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Increasing the Efficiency of Cattle Bone Ash P Fertilization with Nano Technology and Its Effect on the Growth and Yield of Shallots

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ABSTRACT

The study investigates the efficacy of nano-sized cattle bone ash as an alternative phosphorus source for shallot cultivation, aiming to reduce dependence on mined phosphate rock. The experimental study was arranged in a 4 x 3 factorial Completely Randomized Design. The first factor was the recommended dose of P fertilizer, consisting of 100%, 80%, 60%, and 40%. The second factor was using nano cattle bone ash as a foliar application, applied 3, 4, and 5 times. The observation was made on the plant growth and yield of shallot. Data analysis was conducted with an ANOVA and continued with the DMRT. The results showed no interaction effect of the dose of P fertilizer and the frequency of spraying nano cattle bone ash on the growth and yield of shallots. The application of P fertilizer at 40% of the recommended dose could already produce shallots that were the same as the application of P fertilizer according to the recommended dosage. The spraying frequency of three times was able to provide high shallot yields. In the future, it is expected that spraying cow bone ash with nanotechnology can be applied three times with a 40% recommended dose of P to increase fertilization efficiency.

Keywords: Foliar application; Nano hydroxyapatite; Phosphate efficiency; Shallot yield

ABSTRAK

Penelitian ini mengkaji efektivitas abu tulang sapi berukuran nano sebagai sumber fosfor alternatif untuk budidaya bawang merah, dengan tujuan mengurangi ketergantungan pada batu fosfat yang diambil dari tambang. Penelitian eksperimental ini disusun dalam Desain Acak Lengkap faktorial 4 x 3. Faktor pertama adalah dosis yang direkomendasikan dari pupuk P, terdiri dari 100%, 80%, 60%, dan 40%. Faktor kedua adalah penggunaan abu tulang sapi berukuran nano sebagai aplikasi daun, diberikan sebanyak 3, 4, dan 5 kali. Pengamatan dilakukan terhadap pertumbuhan tanaman dan hasil bawang merah. Analisis data dilakukan dengan ANOVA dan dilanjutkan dengan Uji Jarak Berganda Duncan (DMRT). Hasil penelitian menunjukkan bahwa tidak ada interaksi antara dosis pupuk P dan frekuensi penyemprotan abu tulang sapi berukuran nano terhadap pertumbuhan dan hasil bawang merah. Aplikasi pupuk P pada dosis 40% dari yang direkomendasikan sudah mampu menghasilkan bawang merah yang setara dengan aplikasi pupuk P sesuai dosis yang direkomendasikan. Frekuensi penyemprotan sebanyak tiga kali mampu memberikan hasil panen bawang merah yang tinggi. Diharapkan di masa depan, penyemprotan abu tulang sapi dengan nanoteknologi dapat dilakukan sebanyak tiga kali dengan dosis pupuk P sebesar 40% dari yang direkomendasikan untuk meningkatkan efisiensi pemupukan.

Kata kunci: *Aplikasi foliar; Nano hidroksiapatit; Efisiensi fosfat; Hasil bawang merah*

INTRODUCTION

Phosphorus (P) is an essential nutrient for the growth and development of shallots. It holds the second most important rank among all plant elements due to its crucial function in several physiological processes, including phospholipids, nucleic acid, phosphor-protein, and metabolites (Ajmera et al., 2019). However, due to complex edaphic processes, the soil's soluble inorganic phosphate concentration is usually low (Bindraban et al., 2020). Thus, applying phosphate fertilizers is necessary to meet crop demands, sometimes at high rates, to ensure enough is available in the soil (Hussain et al., 2021). Nevertheless, the availability of phosphate fertilizers is typically reduced due to absorption and organic complexes in the soil (Bindraban et al., 2020). To address the problem

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of strong phosphate binding to the soil matrix, more fertilizer than required by the crop is often applied, resulting in excess P content in the soil solution. Eventually, this can lead to the leaching of excess P with percolating water and pose a risk for eutrophication in groundwater (Ngatia et al., 2018). Additionally, most phosphate fertilizers come from mined phosphate rock, a finite resource. Therefore, it is necessary to increase phosphate use efficiency to ensure sustainable agriculture (Ajmera et al., 2019; Bindraban et al., 2020; Weeks & Hettiarachchi, 2019).

