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Research Article

Effect of Swiftlet (Aerodramus fuciphagus) manure on growth and yield of shallots in Ultisols

Eko Suprijono[1], Azadin Jumaidi[2], Alnopri[3], Nanik Setyowati[4]*and Zainal Muktamar[5]

Department of Crop Production, University of Bengkulu, Jl. WR Supratman, Bengkulu, Indonesia

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Abstract

Shallots (Allium cepa var. aggregatum) are an essential horticultural crop in Indonesia for domestic use and export. Their productivity is influenced by soil fertility, with Ultisol, posing challenges due to low fertility. Swiftlet manure, rich in nutrients, has the potential as an organic amendment to improve soil conditions and enhance crop yield. This study examines the effect of different doses of swiftlet manure on the growth and yield of shallots in Ultisols. The study was conducted from August to October 2023 in Pondok Suguh Village, Pondok Suguh Subdistrict, Mukomuko Regency, Bengkulu. The experiment used a Completely Randomized Design (CRD) with a treatment of swiftlet manure, consisting of 0 tons/ha (control), 5, 10, 15, 20, 25, and 30 tons/ha, combined with synthetic N, P, K fertilizers at half of the recommended dose. The recommended dose for synthetic fertilizer was 435 kg/ha urea, 250 kg/ha SP-36, and 125 kg/ha KCl. Data were analyzed using Analysis of Variance (ANOVA) at the 5% significance level and the treatment means were separated using Duncan's Multiple Range Test (DMRT) at the 5% level. The study showed that the plant height and leaf number of shallots at various doses of swiftlet manure tended to increase, producing taller plants and more leaves compared to the control. Swiftlet manure at doses of 20, 25, and 30 tons/ha resulted in no significant differences in plant height, leaf number, fresh weight, and dry weight of bulbs. Swiftlet manure at a dose of 20 tons/ha produced 7.5% and 15.5% higher fresh bulb weight and 19.3% and 18.1% higher dry bulb weight than at 25 and 30 tons/ha doses, respectively. This finding supports sustainable agriculture practices in shallot cultivation.

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Introduction

Shallots production in Indonesia continuously increased from 2019-2021. The production was 1,580,247 tons in 2019, 1,815,445 tons in 2020, and 2,004,590 tons in 2021. However, shallots production in Bengkulu Province fluctuated during the same period which was 523 tons in 2019, 1,153 tons in 2020, but decreased to 990 tons in 2021 (Badan Pusat Statistika, 2022). In 2021, shallots consumption in Bengkulu Province was significantly higher than the production which was 595,000 tons/year. This figure shows that the increase in shallots production is necessary to meet the need of the horticultural commodity. Many factor determines shallots production, including improving technical culture by

[1] Department of Crop Production, University of Bengkulu, Jl. WR Supratman, Bengkulu, Indonesia
[2] Agroecotechnology Study Program, University of Bengkulu, Jl. WR Supratman, Bengkulu, Indonesia
[3] Department of Crop Production, University of Bengkulu, Jl. WR Supratman, Bengkulu, Indonesia
[4] Department of Crop Production, University of Bengkulu, Jl. WR Supratman, Bengkulu, Indonesia
5 Corresponding Author: Department of Crop Production, University of Bengkulu, Jl. WR Supratman, Bengkulu, Indonesia E-mail: nsetyowati@unib.ac.id

applying organic and synthetic fertilizers.

The soil in the Bengkulu region of Indonesia is dominated by Ultisols. This soil is typically acidic, with high levels aluminum saturation, and low in essential nutrients such as calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^+), and sodium (Na^+). These characteristics cause the soil less fertile than other soil order like Alfisols or Mollisols (Britannica, 2012; Kettler & Bill Zanner, 2024). Nevertheless, Ultisols play an essential role in developing dryland agriculture in Indonesia. Oktari et al. (2021) noted that problems of Ultisols include acidic soil reactions (pH), high aluminum saturation, and low nutrient content. The soil often exhibit reddish or yellowish hues due to iron oxides, which are prominent after extensive leaching. The surface horizon is typically humus-rich but can be nutrient-poor (Britannica, 2024; McClellan, 2024). Improving Ultisols for crop production involves several strategies to enhance their physical and chemical properties, such as liming and organic fertilization to reduce limiting factors for agricultural productivity. Regular fertilization, especially with phosphorus- and potassium-rich fertilizers, is crucial because Ultisols are often low in these nutrients. Combining organic and synthetic fertilizers can aid in mobilizing nutrients already present in the soil (Ardian et al., 2022).

