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Comparative Study of *Mucuna bracteata* DC. and *Pueraria phaseoloides* Cover Crop on the Physical Properties of Ultisol Soil

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ABSTRACT

Ultisol soil is known has poor physical properties like high bulk density, low porosity, acidic pH, and low organic matter and nitrogen. This study was conducted to compare the effects of two cover crops: *Mucuna bracteata* DC. and *Pueraria phaseoloides*. This study was conducted in a greenhouse setting. Result showed that both cover crops improved the physical properties of the soil, where the *Pueraria phaseoloides* showed a greater positive impact, notably reducing the bulk density, increasing the porosity, and enhancing the soil pH, organic matter, and nitrogen levels. Therefore, *Pueraria phaseoloides* is recommended as a more effective cover crop for improving Ultisol soil quality.

Keyword: *Mucuna bracteata* DC., Physical properties of soil, *Pueraria phaseoloides*, Ultisol soil

1. Introduction

Soil is a natural material composed of solid, liquid, and gas components, and plays a vital role as a growing medium for plants and a habitat for organisms [1]. Ultisols are a widespread soil type in Indonesia, particularly in Kalimantan and Sumatra, with physical and chemical characteristics that are less conducive to fertility, such as low porosity, acidic pH, and low organic matter content [2]. The use of cover crops, particularly legumes such as *Mucuna bracteata* DC. and *Pueraria phaseoloides*, is considered effective in improving the physical and chemical properties of Ultisols. *Mucuna bracteata* DC. is known to suppress weeds and fix nitrogen [3]. *Pueraria phaseoloides* has good resilience and can increase soil fertility and control erosion [4].

Various methods can be applied to improve soil physical and chemical characteristics, such as the application of inorganic fertilizers, lime, compost, and soil amendments. However, these approaches often require continuous input and may have long-term environmental impacts. Therefore, the use of cover crops has gained attention as a more sustainable and environmentally friendly alternative. Cover crops not only contribute organic matter to the soil but also improve soil structure, enhance biological activity, reduce erosion, and increase nutrient availability through natural processes. In addition, leguminous cover crops are capable of fixing atmospheric nitrogen, which further supports soil fertility improvement. For these reasons, this study focuses on the use of *Mucuna bracteata* DC. and *Pueraria phaseoloides* as sustainable biological approaches to improving Ultisol soil properties.

Research on the effects of cover crops *Mucuna bracteata* DC. and *Pueraria phaseoloides* on the physical properties of Ultisol soils is still rare, directly comparing the two crops. Mucuna bracteata DC. can increase biomass, improve soil structure, and increase nitrogen content through symbiosis with Rhizobium [5]. The use of compost also improves oil palm growth and the physical and chemical properties of Ultisol soils [6]. *Pueraria phaseoloides* is resistant to acidic soils and nutrient deficiencies, effectively suppresses weeds, and improves soil structure through the addition of organic matter [7]. This study lasted one month during the early growth phase, with the aim of comparing the effects of the two cover crops to provide recommendations for the most effective plants in sustainable Ultisol soil management.

However, studies directly comparing the short-term effects of *Mucuna bracteata* DC. and *Pueraria phaseoloides* on the physical and chemical properties of Ultisol soil under greenhouse conditions are still limited. Therefore, the novelty of this study lies in the direct comparison of these two leguminous cover crops within a short experimental period. This study aimed to evaluate and compare their effects on selected physical and chemical properties of Ultisol soil to determine the more effective species for sustainable soil management.

2. Methods

2.1. Research Location

This research was conducted from February to March 2025 in the Greenhouse of the Central Laboratory, Faculty of Agriculture, Universitas Sumatera Utara, Indonesia. The Ultisol soil samples were collected from Bandar Labuhan Village, Tanjung Morawa District, Deli Serdang Regency, North Sumatra Province.

Based on regional soil classification data, the dominant soil type in the sampling area is classified as Ultisol according to the USDA Soil Taxonomy system. In the Indonesian soil classification system, this soil is commonly referred to as podzolic soil. The classification confirms that the soil sample used in this study belongs to the Ultisol order.