Various approaches have been taken to enhance the efficiency of phosphate utilization, including using alternative P sources (Weeks & Hettiarachchi, 2019). For instance, using minerals with limited solubility, such as hydroxyapatite, has been proposed (Samreen et al., 2019). Hydroxyapatite naturally exists in bone and eggshells (Vinoth et al., 2021). Cattle bones, in particular, contain a high amount of calcium hydroxyapatite $Ca_{10}(PO_4)_6(OH)_2$ and calcium carbonate ($CaCO_3$), approximately 85.84%, making them feasible as alternative P sources (Vinoth et al., 2021). In addition, cattle bones are easy to find because they are always available at the abattoir. Moreover, cattle bones are easily accessible as they are commonly available at the abattoir. Previous studies indicate that the slaughter of 500-700 kg of cattle can produce roughly 50 kg of bone (Yusnita et al., 2014), and the number of bones made from slaughtering cattle can account for up to 10% of the total weight (Kuswati et al., 2022). Based on prior research, cattle bones contain approximately 16.85% phosphorus, 42.8% calcium, and 1.79% sodium and magnesium (Mulyono & Hidayat, 2020).

The primary challenge of using hydroxyapatite as a replacement for P fertilizer lies in its low solubility compared to other P fertilizers (Sittitut et al., 2022). Nanotechnology is employed to modify the size of hydroxyapatite particles, making them more easily absorbable by plants (Maghsoodi et al., 2020). In a study by Montalvo et al. (2015), applying Nano hydroxyapatite resulted in higher P uptake and shoot dry matter yield than bulk hydroxyapatite in four wheat varieties grown in Oxisols and Andisol soils. Similarly, Xiong et al. (2018) found that applying nano hydroxyapatite with different surface charges led to higher shoot and root fresh biomass in sunflowers than rock phosphate growth in vertisol and ultisol soils. Furthermore, Hariyono & Nagari (2022) reported that applying nano bone ash in paddy cultivation resulted in increased height, number of tillers, and weight of grains per clump compared to the absence of nano bone ash application.

Hydroxyapatite derived from cattle bone can serve as an alternative source of P fertilizer by enhancing its solubility using nanotechnology (Hariyono & Nagari, 2022; Montalvo et al., 2015; Mulyono & Hidayat, 2020; Xiong et al., 2018). This research involves the process of calcining cattle bones to extract hydroxyapatite (Hart et al., 2022), followed by nanofication using a ball mill (Kumalasari et al., 2022), resulting in an alternate P-source fertilizer. The objective of this study was to assess the appropriate doses of nano-hydroxyapatite from cattle bone for foliar application in shallots while simultaneously reducing the dose of superphosphate as a commercial fertilizer in the root system, with a starting dose of 220 kg ha^{-1} P_2O_5. By utilizing nano cattle bone ash obtained through the calcination and nanofication process, the aim is to decrease reliance on commercial super phosphate fertilizer.

MATERIALS AND METHODS

Experimental Design

This experiment was conducted at the Greenhouse of the Faculty of Agriculture, Universitas Muhammadiyah Yogyakarta, from June to December 2020. The cattle bones used for the research were collected from various meatball restaurants and grill restaurants in Yogyakarta—Shallots cv. Tajuk was used in this experiment due to their excellent adaptability in rainy or dry seasons and low or high land. These cultivars have a weight per bulb of 5 –12 with 5-15 bulbs per clump and a diameter of 1.7-3.2 cm per bulb, with a potential yield of 12–16-ton ha^{-1} (Direktorat Perbenihan Hortikultura, 2016). Commercial Super Phosphate obtained from PT. Petro Kimia Gresik was used in this study. It contains 36% P2O5 and 5% S, with a 220 kg ha^{-1} $P_2O_{5\ dose}$.