Organic fertilizers enhance soil structure, increase its ability to retain moisture and promote beneficial microbial activity. Organic fertilizers release nutrients gradually as they decompose and contain a broader range of nutrients, including micronutrients that may not be present in synthetic options. The fertilization also improves water movement and nutrient availability over time (Assefa & Tadesse, 2019). On the other hand, excessive use of synthetic fertilizers can harden the soil, reducing its water-holding capacity, leading to unfavorable environment to plant growth. Excessive use of synthetic fertilizer can also cause plant damage and environmental pollution and destroy beneficial microorganisms (Tripathi et al, 2020; Sabry, 2015).

The use of organic fertilizer can replace or be combined with synthetic fertilizer in plant cultivation (Setyowati et al., 2024; Setyowati et al., 2023a; Setyowati et al., 2023b; Suprijono et al., 2023). Several types of organic fertilizer come from nature, including manure, wild animal manure, green manure, compost, humus, biological fertilizer, and agricultural industry waste (Sutedjo, 2018). Swiftlet manure is rich in nutrients for plant growth.

Recently, swiftlet nest farmers have not yet harnessed the benefits of swiftlet manure, leaving it as mere waste. According to Sutedjo (2018), swiftlet manure contains 50.46% organic carbon, 11.24% total nitrogen, and a C/N ratio of 4.49, with a pH of 7.97, 1.59% phosphorus (P), 2.17% potassium (K), 0.30% calcium, and 0.01% magnesium. These qualities indicate its potential as an organic fertilizer. Compared to other animal manures, swiftlet manure offers significantly higher levels of macronutrients like nitrogen (N), phosphorus (P), and potassium (K) (Ramadhan et al., 2024). For instance, chicken manure contains 1.7% N, 1.90% P_2O_5, and 1.50% K_2O, cow manure provides 0.29% N, 0.17% P_2O_5, and 0.35% K_2O; and sheep manure has 0.55% N, 0.31% P_2O_5, and 0.15% K_2O (Roidah, 2013).

Iqbal & Ulpah (2022) found that swiftlet manure has a significant impact on shallot growth, identifying 93.75 g/plant as the optimal dose for cultivation. Similarly, Wibowo (2016) observed that a 10-ton/ha dose of swiftlet manure enhances Hiyung chili yields, while Yanto (2019) reported that a 15-ton/ha dose is ideal for Kenaf plants (Hibiscus cannabinus L.). A study by Widayani (2021) also highlighted that a 25-ton/ha application of swiftlet manure enhances shallot growth and yield. Additionally, a combination of 30 tons/ha of swiftlet manure with 400 kg/ha of synthetic N, P, and K fertilizers improved both fresh and dry weight of shallot bulbs. Hasani & Muhdiar (2019) noted that applying 20 tons/ha of swiftlet manure compost yielded the best results for leaf count, plant height, and overall shallot production The research aims to explain the growth patterns of plant height and number of leaves at various doses of swiftlet manure fertilizer in Ultisol and determine the appropriate dose of swiftlet manure fertilizer for the growth and yield of shallots.

Method

The study took place in Pondok Suguh Village, Pondok Suguh District, Mukomuko Regency, Bengkulu Province, Indonesia, from August to October 2023, at an elevation of 150 meters above sea level. The experiment used a completely randomized design (CRD), with three repetitions. The experiment included seven swiftlet manure treatment levels (0 tons/ha, 5 tons/ha, 10 tons/ha, 15 tons/ha, 20 tons/ha, 25 tons/ha, and 30 tons/ha). Each treatment was paired with synthetic N, P, and K fertilizers at half the recommended dose, based on Silaen (2022), which specifies 435 kg/ha of urea, 250 kg/ha of SP-36, and 125 kg/ha of KCl.

The treatment notations are as follows:

W0: 434.78 kg/ha urea, 250 kg/ha SP-36, and 125 kg/ha KCl/plant (100% urea, SP-36, and KCl) as control treatment (Silaen, 2022),

W1: 5 tons/ha of swiftlet manure + 50% urea+ 50% SP-36 + 100% KCl

W2: 10 tons/ha of swiftlet manure + 50% urea+ 50% SP-36 + 100% KCl

W3: 15 tons/ha of swiftlet manure + 50% urea+ 50% SP-36 + 100% KCl

W4: 20 tons/ha of swiftlet manure + 50% urea+ 50% SP-36 + 100% KCl

W5: 25 tons/ha of swiftlet manure + 50% urea+ 50% SP-36 + 100% KCl

W6: 30 tons/ha of swiftlet manure + 50% urea+ 50% SP-36 + 100% KCl

The planting medium consisted of Ultisols collected from a depth of 20 to 40 cm. The soil was air-dried for two days and then sieved through a 0.5 cm^2 mesh to eliminate debris and achieve a uniform medium. It was then mixed with rice husk charcoal in a 2:1 ratio, and dolomite lime was added at a rate of 29.220 g per polybag. This soil mixture was then packed into polybags, with each polybag containing 10 kg of the mixture.

