Effectiveness of various doses of silica nanoparticles from Dayang Rindu rice husk on phosphorus availability in ultisol soil

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Abstract. Silica nanoparticles are one of the research that continues to grow and become a concern in various fields ranging from health, animal husbandry, industry and agriculture. This study tested various doses of silica nanoparticles from dayang rindu rice husk to increase P availability in Ultisol soil. The experiment was conducted between December 2024 and January 2025 at the greenhouse of the Umar Ibnu Khotob Orphanage in Lubuklinggau, South Sumatra, Indonesia. The research was arranged in nonfactorial complete randomized design (CRD) then the soil was incubated for 30 days by paying attention to soil moisture and then the soil was analyzed in the UNIB laboratory in a composite manner. The results of the laboratory test were subsequently subjected to descriptive abalysis. The doses used in the control study without naoparitkle silica treatment, 10 ppm, 20 ppm, 30 ppm, 40 ppm, 50 ppm, 60 ppm, 70 ppm and 80 ppm. The results showed that the dose of 10 ppm showed the optimum dose. The results of this study indicate that silica nanoparticles from dayang rindu rice husk have the potential as a solution to overcome inhibiting factors in the utilization of ultisol soil.

1 Introduction

Soil is the key to success in supporting the productivity of agricultural enterprises. Soil is not only a place for plants to grow but, more importantly, it serves as a reservoir for water, a habitat for various soil microorganisms, and provides the nutrients needed by plants. Soil with a complex ecosystem, both material and morphological, makes soil an important factor in supporting nutrient cycles, soil productivity, and plant productivity [1].

The productivity of plants is greatly influenced by the soil's ability to provide

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the nutrients needed by the plants. Based on the plant's nutrient requirements, nutrients are divided into macro and micronutrients. Macro nutrients are needed in large quantities, while micronutrients are needed by plants in small amounts. One of the macro nutrients is phosphorus. Phosphorus is very important in supporting plant production [2]. Phosphorus is needed by plants to stimulate root growth, promote seed formation, stimulate cell division and elongation of plant cells, encourage flowering and fruiting, and transport energy from plant metabolism. Some soil types with low phosphorus content include acidic, alkaline soils, high clay soils, and calcareous soils. The concentration of low soil is often below 2 [µmol P/L] [3]. The availability of P in agricultural land is important to support optimal plant growth.

As an effort to increase agricultural production, especially food crops, in addition to the use of superior seeds, adequate agricultural production facilities, and the extensification of agriculture on marginal lands, namely the utilization of ultisol soil, are also being implemented. Obstacles in utilizing ultisol as agricultural land include low soil pH, low soil fertility, such as low nitrogen, phosphorus, organic carbon, cation exchange capacity, and high aluminum accumulation, soil fertility, and water scarcity [4, 5].

Various efforts have been made to improve the fertility of ultisol soil, but there is still little research using nanoparticles as one of the solutions to enhance the soil chemistry of ultisol, especially to increase the availability of phosphorus in the soil. Nanoparticles are currently a popular and rapidly developing area of research in the fields of livestock, health, and agriculture. In the field of agriculture, nanoparticles are believed to be one of the right choices to address agricultural problems in the future. The use of silica nanoparticles in agriculture is able to overcome climate stress and is environmentally friendly [6].

Nanoparticles are colloidal or solid particles that range in size from 1-1000 nm [7, 8]. The application of silica nanoparticle technology not only improves the chemical properties of the soil but also enhances plant resistance to abiotic stress and is considered effective in reducing heavy metal contaminants in the soil [9]. This study aims to examine the effect of applying silica nanoparticles derived from Dayang Rindu rice husk on available P in ultisol soil by testing various doses, including control without silica nanoparticles, 10 ppm, 20 ppm, 30 ppm, 40 ppm, 50 ppm, 60 ppm, 70 ppm, and 80 ppm. Dayang Rindu rice husk was chosen as a material for making silica nanoparticles because in addition to being a local superior rice it is also based on its higher silica content compared to paddy rice which is widely grown by farmers in the research area, Dayang Rindu rice husk has a silica content of 5.50% higher than paddy rice with a silica content of 5.0%.

2 Materials and methods

2.1 Location, equipment, and materials

The soil used for the research was taken from the Aisyiyah orphanage in Lubuklinggau City, South Sumatra Province. The soil was analyzed at the soil fertility laboratory of the University of Bengkulu. The research location is situated in a lowland area with an elevation ranging between 100 to 129 meters above sea level. The experiment was conducted between December 2024 and January 2025.

The equipment used in this research is categorized into field and laboratory tools. Field activities use instruments such as soil forks and hoes. Laboratory activities, on the other hand, require equipment such as pH meters and Atomic Absorption Spectrophotometers (AAS) to analyze the chemical properties of the soil.

The materials used in the research are silica nanoparticles from dayang rindu rice husk with a size of 120 nm. In addition, various chemical reagents were used to analyze the chemical properties of the soil.

2.2 Experimental design

The research was designed in a completely randomized design (CRD) non-factorial, then the soil was incubated for 30 days while considering soil moisture, and subsequently, the soil was analyzed in the laboratory in a composite manner. The doses used in the control 0 ppm, 10 ppm, 20 ppm, 30 ppm, 40 ppm, 50 ppm, 60 ppm, 70 ppm, and 80 ppm.