The experimental setup followed a completely randomized design (CRD) with a 4 x 3 factorial design. The first factor was the dose of P fertilizer, consisting of P1 (100% dose of P fertilizer), P2 (80% dose of P fertilizer), P3 (60% dose of P fertilizer), and P4 (40% dose of P fertilizer). The second factor was the frequency of spraying nano cattle bone ash, including Q1 = 3 times (at 2, 3, and 4 WAP), Q2 = 4 times (at 2, 3, 4, and 5 WAP), and Q3 = 5 times (at 2, 3, 4, 5, and 6 WAP). Therefore, this study had a total of 12 treatment combinations, with each treatment being replicated 3 times. Each replication consisted of nine sample plants (three for harvest and six for destructive sampling at 3 WAP and 6 WAP). In total, 324 shallot plants were used in this research.

Calcination and Nanofication of Cattle Bone

In this study, cattle bones were collected from various restaurants in Yogyakarta. Before use, the bones were washed in water to remove any impurities, such as residual meat. The cleaned bones were then soaked in 1 N hydrochloric acid for 24 hours to remove any remaining impurities and subsequently rinsed with water and dried at 70^{0}C for 24 hours in an oven (Barua et al., 2019). This process effectively eliminated residual proteins, fats, and other tissues. The remaining bones were then calcinated at 800^{0}C in a muffin furnace for eight hours to produce white granular bone ash (Barua et al., 2019). The modified technique of Bahrololoom et al. (2009) and Sharifianjazi et al. (2021) was utilized to produce nano-sized particles of bone ash. Specifically, the white granular bone ash was ground into powder using a hammer mill. The powder was mixed with small iron balls and water in a 2:1:5 ratio and milled using a ball mill for eight hours. This milling process was based on the principle of deformation of materials on ball surfaces due to collisions with other balls, resulting in the nanofication of the bone ash powder.

Based on the findings obtained from Scanning Electron Microscopy (SEM) and X-ray Diffraction (XRD) analysis, it was determined that the diameter of the nano cattle bone ash particles was distributed as follows: 58.6% of the particles had a diameter below 50 nm, 18.4% had a diameter between 50-100 nm, and 33% had a diameter above 100 nm. The largest observed particle size of the nano cattle bone ash was 394 nm. Furthermore, the elemental composition analysis revealed that the nano cattle bone ash consisted of the following percentages: 42.8% calcium, 38.8% oxygen, 16.85% phosphorus, 1.08% sodium, and 0.71% magnesium. These elements were identified in the composition of the cattle bone ash. Based on these findings, it can be deduced that the general formula for cattle bone ash is $Ca_5(OH)(PO_4)_3$, which corresponds to the compound known as hydroxyapatite.

Application of Commercial Fertilizer and Nano Cattle Bone Ash

A single shallot bulb was planted in a polybag measuring 35×35 cm, filled with 5 kg of growing media. The planting media consisted of a mixture of soil particles with a diameter of less than two mm. Each polybag was supplemented with 4.5 g

Table 1. Volume and dose of nano cow bone ash applied to each plant age

Plant Age (Week After Planting)	The volume of Nano cattle bone ash (liter h^{-1})	Dose of Nano cattle bone ash (kg h^{-1})
2 WAP	800	3.2
3 WAP	800	3.2
4 WAP	1200	4.8
5 WAP	1800	7.2
6 WAP	2000	8.0