The swiftlet manure was obtained from swiftlet farmers in Muko Muko Regency. The swiftlet manure was prepared by mixing 10 kg of swiftlet waste with 10 ml of EM4, 100 g of palm sugar, and 10 liters of water. This mixture was thoroughly incorporated and placed in a sealed container, which was opened every five days for stirring before being resealed. After 49 days, the compost was fully processed and ready for application.

The swiftlet manure was applied a week prior to planting, thoroughly mixed into each polybag according to the designated treatments. Fertilization involved a base application and follow-up fertilizers. The base fertilizers, P and K, was applied a week before planting by evenly spreading across the soil surface in each polybag. The first follow-up N fertilizer was applied 15 days after planting, with the second follow-up application given 30 days after planting.

For planting, the shallot bulbs were trimmed by cutting off the top third of each bulb. One bulb was placed in each polybag, with half of the bulb buried in the prepared planting medium, ensuring the tip faced upward and the cut side aligned with the soil surface. A thin layer of soil was added on top, followed by watering to maintain soil moisture.

The shallots were watered every morning and evening to maintain soil moisture. Weed was controlled manually every week until harvesting. Pest and disease were controlled using chemical pesticide whenever signs of pest and disease infestation appeared.

Harvesting took place 70 days after planting (DAP), with indicators such as yellowing and wilting of leaves, partial emergence of bulbs at the soil surface, and the outer bulb layers turning red. The observed variables included plant height (cm) and the number of leaves per clump, recorded weekly from 1 to 7 weeks after planting (WAP), along with stem diameter (mm), number of bulbs per clump, bulb diameter (mm), fresh bulb weight per clump (g), and dry bulb weight per clump (g). Additionally, supporting data such as N, P, K, and organic C content, as well as information on rainfall, temperature, and humidity, were also collected.

Data Analysis

The measurement and observation data were then analyzed using Analysis of Variance (ANOVA) at a 5% significance level. If a significant effect was identified, the analysis was followed by Duncan's Multiple Range Test (DMRT) at a 5% level.

Results and Discussion

Research Overview

Throughout the research period, the average air temperatures were 35.4°C in August, 26.2°C in September, and 27.1°C in October, with corresponding humidity levels of 84%, 75%, and 73%. Sunlight exposure averaged 81.7%, 81.9%, and 84.5%, while recorded rainfall amounts were 13.92 mm in August, 0 mm in September, and 2.0 mm in October 2023 (BMKG, 2023). These environmental conditions were favorable for shallot cultivation, as outlined by Sutarya &

Grubben (1995), who recommend minimum sunlight exposure of 70% (more than 12 hours daily), air temperatures between 25-32°C, and humidity levels of 50-70% for optimal growth.

Figure 1. Shallots affected by powdery mildew disease

During the study, the plants experienced powdery mildew disease, identified by white spots on the undersides of the leaves. The infection intensity reached approximately 20% on the shallot plants. To manage this, a fungicide containing Azoxystrobin 200 g/L and Difenoconazole 125 g/L was applied twice weekly at a concentration of 1 ml per liter of water. Additionally, disease control included a fungicide with active ingredients mefenoxam 4% + mancozeb 64%, and methomyl 25%, sprayed weekly at dosages of 2 g/L and 1 g/L, respectively.

Effect of swiftlet manure on the growth and yield of shallot

The data analysis showed that applying swiftlet manure at various doses significantly affected plant height, number of leaves, and bulb weight (Table 1).

Table 1. Effect of swiftlet manure dosage on the growth and yield of shallot

Variables	F-calc.	Notation	Coev. Var. (%)
Plant height 7 WAP	5.74	*	11.95
Leaves number 7 WAP	10.56	*	16.68
Stem diameter	0.61	ns	28.11
Bulb number	0.68	ns	31.89
Bulb diameter	1.14	ns	18.08
Fresh weight	6.28	*	24.90
Bulb dry weight	10.77	*	24.27

Note: * = significant effect on the 5% F test, ** = very significant effect on the 5% F test, ns = not significant effect on the 5% F test.