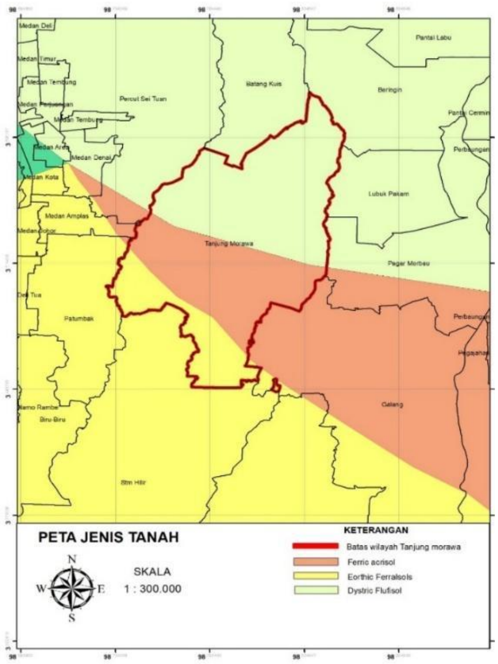

Figure 1. Type of Soil Map

2.2. Material and Tools

The materials used in this research consisted of Ultisol soil samples, seeds of *Mucuna bracteata* DC., and seeds of *Pueraria phaseoloides*, which had been previously selected and screened for uniformity. Polybags measuring 18 × 21 cm were used as planting containers.

The tools utilized in this study included a soil thermometer for measuring soil temperature, a pH meter for measuring soil acidity, weighing scales for determining soil mass, and laboratory equipment for analyzing bulk density, particle density, porosity, organic matter content, and total nitrogen.

2.3 Reseach Design

This study employed an experimental method using a Completely Randomized Design (CRD). The experiment consisted of three treatments, namely P0 : Control (without cover crop); P1 : *Mucuna bracteata* DC.; P2 : *Pueraria phaseoloides*. Each treatment was replicated six times, resulting in a total of 18 experimental units. The experiment was conducted under greenhouse conditions for one month during the early growth phase of the cover crops. The observed parameters included soil texture, bulk density, particle density, porosity, soil pH, soil temperature, organic matter content, and total nitrogen content. Data obtained were analyzed to compare the effect of each cover crop treatment on the physical and chemical properties of Ultisol soil.

2.4. Soil Physical Properties Measurement

The physical properties of the soil analyzed in this study included soil texture, bulk density, particle density, porosity, and soil temperature.

2.4.1 Soil Texture

Soil texture was determined in the laboratory by measuring the percentage of sand, silt, and clay fractions. The analysis was carried out using the hydrometer method (Bouyoucos method), which is based on the sedimentation rate of soil particles in suspension according to Stokes' law. In this method, soil samples were dispersed in a solution and allowed to settle, and hydrometer readings were taken at specific time intervals to estimate the proportions of sand, silt, and clay. Texture classification was determined based on the relative proportion of these fractions using the soil texture triangle.

2.4.2. Bulk Density

Bulk density (ρb) was calculated as the ratio between the mass of oven-dried soil and the total soil volume using the following formula: [8]

$$(\rho b) = \frac{Mp}{Vt} \tag{1}$$

Where
ρb = Bulk density (g/cm³)
Mp = Mass of soil solids (g)
Vt = Total volume (cm³)

2.5. Particle Density

Particle density (ρs) was determined as the mass of soil solids per unit volume of soil particles using the formula: [8]

$$(\rho s) = \frac{Mp}{Vp} \tag{2}$$

Where
ρs = Particle density (g/cm³)
Mp = Mass of soil solids (g)
Vp = Soil solids volume (cm³)

2.6. Porosity

Soil porosity was calculated using the relationship between bulk density and particle density [8]

$$(\mathrm{Pt}) = \left(1 - \left(\frac{\rho b}{\rho s}\right)\right) x100\% \tag{3}$$

Where
Pt: Total soil porosity (%)
ρb: Soil bulk density (g/cm³)
ρs: Soil particle density (g/cm³)

The soil porosity classification according to Sutanto (2005) is shown in Table 1. [9]

Table 1. Soil Porosity Classes

Porosity (%)	Class
100	Extremely Porous
60-80	Porous
50-60	Good
40-50	Fair
30-40	Poor
<30	Very Poor

2.7. Soil Temperature

Soil temperature refers to the thermal condition within the soil profile and plays an essential role in supporting plant growth and development. An optimal soil temperature for most plant species generally ranges between 20°C and 30°C. When soil temperature falls below 20°C (suboptimal) or exceeds 35°C (supraoptimal), plant growth tends to decline significantly. Furthermore, various physical, chemical, and biological processes occurring in the soil are strongly influenced by soil temperature (Ali and Omofunmi, 2021). Soil temperature was recorded daily at a depth of 5 cm using a soil thermometer, and measurements were conducted at 09:00 a.m. throughout the experimental period to maintain consistency.

2.8. Soil Chemical Properties Measurement

The chemical properties analyzed included soil pH, organic matter content, and total nitrogen content.

2.8.1 Soil pH

Soil pH was measured using a pH meter in the laboratory. The classification of soil pH followed the criteria established by the Soil Research Center (1983).