2.3 Production of silica nanoparticles from dayang rindu rice husk, soil sampling, and analysis

Production of silica nanoparticles from dayang rindu rice husk with a nano particle size of 120 nm using the green synthesis method. 500 grams of rice husks after being baked at a certain temperature will become 50 grams of ash, then the ash is synthesized to produce silica nanoparticles.

Soil samples were taken from the 0 – 20 cm layer of the tilled soil, the soil was collected and air-dried, then sieved with a 40 mesh size, after which the soil was weighed to 1 kilogram and placed into a 10 cm x 20 cm polybag. To determine the soil moisture content, the soil field capacity is measured using the free drainage method. The procedure is carried out by taking a soil sample into a 3-inch diameter, 15 cm high varalon pipe with a strimin cloth installed at the bottom. Fill the pipe with soil until full, then place it on a stand that already contains water and soak it for 24 hours. After 24 hours, drain it until no more water drips, take a 20-gram sample, place it in a dish, and then oven-dry it at 105°C until a constant weight is achieved.

The field capacity obtained is 31%, so for 1 kg of research soil, the amount of water to be added is 310 ml/polybag. This will serve as the basis for the treatment in adding nanoparticles in the greenhouse.

3 Results and discussion

3.1 Characteristics of the early soil

Before being carried out, the application of silica nanoparticles from rice husks is given to the soil laboratory for initial analysis. The characteristics of the soil before treatment are listed in Table 1 below.

Table 1. Soil characteristics before treatment

Parameter	Unit	Value	Criteria
pH	-	3,9	Extreme acid
CEC	-	13,39	Low
p-bray	Ppm	3,03	Very low
C organik	%	0,67	Very low
Sandy	%	1,4	-
clay	%	72,0	-
silt	%	26,6	-

The results of the preliminary soil analysis before treatment showed that the soil pH was very acidic, the CEC was low, the available P was very low, and the C-organic was very low.

3.2 Soil chemistry after treatment

The treatment dose of silica nanoparticles was given Codes S0, S1, S2, S3, S4, S5, S6, S7, and S8 with sequential treatment doses starting from 0 ppm (without the administration of silica nanoparticles), 10 ppm, 20 ppm, 30 ppm, 40 ppm, 50 ppm, 60 ppm, 70 ppm and 80 ppm, after being incubated for the next 30 days, the applied soil was analyzed in a composite manner based on the dose and then looked at several observation parameters including pH, CEC, and p Bray.

Table 2. Soil characteristics after treatment silica nanoparticle

Kode Sample	pH	CEC	P Bray
S0	4,47	16,11	4,37
S1	4,6	17,89	12.19
S2	4,53	20,18	8,33
S3	4,47	30,34	8,63
S4	4,55	27,01	10,38
S5	4,52	23,18	4,54
S6	4,52	28,59	5,10
S7	4,55	28,89	10,88
S8	4,47	24,78	9,90

The highest available P in the treatment with a 10ppm dose showed the highest results and the lowest in S0 or without the application of silica nanoparticles (Fig.1). This result indicates that the 10ppm dose treatment provides a good response to P availability in ultisol soil. The lowest result in S0 is the control treatment without the application of silica nanoparticles, where the media was only maintained with soil moisture by considering its salinity.

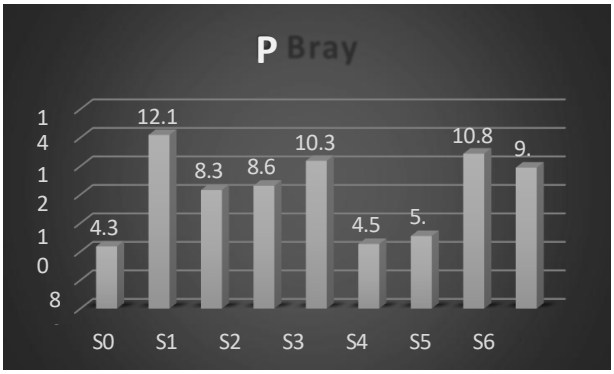

Fig. 1. P avabaility with apliccation nanopartiles silica

Nanoparticles can influence P availability because silica nanoparticles can improve soil pH and soil EC (Table 2). The addition of silica can enhance the availability and delivery of macro-nutrients through complex mechanisms related to nutrient translocation in root and plant tissues [10]. [11] Reported that silica application improves P availability and raises pH. The increase in soil pH occurs due to the reaction of $SiO3^{2-}$ anions with H^{+} protons in the soil solution [12]. Although a dose of 10 ppm has already shown effective results, nano-sized Si fertilization is more effective because its average distribution and small size are easily absorbed by plants [13], and more targeted [12, 14]. Nanoparticle fertilizers with a large surface area and small dimensions allow for more precise nutrient dispersion within plant tissues. Nanosilica fertilizers derived from rice husks are an important alternative source of silica, which can be an excellent choice for effective phosphorus fertilizer use.

4 Conclusion

The research results indicate that a dose of 10 ppm is the optimal dose. The results of this study indicate that silica nanoparticles from dayang rindu rice husk have the potential to be a solution for overcoming the limiting factors in the utilization of ultisol soil.

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