Table 2. Total Phosphor applied in each treatment

Treatment	Dose of Phosphor (kg h^{-1})
Factor 1. P fertilizer of Super Phosphate	
100% dose of P fertilizer	220 kg P_2O_5
80% dose of P fertilizer	176 kg P_2O_5
60% dose of P fertilizer	132 kg P_2O_5
40% dose of P fertilizer	88 kg P_2O_5
Factor 2. Frequency of spraying nano cattle bone ash	
3 times (2, 3, and 4 WAP)	1.8 kg P_2O_5
4 times (2, 3, 4, and 5 WAP)	3.1 kg P_2O_5
5 times (2, 3, 4, 5 and 6 WAP)	4.4 kg P_2O_5

of manure and 240 g of coconut coir. For nitrogen fertilization, a total dose of 250 kg ha^{-1} was applied. The fertilization was achieved by adding 60 g of urea per polybag as the base fertilizer (58% of the total dose). Two weeks after planting, a follow-up application of 30% of the total dose (10.8 g of ZA) was given, followed by another 12% of the total dose six weeks after planting.

Similarly, potassium fertilization was carried out using a total dose of 250 kg ha^{-1}. The base fertilizer comprised 50 g of potassium chloride per polybag (26% of the total dose). An additional 30% of the total dose was applied two weeks after planting, and the remaining 44% was given six weeks after planting. Commercial Super Phosphate, containing 220 kg ha-1 of P2O5, was applied as the base fertilizer. Following the treatment protocol, 26.4 g of SP36 per polybag—the application of Commercial superphosphate was applied as the base fertilizer following the specific treatment requirements. The follow-up fertilizers were applied using the top-dressing method, while the base fertilizer was incorporated into the soil.

According to Medina et al. (2019), nano cattle bone ash was applied at a concentration of 0.4%. This concentration involved diluting four grams of nano cattle bone ash in one litter of distilled water. The solution was applied via foliar application directly onto the leaves, specifically in the morning between 7-9 AM. The application volume was adjusted based on plant growth and can be found in Table 1, along with the corresponding doses of cattle bone ash. Using a planting space of 25 x 25 cm and factoring in an 80% efficiency in the planting area, a total population of 20,000 plants h^{-1} was achieved, and it used for the calculation of the application volume. Table 2 provides the total phosphorus (P) applied for each treatment. The maximum dose used was 200 kg h-1 P_2O_5 via soil application and 4.8 kg h^{-1} P_2O_5 via foliar application. On the other hand, the minimum dose applied was 88 kg P_2O_5 via soil application and 1.8 kg P_2O_5 via foliar application.

Plant Growth and Yields Observation

The research encompassed the observation of various variables, including plant growth (plant height, number of leaves, fresh and dry weight of roots, fresh and dry weight of shoots, and leaf area) and the yield of shallots (fresh weight of bulbs per plant, number of bulbs per plant, weight per bulb, bulb diameter, and weight of dried bulbs). Plant height and number of leaves were recorded weekly from 1 week after planting (WAP) until 7 WAP. Plant height was measured using a ruler, starting from the tip of the uppermost leaf to the part of the plant in contact with the ground. The number of leaves was determined through direct counting.

At 6 WAP, three plant samples were selected to measure the fresh and dry weight of roots, fresh and dry weight of crown, and leaf area. The fresh weight of roots and shoots was obtained by separating them from the plant and directly weighing them using an analytical balance (with an accuracy of ± 0.01). The dry weight of roots and shoots was determined by placing them in an oven at 60°C until a constant weight was achieved. Leaf area was measured using a delta-t leaves area meter, considering that shallot leaves are cylindrical. The measured leaf area was then multiplied by two.

The yield of shallots was assessed at 9 WAP, which included the measurement of fresh weight of bulbs per plant, number of bulbs per plant, weight per bulb, bulb diameter, weight of sun-dried bulbs, and weight of oven-dried bulbs. Shallot bulbs were carefully cleaned from the soil and separated from their shoots. They were then weighed directly using an analytical balance (with an accuracy of ± 0.01). The number of bulbs per plant was determined by counting the normal bulbs, excluding any empty or wet bulbs affected by disease. Five bulb samples were measured for each plant for their weight and diameter. Bulb weight was measured using an analytical balance, while diameter was measured using a caliper.

