eISSN: 2721-5717; pISSN: 2747-2124 https://journal.unhas.ac.id/index.php/zonalaut

ZONA LAUT

JOURNAL OF OCEAN SCIENCE AND TECHNOLOGY INNOVATION

Soil Fertility Management in Coastal Areas through the Application of Organic Amendments with Different C/N Ratios: A Study on Lembah Palu Shallot

Lisa Indriani Bangkele[1], Idris[1*], Kasman Kasim[1], Syarifuddin Ende[1], Siti Fathurahmi Wahid[2], Nur Aisyah[1], Nilsa[2]

[1]Agrotechnology Study Program, Faculty of Agriculture, Alkhairaat University, Indonesia
[2]Agricultural Product Technology Study Program, Faculty of Agriculture, Alkhairaat University, Indonesia
[*]lisa24in.b@gmail.com

Abstrak

Lembah Palu shallot is a high-value local horticultural commodity of Central Sulawesi, its adapted to the dry lowland climates makes it a promising crop for coastal agriculture. Agricultural development in coastal areas requires soil-management technologies that improve nutrient availability, enhance the rhizosphere environment, and sustain crop productivity. This study evaluated the effects of organic amendments with different carbon-to-nitrogen ratio (C/N ratio) on soil pH, rhizosphere microorganism populations, nitrogen (N), phosphorus (P), and potassium (K) acquisition, and the yield of Lembah Palu shallot. A one-factor randomized block design was used with five treatments: unamended control, cattle manure (C/N 19.8), rice husk (C/N 40.7), cocopeat (C/N 90.6), and vegetable compost (C/N 13.5). The measured variables included soil N, P, and K; plant-tissue N, P, and K acquisition; rhizosphere microorganism colony numbers; bulb numbers; fresh and oven-dry bulb weights; and yields per hectare. The results demonstrate organic amendments with different C/N ratio influenced soil nutrient dynamics, rhizosphere microorganism abundance, plant-tissue nutrient concentrations, and yield of Lembah Palu shallot. Among the amendments evaluated, cocopeat (C/N 90.6) produced the highest tissue N concentration (3.57%), bulb number (8.50 bulbs clump^{-1}), bulb dry weight (0.09 g clump^{-1}), numerical fresh bulb yield (5.87 t ha^{-1}), and oven-dry bulb yield (0.05 t ha^{-1}), significantly higher than cattle manure and vegetable compost treatments. The favorable performance and characteristics of cocopeat could associated with gradual nutrient release and improved root-zone conditions, particularly water retention and aeration, which can enhance nutrient acquisition in porous coastal soils. Because cocopeat is derived from locally available coconut residues, its use may also support agricultural-waste utilization and sustainable agriculture in coastal areas.

Keywords: Lembah Palu shallot; soil fertility, coastal areas; organic amendments; C/N ratio; NPK acquisitin

1. INTRODUCTION

Lembah Palu shallot (Allium cepa L. var. aggregatum) is a leading horticultural commodity in Central Sulawesi, with high economic value, growing market demand, and good adaptation to dry lowland agroecosystems. These characteristics make it a potentially strategic crop for coastal agricultural development, particularly for strengthening local economies and food security. However, its productivity remains low and variable, largely because of limited soil nitrogen (N), phosphorus (P), and potassium (K) availability [1], [2]. This constraint is especially important in coastal areas, where light-textured soils generally have low water- and nutrient-retention capacity and therefore require organic amendments to improve soil and rhizosphere functions [3]. This study compares organic materials with different decomposition characteristics and water-holding capacities, thereby contributing evidence for the use of coastal areas to expand local shallot cultivation.

The availability of soil nutrients, particularly nitrogen (N), phosphorus (P), and potassium (K), is strongly influenced by the decomposition of applied organic matter. Among the factors regulating this process, the carbon-to-nitrogen (C/N) ratio is one of the most important because it controls the rate and pathway of microbial decomposition, thereby affecting nutrient mineralization and availability [4]. Effective management of the C/N ratio is especially critical in coastal agricultural systems, where porous soils and high permeability can accelerate nutrient losses through leaching. Organic materials with a low C/N ratio (<20) generally decompose rapidly, promoting mineralization and releasing nitrogen in plant-available forms such as NH_4^+ and NO_3^-. In contrast, organic amendments with a high C/N ratio (>30) decompose more slowly and may initially induce microbial nitrogen immobilization, as soil microorganisms temporarily utilize available nitrogen for biomass synthesis, thereby reducing nitrogen availability for plant uptake [5], [6]. Therefore, selecting organic amendments with an appropriate C/N ratio is essential for improving nutrient-use efficiency, maintaining soil fertility, and enhancing crop productivity in coastal farming systems.

