Organic content, the better the soil quality. Base saturation and CEC values in the soil were also classified as low. This implied that the availability of nutrients in the soil was low.

Analysis of variance for plant height, number of leaves, plant weight and root volume

Table 6. Effect of *Tithonia diversifolia* fertilizer on the growth and yield of eggplant in red-yellow podzolic soil

Administration of *T. diversifolia*	Plant height (cm)	No. of leaves	No. of fruits	Fruit length (cm)	Fruit diameter (mm)	Fruit weight (g)
T_1	57.61±1.07a	34.50±2.75a	7.52±0.13a	17.80±0.10a	41.13±0.85a	1031.69±43.40a
T_2	60.50±0.28b	40.11±1.35b	8.45±0.77ab	18.67±0.12a	42.11±1.12ab	1098.90±57.53ab
T_3	62.33±1.04c	41.22±0.53b	8.93±0.12b	19.60±0.86b	43.22±0.47b	1182.75±14.57b

Same letters are not significant.

parameters had a noticeable effect with the application of *T. diversifolia* fertilizer. Spinach with the application of *T. diversifolia* biomass of 20 t/ha (T_3) had the best growth on all parameters (Table 8). Overall, the application of 15-20 t/ha of *T. diversifolia* organic fertilizer can improve the quality of marginal soil used in all three stages of the research. This is consistent with previous studies conducted by Hafifah *et al.* (2016), Dayo-Olagbende *et al.* (2020) and Farni *et al.* (2022).

The addition of organic fertilizers has a significant impact on the activity of microflora and microfauna in the soil, enhancing soil quality, aeration, moisture retention and increasing the soil's capacity for buffering and exchange (Hafifah *et al.*, 2016).

Green manure of *T. diversifolia* had C-organic 24.2%, N 2.23%, P 0.48%, K 3.31%, Ca 2.60%, Mg 0.61% and C/N 10.85 (Table 1). The green manure content of *T. diversifolia* in this study is similar from the research conducted by Hafifah *et al.* (2016) 31.76% C-organic, 4.46% total N, 7.12 C/N ratio, 54.91% organic matter, 0.61% total P and 3.75% total K. Additionally, green manure of *Tithonia diversifolia* contributed more favourably to a decrease in soil bulk density as well as increase in soil organic carbon, total soil N, total porosity, soil P availability and soil K exchangeable in inceptisol soil.

Increased soil porosity and aeration as a result of the treatment of organic manure also contribute to the soil's increased water-holding capacity, which is related to soil water retention (Das and Ghosh, 2022). High levels of organic matter can improve soil's ability to retain water. Adding organic manures increases the soil's ability to hold water compared to applying simply inorganic fertilizer (Rashmi *et al.*, 2020). In addition to the provision of essential plant nutrients to soils, organic manure improves soil structure through enhanced soil water holding capacity, aeration and drainage which encourage good root formation and plant growth (Wiesmeier *et al.*, 2015).

Organic matter causes an increase in pH that is linked to an exchange process between –OH free and organic acid anions, which raise the concentration of OH ions in the soil solution (Puteri *et al.*, 2021). It demonstrates how applying *T. diversifolia* green manure suspected to be able to enhance soil organic matter.

Utilization of organic material due to the production of organic acids during the breakdown of organic materials, *T. diversifolia* has been shown to enhance soil P levels (Setyowati *et al.*, 2022). The complex metals with Al and Fe also limit the reactivity of Al and Fe on P fixation. This method may aid in reducing P sorption and solubilizing P. Organic acids also combined with clay minerals to create complexes, which added H+ ions to the surface of the clay mineral, giving it a positive charge (Arif *et al.*, 2021). The clay mineral's positive charge will draw organic anion (R-COO) from organic material, forming the organocompound (Al-chelate) with Al and fe complexes. The type of organic acids released during the decomposition process and the soil pH have an impact on how much accessible P is in the soil when it uses the chelate mechanism. Chelates can dissolve more inorganic phosphate, increasing the amount of accessible P in the soil (Gao *et al.*, 2020).

The rise in exchangeable K on plots treated with *T. diversifolia* was most likely brought on by a significant release of this nutrient from the decaying residues that had high K concentrations. This was made possible by the *T. diversifolia* biomass's provision of macronutrients (N, P, K, Ca and Mg), as well as microelements. The use of *T. diversifolia* in the medium reduced the demand for nitrogen and potassium from inorganic fertilizers, enhanced soil acidity, decreased the solubility of aluminum and preserved the soil's supply of important minerals like phosphorus, calcium and magnesium (Rusaati *et al.*, 2020). Nitrogen

Table 8. Effect of *T. diversifolia* fertilizer on the growth of spinach plant in alluvial soil

Administration of *T. diversifolia*	Plant height (cm)	No. of leaves	Plant weight (g)	Root volume (cm^3)
T_1	16.07±1.39b	9.02±1.79b	22.04±2.24b	5.70±0.71b
T_2	16.37±1.99b	9.20±2.02b	22.86±3.47b	6.04±1.04b
T_3	19.44±1.73c	10.91±2.15c	32.38±5.65c	8.13±1.70c

Same letters are not significant.

contributed to vegetative growth, but element P contributed to enzymatic processes that were crucial for cell division and directly correlated with plant height. The preservation of turgor pressure, which was essential for enhancing metabolic and photosynthesisal activities, was facilitated by element K (Chen *et al.*, 2022).

CONCLUSION

The application of *T. diversifolia* fertilizer improved the growth and yield of eggplants in red-yellow podzolic soil and spinach in alluvial soil. Moreover, *T. diversifolia* was also effective in soil reclamation on former gold mining sites, as evidenced by a mercury content reduction up to 45.61%.

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