Statistical Analysis

The collected data were analyzed using the F-test at a significance level (α) of 5% using the SAS OnDemand software. Subsequently, a means comparison was conducted using the Duncan Multiple Range Test at a significance level (α) of 5%.

RESULTS AND DISCUSSION

Plant Growth

Based on the analysis of variance (ANOVA), no significant interaction was observed between reducing the recommended dose of phosphorus (P) fertilizer and the frequency of spraying nano bone ash on the growth of shallots. This lack of interaction was evident in various variables, such as plant height, number of leaves, leaf area, root fresh weight, root dry weight, shoot fresh weight, and shoot dry weight. According to Table 3, no significant differences were observed in the measured responses when the P fertilizer dose was reduced to 60% of the recommended dose, and nano hydroxyapatite from cow bone ash was applied at a dose ranging from 3.2 to 8 kg per hectare. These findings suggest that the utilization of nano hydroxyapatite derived from bovine bones, with a P dose ranging from 1.8 to 4.4 kg P_2O_5, can effectively substitute for traditional soil application of P by up to 60%, equivalent to 132 kg per hectare (ha). Bindraban et al. (2020) and Avila-Quezada et al. (2022) explain that the foliar application of nano hydroxyapatite fertilizer can bypass barriers to phosphorus uptake through the roots, such as pH factors, organic matter content, and soil fixation.

The findings are consistent with several previous studies. A study conducted by Mulyono et al. (2022) on corn plants in entisol soil showed that foliar application of nano bone ash could replace SP-36 fertilizer applied through the roots. The combination of 25% nano bone ash and 75% SP-36 resulted in improved leaf area and fresh shoot weight compared to using 100% SP-36 without foliar rice husk ash. These results align with the research conducted by Załuszniewska & Nogalska (2022), where the application of meat and bone provided better results for winter oilseed rape and winter wheat compared to commercial NPK fertilizers. Another study conducted by Maulidayanti et al. (2023) on edamame soybeans demonstrated that the application of nano bone ash at a concentration of 0.15% and a frequency of 3 times was able to substitute up to 50% of the requirement for SP36 fertilizer. This study's results align with Genesiska et al. (2022), who reported that foliar application of various concentrations of chicken bone ash nano phosphate fertilizer and SP-36 had the same effects on the fresh weight and dry weight of shoots of

Table 3. Effects of P fertilizer doses on shallot plant growth at the six weeks after planting (WAP)

Treatment	Plant height (cm)	Number of Leaves	Leaves area (cm^2)	Root Fresh Weight (g)	Root Dry Weight (g)	Crown Fresh Weight (g)	Crown Dry Weight (g)
Factor 1. P fertilizer Super Phosphate							
100% dose of P fertilizer	35.43^{a}	42.40^{a}	528.89^{a}	6.13^{a}	0.93^{a}	49.92^{a}	4.23^{a}
80% dose of P fertilizer	36.41^{a}	43.20^{a}	549.78^{a}	6.18^{a}	0.97^{a}	50.70^{a}	4.28^{a}
60% dose of P fertilizer	35.85^{a}	45.07^{a}	516.44^{a}	6.13^{a}	0.95^{a}	49.61^{a}	4.61^{a}
40% dose of P fertilizer	34.91^{a}	43.48^{a}	530.44^{a}	5.61^{a}	0.87^{a}	48.00^{a}	3.90^{a}
Factor 2. Frequency of spraying nano cattle bone ash							
3 times (2, 3, and 4 WAP)	34.99^{p}	42.62^{p}	526.67^{p}	5.96^{p}	0.93^{p}	47.28^{p}	4.28^{p}
4 times (2, 3, 4, and 5 WAP)	35.52^{p}	42.46^{p}	523.08^{p}	6.04^{p}	0.93^{p}	49.06^{p}	4.04^{p}
5 times (2, 3, 4, 5 and 6 WAP)	36.45^{p}	45.55^{p}	544.42^{p}	6.05^{p}	0.94^{p}	52.33^{p}	4.46^{p}
Interaction	(-)	(-)	(-)	(-)	(-)	(-)	(-)

Remark: Means followed by the same letters in the same column are not significantly different (F Test, α = 5%).

soybean plants. Dhiba (2019) also reported that nano phosphate fertilizer of cattle bone ash given as a foliar application gave the same effect as SP-36 fertilizer on fresh weight and dry weight of rice.