The number of bulbs, bulb diameter and stem diameter of the shallots did not differ among treatments. Plants fertilized with swiftlet manure at various doses did not produce significantly different stem diameters, number of bulbs, or bulb diameters compared to the control or those fertilized with synthetic fertilizers at the recommended dose.

Growth Patterns of Plant Height and Number of Shallot Leaves

Vegetative growth of shallots is represented by plant height and number of leaves. The pattern of plant height growth in weeks 1 WAP – 7 WAP showed a positive linear pattern (Figure 2).

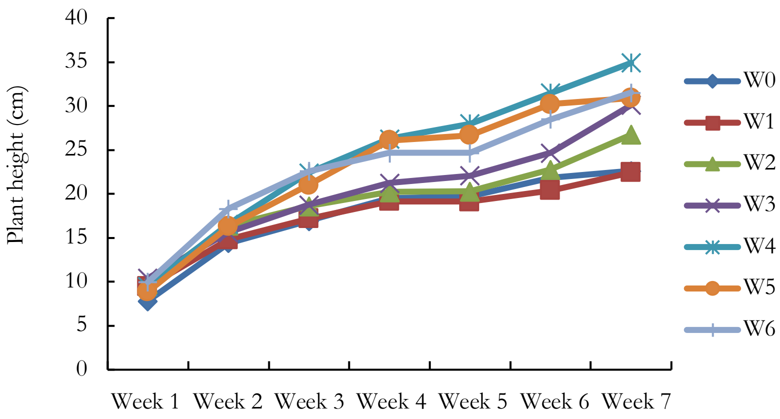

Figure 2. Shallot plant height 1 to 7 weeks after planting

Swiftlet manure started to affect plant height four weeks after planting. Figure 2 shows that the highest plant height was observed in treatment W4 (20 tons/ha of swiftlet manure + 217.5 kg/ha urea, 125 kg/ha SP-36, and 125 kg/ha KCl per plant), while the lowest plant height was observed in treatment W0 (434.78 kg/ha urea, 250 kg/ha SP-36, and 125 kg/ha KCl per plant or the control treatment).

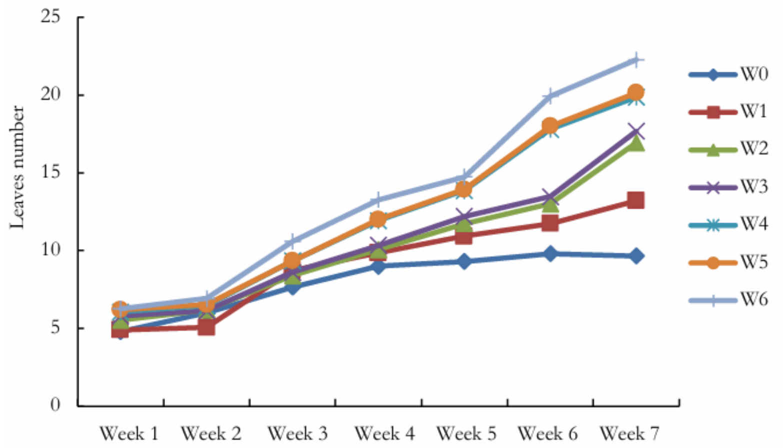

Figure 3. Shallot leaves number 1 to 7 weeks after planting

The growth pattern of leaf number in shallot plants follows a positive linear pattern and starts to show an effect in the third week (Figure 3). The highest number of leaves was produced by treatment W6 (30 tons/ha of swiftlet manure + 217.5 kg/ha urea, 125 kg/ha SP-36, and 125 kg/ha KCl per plant). Meanwhile, the lowest number of leaves was observed in treatment W0 (434.78 kg/ha urea, 250 kg/ha SP-36, and 125 kg/ha KCl per plant or the control treatment). Therefore, applying swiftlet manure combined with synthetic N, P, and K fertilizers at half the recommended dosage can enhance the vegetative growth of shallot plants.

In general, swiftlet manure combined with N, P, and K fertilizers resulted in taller plants and more leaves than plants fertilized only with synthetic fertilizers or without adding organic fertilizers. Swiftlet manure combined with N, P, and K fertilizers provides essential nutrients effectively, supporting shallot leaf growth. Rich in organic matter, swiftlet manure improves nutrient availability and uptake while enhancing soil structure, porosity, and water retention. This result leads to better root development, increased microbial activity, and a more sustained nutrient release, promoting healthier soil and more vigorous plant growth with taller plants and more leaves (Panjaitan et al, 2023; Zhou et al, 2022).