2.8.2 Organic Matter Content

Organic matter content was calculated using the formula: [10]

$$OM = \%\ Organic\ C \times 1.724 \tag{4}$$

Where

OM = Organic Matter
% Organic C = Percentage of Organic Carbon content in the soil
1.724 = Conversion factor used to convert Organic Carbon content to Organic Matter

2.8.3 Total Nitrogen

Total nitrogen content was analyzed in the laboratory using standard soil analysis procedures and expressed as a percentage (%).

2.9. Data Analysis

The data obtained from all measured parameters were analyzed descriptively and statistically to compare the effects of each treatment. Analysis of variance (ANOVA) was applied to determine significant differences among treatments at a 5% significance level.

3. Result and discussion

3.1 Soil Texture

The soil texture measurement data can be seen in Table 2. Soil texture before treatment showed slight variation, with sand content ranging from 54–58% and clay content from 34–38%. After the cover crop treatment, the measured sand fraction ranged from 75–79% and clay fraction from 14–16%, resulting in a sandy loam classification across treatments. However, soil texture is generally considered a permanent soil property that is not easily altered within a short experimental period [11]. Therefore, the observed differences in particle fraction percentages are more likely attributed to sampling variability or measurement differences rather than actual changes in soil particle size distribution. Although texture itself remains relatively stable, improvements in soil structure, aggregation, and porosity may influence soil physical behavior without fundamentally changing the soil texture class.

Table 2. Results of soil texture measurements

Treatment	Before treatment			Soil texture	After treatment			Soil texture
	Fraction (%)				Fraction (%)			
	Sand	Silt	Clay		Sand	Silt	Clay	
P0 (Control)	54	10	36	Sandy Loam	79	5	16	Sandy Loam
P1 (*Mucuna bracteata* DC.)	58	8	34	Sandy Clay Loam	75	11	14	Sandy Loam
P2 (*Pueraria phaseoloides*)	56	6	38	Sandy Clay	77	9	14	Sandy Loam

3.2. Bulk Density, Particle Density and Porosity

The measurement results for bulk density, particle density and porosity are presented in Table 3. The bulk density of Ultisol soil before treatment was 1.15 g/cm³, which falls within the range generally classified as loose soil rather than dense soil. After treatment, the values slightly decreased to 1.14 g/cm³ (control), 1.11 g/cm³ (*Mucuna bracteata* DC.), and 1.10 g/cm³ (*Pueraria phaseoloides*), with the lowest value observed in *Pueraria phaseoloides*. However, the differences among treatments were relatively small, indicating that the bulk density remained within the same classification range. The slight reduction in bulk density in treatments with cover crops may be associated with the decomposition of cover crop biomass, which can increase organic matter content and improve soil aggregation and pore space [12]. Lower bulk density is generally associated with looser soil conditions, better root development, and improved air and water movement within the soil [13].

Table 3. Results of bulk density, particle density and porosity analysis

Treatment	*(Bulk Density)* (g/cm³)		*(Particle Density)* (g/cm³)		Porosity (%)			
	Before treatment	After treatment	Before treatment	After treatment	Before treatment	Class	After treatment	Class
P0 (Control)	1.15	1.14	2.70	2.82	57.47	Good	59.33	Good
P1 (*Mucuna bracteata* DC.)	1.15	1.11	2.70	2.74	57.47	Good	59.72	Good
P2 (*Pueraria phaseoloides)*	1.15	1.10	2.70	2.73	57.47	Good	59.75	Good

The particle density in the before treatment phase was 2.70 g/cm³, increasing after treatment to 2.82 g/cm³ (control), 2.74 g/cm³ (Mucuna bracteate DC.), and 2.73 g/cm³ (Pueraria phaseoloides). This increase indicates changes in mineral composition or loss of light organic matter due to root activity and biomass decomposition [14].

Soil porosity before treatment was 57.47% (good class) and increased in all treatments, namely 59.33% in the control (P0), 59.72% in Mucuna bracteata DC. (P1), and 59.75% in Pueraria Phaseoloides (P2), with the highest increase in P2. According to Baver (1956), increasing organic matter from plant cover stimulates the formation of soil aggregates, increases pores, and reduces soil density so that porosity increases [15]. This condition not only improves porosity, but also increases the capacity to hold air through micropores, so that air and air circulation are better. Thus, planting Mucuna bracteata DC. and Pueraria Phaseoloides plays an important role in improving soil structure, increasing porosity, and increasing the soil's ability to store air.

3.3 Soil pH

Data from soil pH measurements during the study can be seen in Table 4.