Phosphorus is involved in numerous physiological processes within plants, such as cell division and elongation, essential for promoting plant growth. (Balzergue et al., 2017; Nadeem et al., 2022). Consequently, plants treated with nano cattle bone ash and SP36 fertilizer at a dosage of 40% of the recommended dose, reaching the optimal height for cv. Tajuk. The role of phosphorus in cell elongation and cell division also impacts the number of leaves and leaf area. Leaf development and the formation of new leaves, especially in monocotyledonous plants, are significantly influenced by phosphorus (Kavanová et al., 2006).

Phosphorus, as a vital nutrient in plants, functions as a crucial component in adenosine triphosphate (ATP) molecules, which serve as the primary energy source in plants (Hasanuzzaman et al., 2018; Malhotra et al., 2018). ATP is required in various metabolic processes of plants, including photosynthesis, respiration, nutrient transport, and energy transfer within plant cells (Hasanuzzaman et al., 2018; Tyutereva et al., 2022). When an adequate supply of phosphorus is ensured, the assimilation of photosynthetic products and plant growth processes can occur optimally. Fresh and dry weights of roots and shoots, which represent the manifestation of assimilation results and plant growth, are greatly influenced by the intake of energy transferred through ATP.

Firmansyah et al. (2017) also mention that P fertilization can improve plant vegetative growth. Using phosphorus (P) nutrients for plants stimulates root growth, forms a good root system, and activates plant tissue growth (Ajmera et al., 2019). Pratama et al. (2014) reported that cattle bone ash could increase pH, soil available P, plant P uptake, plant height, plant crown dry weight, and plant root dry weight. These finding align with the results of Utami (2016), stating that using nano cattle bone ash as a source of phosphorus effectively replaces SP-36 in sweet corn cultivation.

Based on Table 3, the frequency of administering nano hydroxyapatite did not significantly impact plant growth. Specifically, providing nano hydroxyapatite three times during weeks 2, 3, and 4, at a dose equivalent to 1.8 kg P_2O_5 per hectare, was found to fulfill the plant's nutrient requirements. On the other hand, administering a higher dosage, exceeding 1.8 kg, did not lead to considerable improvements in plant growth. These observations align with Mitscherlich's law of diminishing returns, which asserts that as the levels of a limiting factor, such as nutrients, increase, the additional benefit or productivity gained from each unit of the factor decreases. In essence, there exists a point at which plants cannot sustain indefinite growth, and a maximum production limit is reached (Ferreira et al., 2017). According to the research findings of Ros et al. (2020), the higher the application of phosphorus fertilizer, the lower its influence on phosphorus uptake.

Yield of Shallot

The analysis of variance (ANOVA) results indicated no significant interaction effect of reducing the recommended dose of phosphorus (P) fertilizer and the frequency of spraying nano bone ash on the growth of shallots. This lack of interaction was observed across multiple variables, including fresh weight of bulb per plant, number of bulbs per plant, weight per Bulb, and bulb diameter.

According to Table 4, the reduction in recommended fertilizer doses did not significantly affect the fresh weight of bulbs per clump, number of bulbs per plant, weight per bulb, bulb diameter, and dry bulb weight. These results highlight that nano cattle bone ash has the potential as a nutrient source that is as good as artificial fertilizers for shallot crop yields. The application of a 40% dose of P fertilizer, equivalent to 88 kg P_2O_5, along with foliar application of nano cattle bone ash at doses ranging from 1.8 to 4.4 kg P_2O_5, was able to achieve shallot yield comparable to the application of P fertilizer at the recommended dose of 220 kg P_2O_5 without the addition of nano cattle bone ash.