Growth and yield of shallots at various swiftlet manure doses

The analysis of variance showed that the dose of swiftlet manure affected the growth and yield of shallot plants (Table 1). Treatment with swiftlet manure doses began to influence plant height four weeks after planting, while the number of leaves started three weeks after planting.

Table 2 demonstrates that the W3 treatment, with a fertilizer dose of 15 tons/ha, resulted in plant heights that were not significantly different from the W4, W5, and W6 treatments. This finding has practical implications for optimizing fertilizer use in shallot cultivation.

Table 2. Effect of swiftlet manure fertilizer on the growth and yield of shallots

Swiftlet dose	Variables			
	Plant height (cm)	Leaves number	Bulb fresh weight (g)	Bulb dry weight (g)
W0	22,63 b	9,66 c	32,3 c	15, 9 c
W1	22,43 b	13.2 c	33,2 c	19,4 c
W2	26,73 b	16.93 b	42,8 b	25,4 c
W3	30,10 a	17,67 b	51,4 b	31,2 b
W4	34,90 a	19.87 a	79,0 a	57,4 a
W5	30,90 a	20,13 a	73,5 a	48,1 a
W6	31,53 a	22,26 a	68,4 a	48,6 a

Note: Numbers followed by the same letter in the same column are not significantly different at the 5% DMRT level.

Thus, applying swiftlet manure at 15 tons/ha along with half the recommended dose of synthetic fertilizers resulted in taller plants compared to shallots fertilized solely with synthetic fertilizers. Table 2 also indicates that the leaf count in treatment W4 was comparable to that in treatments W6 and W5. These findings suggest that applying swiftlet manure at doses of 15 or 20 tons/ha can enhance shallot plant height and leaf number. This improvement in growth demonstrates that, beyond supplying nutrients, swiftlet manure can also enhance the soil chemical and physical properties. According to Siregar (2024), the nutrients in soil must adequately support the needs of shallot plants to ensure proper growth and development, as reflected in plant height and leaf number.

Potassium is crucial for the photosynthesis process in shallots. It regulates the opening and closing of stomata, which optimizes carbon dioxide uptake while minimizing water loss. This regulation enhances the efficiency of photosynthesis, leading to better growth and higher yields (Bhermana et al., 2021). Adequate potassium levels also stimulate the formation of new roots in shallots (Muhardi, 2022). Potassium nutrients help improve plant growth, aid the photosynthesis process, and stimulate the formation of new roots during the development of shallot plants. Additionally, potassium helps form carbohydrates and proteins, absorbs water and soil nutrients, strengthens plant stems, and improves fruit quality (Jenkins, 2024).

The soil analysis results in this study showed nitrogen (N) content of 0.10% (low), phosphorus (P) at 5.24 ppm (moderate), potassium (K) at 0.29 (low), and carbon (C) at 1.65% (moderate), with the soil being acidic. Soil nutrient content showed unfavorable soil conditions for plant growth and can be improved by adding swiftlet manure, which provides nutrients for shallot plants. Swiftlet manure contains N = 3.08%, P = 1.18 ppm, K = 0.83 ppm, C = 21.15%, and has a pH of 7.1. The addition of swiftlet manure to the planting media can increase microbial activity in the soil.

Swiftlet manure can enhance microbial activity, which supports the vegetative growth of plants. Sutedjo (2018) highlighted that various microbial activities in animal manure produce growth hormones such as auxins, gibberellins, and cytokinins, which stimulate the growth of plant organs like the increase in leaf number, number of branches, and the development of root hairs. The development of root hairs improves nutrient absorption by plants, resulting in better plant growth. Applying swiftlet manure provides N, P, and K nutrients that plants can utilize for their growth. Nitrogen is essential for cell division and elongation, which are critical processes in stem growth. Higher nitrogen availability promotes the synthesis of proteins and nucleic acids, enhancing the capacity for cell expansion and leading to taller stems (Souza & Tavares, 2021). Nitrogen enhances the uptake of minerals such as phosphorus and potassium by improving root function and efficiency. This interaction is vital for balanced nutrition and optimal plant development (Xu et al., 2020). Phosphorus is responsible for stimulating growth and accelerating root development in plants.