Table 4. Soil pH value

Treatment	pH Tanah			
	Before treatment	criteria	After treatment	criteria
P0 (Control)	4.5	Acidic	4.4	Acidic
P1 (*Mucuna bracteata* DC.)	4.5	Acidic	5.5	Acidic
P2 (*Pueraria phaseoloides*)	4.5	Acidic	5.7	slightly acidic

The soil pH before treatment was 4.5, classified as acidic according to the typical Ultisol pH range of 4.0–5.5. After treatment, the pH increased to 5.5 in *Mucuna bracteata* DC. and 5.7 in *Pueraria phaseoloides* (slightly acidic), while the control slightly decreased to 4.4. The observed increase in pH in the cover crop treatments is more likely associated with the addition and partial decomposition of organic matter, which can contribute to the release of basic cations and buffering compounds that reduce soil acidity [16]. In this study, the improvement in pH is considered primarily related to the increased organic matter input from cover crop biomass, as organic matter content was also observed to increase.

Soil pH plays a crucial role in nutrient availability, microbial activity, and plant growth, with an optimal range generally between 6.0 and 7.0 for most crops [17].

3.4 Soil Temperature

The data from the soil temperature measurements obtained during the research can be seen in Table 5.

Table 5. Results of soil temperature measurements

Treatment	Average soil temperature (°C)
P0 (Control)	30.55
P1 (*Mucuna bracteata* DC.)	29.90
P2 (*Pueraria phaseoloides*)	29.86

The highest average soil temperature was found in the control (P0) at 30.55°C, while the treatments with cover crops Mucuna bracteata DC. (P1) and Pueraria Phaseoloides (P2) showed lower temperatures at 29.90°C and 29.86°C, respectively. This decrease is in line with the opinion of Asbur (2017) who stated that ground cover crops act like mulch, capable of lowering soil temperature, maintaining humidity, and reducing evaporation, thus creating more stable soil conditions and supporting plant growth [18].

3.5 Organic Content

Data from the results of measuring the organic matter content of the soil during the study can be seen in Table 6.

Table 6. Results of analysis of soil organic matter content

Treatment	Soil Organic Matter (%)			
	Before treatment	Criteria	After treatment	Criteria
P0 (Control)	0.74%	Very Low	0.99 %	Very Low
P1 (*Mucuna bracteata* DC.)	0.74%	Very Low	2.18%	Modarate
P2 (*Pueraria phaseoloides*)	0.74%	Very Low	2.20%	Modarate

The soil organic matter content before treatment was 0.74%, which was classified as very low. However, after treatment, it experienced a significant increase in Mucuna bracteata DC. (P1) by 2.18% and Pueraria phaseoloides (P2) by 2.20%, both of which were categorized as moderate. This increase is in line with Merah et al. (2020) who stated that ground cover crops (LCC) with rapid leaf growth and high biomass production can improve soil aggregates, bulk density, and total porosity, thereby significantly increasing organic matter content [19]. Increased organic matter plays a role in improving soil structure, increasing nutrient availability, maintaining moisture, and supporting microorganism activity, which ultimately improves soil fertility and productivity.

3.6 Nitrogen Content

Data on the results of measuring nitrogen content in the soil during the research period can be seen in Table 7.

Table 7. Results of analysis of total nitrogen content in soil

Treatment	Total Nitrogen (%)			
	Before treatment	Class	After treatment	Class
P0 (Control)	0.05	Low	0.07	Low
P1 (*Mucuna bracteata* DC.)	0.05	Low	0.15	Low
P2 (*Pueraria phaseoloides*)	0.05	Low	0.17	Low

The soil nitrogen content before treatment was 0.05%, which is considered low due to the high percentage of sand in Ultisol soil which is susceptible to nutrient leaching. Previous research showed that nitrogen loss can occur through leaching and harvesting. After treatment, there was an increase in nitrogen content, with P0

(Control) values of 0.07%, P1 (Mucuna bracteata DC.) 0.15%, and P2 (Pueraria phaseoloides) 0.17%, where P1 and P2 experienced a significant increase due to high organic matter. Despite the increase, nitrogen levels remained relatively low. The use of legume plants as ground cover contributes to nitrogen fixation from the atmosphere through symbiosis with Rhizobium bacteria, which are effective at an ideal soil pH between 6 and 7, supporting plant growth and nutrient availability.

4. Conclusion

The application of Mucuna bracteata DC. and Pueraria phaseoloides as cover crops on ultisol soil can improve the physical properties of ultisol soil. Pueraria phaseoloides resulted in a decrease in specific gravity and an increase in particle specific gravity, soil porosity, soil organic matter content, soil pH, and soil nitrogen content, which was better than Mucuna bracteata DC.

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