According to Behairy et al. (2015), the P element absorbed a lot in the soil results in a lack of nutrients that plants can absorb. Thus, adding P nutrients in the form of nano cattle bone ash by foliar application is expected to meet plant growth needs and increase photosynthesis results. Sutardi et al. (2022) stated that the achievement of high shallot yields was due to the availability of macronutrients such as N, P, K, Mg, and S so that they were sufficiently available for plants. P element has a role in bulb formation and smooth carbohydrate metabolism (Tekeste et al., 2018). This is in line with Utami (2016), stating that using nano cattle bone ash as a source of phosphorus effectively results in replacing SP-36 in sweet corn cultivation. Similarly, Sekarsari (2020) reported that applying OPEFB nano fertilizer with the foliar method resulted in the highest average fresh weight of shallot bulbs per clump.

Based on Table 4, the frequency of spraying nano cattle bone ash did not significantly affect the fresh bulb weight per plant, number of bulbs per plant, weight per bulb, and bulb diameter. These finding suggest that the frequency of spraying nano cattle bone ash 3, 4, and 5 times (dose 1.8 to 4.4 kg P_2O_5) had the same effects on the yield of the shallot plant. In the bulb formation of shallots,

Table 4. Effects of P fertilizer doses on shallot plant growth at six weeks after planting (WAP)

	Fresh Weight of bulb per Plant (g)	Number of Bulb per Plant (g)	Weight per Bulb (g)	Bulb Diameter (cm)
100% dose of P fertilizer	50.00 a	8.59 a	5.81 a	2.06 a
80% dose of P fertilizer	53.30 a	8.74 a	6.33 a	3.13 a
60% dose of P fertilizer	53.99 a	12.93 a	5.71 a	2.11 a
40% dose of P fertilizer	42.80 a	9.00 a	4.83 a	2.03 a
3 times (2, 3, and 4 mst)	46.78 p	11.64 p	5.16 p	2.06 p
4 times (2, 3, 4, and 5 mst)	47.64 p	8.72 p	5.57 p	2.85 p
5 times (2, 3, 4, 5 and 6 ms)	55.65 p	9.08 p	6.28 p	2.09 p
Interaction	(-)	(-)	(-)	(-)

Remark: Means followed by the same letters in the same column are not significantly different (F Test, α = 5%)

once the redistributed phosphorus reaches the sink tissues, it is reutilized for various crucial metabolic processes. Reutilization of phosphorus in shallot bulb formation ensures the development of larger and healthier bulbs. Ajmera et al. (2019) state that the P element absorbed in the soil results in a lack of nutrients that plants can absorb. Therefore, adding P nutrients as nano cattle bone ash in the foliar application is expected to meet plant growth needs and increase photosynthesis results.

CONCLUSIONS

This research evaluated the effects of reduced phosphorus fertilizer doses and different frequencies of spraying nano bone ash on shallot plant growth and yield. Notably, applying nano cattle bone ash, even at reduced phosphorus doses, yielded comparable results in plant growth variables, including plant height, number of leaves, and weight of roots and shoots. Shallot yield variables, including fresh weight of bulbs per plant, number of bulbs per plant, weight per bulb, and bulb diameter, exhibited no significant differences between treatments, indicating that nano cattle bone ash can effectively replace traditional phosphorus fertilizers without compromising yield. Moreover, the study revealed that varying frequencies of nano bone ash application (3, 4, and 5 times) did not significantly affect shallot yield. This research underscores the potential of nano cattle bone ash as a sustainable phosphorus source, contributing to reduced reliance on mined phosphate rock and offering environmentally friendly alternatives for enhancing crop productivity.

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