The number of leaves at the 7th week in treatment W4 (20 tons/ha) was 19.87, which was not significantly different from treatment W5 (25 tons/ha) with 20.13 leaves, and treatment W6 (30 tons/ha) with 22.26 leaves. The number of leaves in treatments W4-W6 was higher compared to treatments W0 and W1, which had 9.66 and 13.2 leaves, respectively. This result aligns with Iqbal & Ulpah (2022), who found that the swiftlet manure treatment produced the most shallot leaves at a dose of 30 tons/ha, with 22.26 leaves.

The increase in leaf number is associated with the availability of N, P, and K for the plants, which released by synthetic fertilizers and swiftlet manure. Essential nutrients, particularly nitrogen (N), promote cell division and elongation. Nitrogen is an essential component of amino acids and proteins necessary for cell growth. Shallots can grow well, in part because the necessary nutrients are available. Plant growth is a part of the process of cell elongation and cell division, which requires nutrients, water, specific hormones, and carbohydrates (Anisyah et al, 2014).

The highest fresh bulb weight was produced by treatment W4 (20 tons/ha), reaching 79 g, and was significantly different from treatments W0 (control) and W1 (5 tons/ha), which only produced 32.3 g and 33.2 g, respectively. The highest fresh bulb weight per clump was obtained from shallot plants fertilized with swiftlet manure combined with synthetic fertilizers. Swiftlet manure, rich in organic matter, improves water retention in soil and provides essential nutrients like N, P, and K. Potassium helps bind water, enhancing photosynthesis and bulb growth. Research by Iqbal & Ulpah (2022) found that 20 tons/ha of swiftlet manure combined with 30 g KCl per pot produced a bulb weight of 114.48 g. Munawar (2011) noted that organic matter improves soil structure and nutrient availability.

Nutrients such as nitrogen (N), phosphorus (P), and potassium (K) are essential macronutrients that play specific roles in plant growth. Nitrogen is vital for protein synthesis and chlorophyll production, phosphorus aids energy transfer and root development, and potassium regulates water use and enzyme activity (Havlin et al., 1999). Deficiencies in these nutrients can lead to stunted growth, poor yields, and reduced plant health (Ehrmann & Ritz, 2014). Adequate nitrogen levels promote the synthesis of chlorophyll, which is essential for photosynthesis. Enhanced photosynthesis increases the plant's ability to convert sunlight into energy, supporting growth and development (Day et al., 1993). The photosynthesis process yielded assimilate, which helps form vegetative organs such as roots, leaves, and plant tubers.

The highest dry bulb weight was produced from the swiftlet manure treatment at a dose of 20 tons/ha (W4), which was 57.4 g and significantly different from treatments W0, W1, and W3, with dry weights of 15.9 g, 19.4 g, and 25.4 g, respectively. Thus, the use of swiftlet manure can reduce or replace the use of synthetic N, P, and K fertilizers. Study by Iqbal & Ulpah (2022) indicated that swiftlet manure and KCl significantly affected the dry bulb weight per clump, achieving a weight of 100.95 g per clump in the treatment of 20 tons/ha and 30 g/polybag of KCl.

The higher dry bulb weight of shallots in treatment W4 (20 tons/ha) indicates that the high potassium content from swiftlet manure can meet the nutrient needs of the plants, thus enhancing production. Treatment W4 combines swiftlet manure and N, P, and K fertilizers that provide sufficient nutrients for plant growth, allowing the plants to thrive and yield maximum results. According to Hasani & Muhdiar (2019), plants will thrive when the elements (nutrients) they require are available and in a form that the plants can absorb.

Sufficient potassium enhances shallot growth by aiding photosynthesis and organic compound formation, which boosts bulb weight and total yield. According to Siregar (2024), potassium significantly increases dry bulb weight. Bulb shrinkage, or weight loss, indicates quality; less shrinkage suggests better quality and longer storage potential. Shallots gradually lose weight during storage as metabolic processes like respiration release water and CO_2, reducing bulb mass over time.

Implications

The growth patterns in height and leaf count for shallots treated with different doses of swiftlet manure show a positive trend, with doses of 15, 20, 25, and 30 tons/ha resulting in greater plant heights and leaf counts than lower doses. Applying swiftlet manure at 20 tons/ha, in combination with synthetic fertilizers at 217 kg/ha urea, 125 kg/ha SP-36, and 125 kg/ha KCl, leads to higher growth and yield in shallots compared to plants fertilized only with synthetic fertilizers.

Using swiftlet manure at dose 20 tons/ha combined with moderate synthetic fertilizers, enhances shallot growth and yield, offering a sustainable and effective fertilizer strategy for low-fertility soils.

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