Low C/N ratio organic materials generally decompose rapidly and supply nutrients early, but nutrients may be readily leached from porous soils or growing media. High C/N ratio materials release nutrients more slowly but may improve soil physical and biological properties over a longer period, including water retention, aeration, and rhizosphere microbial activity [7], [8]. Sustainable coastal horticulture therefore requires a balance among nutrient release, water retention, and soil biological activity.

Plant uptake of N, P, and K is a critical indicator of the effectiveness with which crops use nutrients released from organic amendments to support physiological processes and bulb formation. Understanding the relationship between amendment C/N ratio, N,P,K uptake, and crop yield is therefore necessary to develop precise and adaptive organic-fertilization strategies for Lembah Palu shallot in coastal agroecosystems.

2. METHODS

The experiment was conducted at the Experimental Farm of the Faculty of Agriculture, Alkhairaat University, from September to December 2025. The site represents a lowland agroecosystem suitable for Lembah Palu shallot. The resulting data were intended to support the development of organic-amendment management practices for shallot production in coastal farming systems.

A one-factor randomized block design was used with five organic-amendment treatments, each applied at a rate commonly recommended for horticultural crops:

- P0: Control (no organic amendment)
- P1: Cattle manure at 25 t ha^{-1}
- P2: Rice husk at 25 t ha^{-1}
- P3: Cocopeat at 25 t ha^{-1}
- P4: Vegetable compost at 25 t ha^{-1}

Each treatment was replicated three times, giving 15 experimental units. Each unit comprised two pots, for a total of 30 experimental pots.

2.1. Experimental Procedures

Preparation and planting: The growing medium, comprising soil and the organic amendment assigned to each treatment, was prepared according to the experimental design. Lembah Palu shallot (Allium ascalonicum L.) bulbs were planted in pots. Crop maintenance included regular irrigation, manual weeding, and mechanical control of pests and diseases.

Soil and microbial analyses: Soil pH was measured before, during, and after the experiment. Plant-available nitrogen (N), phosphorus (P), and potassium (K) concentrations were determined to assess changes in soil nutrient availability. The population of decomposer microorganisms was quantified using the total plate count method.

Plants observations: Vegetative growth was evaluated based on fresh and oven-dry plant weights per clump. Yield components: the number of shallot bulbs, their fresh and oven-dry weights shallots per clump, were measured at harvest. Plant-tissue N, P, and K concentrations were also determined to evaluate nutrients acquisition.

2.2. Data Analysis

The data were analyzed using analysis of variance (ANOVA). When significant treatment effects were detected, mean comparisons were performed using the least significant difference (LSD) test at the 5% significance level ($p < 0.05$).

The evaluated response variables included soil pH, decomposer microbial populations, and plant-available nitrogen (N), phosphorus (P), and potassium (K). Agronomic variables included plant-tissue N, P, and K concentrations, bulb number, and fresh and oven-dry plant and bulb weights per clump. The results were used to formulate technical recommendations for selecting and applying organic amendments based on their C/N ratios in coastal shallot cultivation.

3. RESULTS AND DISCUSSION

3.1. Results

3.1.1. Soil Nitrogen (N)

Soil N concentrations were measured at three observation times to evaluate temporal changes in N availability following the application of organic amendments with different C/N ratios. As presented in Table 1, the treatments produced different initial soil N concentrations, while subsequent observations showed fluctuations that may reflect the combined effects of organic-matter decomposition, microbial N immobilization and mineralization, plant uptake, and nutrient loss from the growing medium.

Table 1. Mean soil N concentrations at three observation times

Treatment	Observation 1	Observation 2	Observation 3
Control	13.32[a]	14.48	10.38
Cattle manure (C/N 19.8)	13.17[a]	15.70	11.78
Rice husk (C/N 40.7)	8.53[b]	12.20	10.87
Cocopeat (C/N 90.6)	13.07[a]	14.55	10.53
Vegetable compost (C/N 13.5)	14.05[a]	13.70	11.28
LSD ($\alpha = 0.05$)	4.31	—	—

Note: Values followed by the same superscript letter within the same column are not significantly different according to the LSD test at $\alpha = 0.05$. Soil N concentrations are expressed in mg kg^{-1}.

At planting, vegetable compost treatment produced the highest soil N concentration (14.05 mg kg^{-1}). Although it did not differ significantly from most treatments, it was significantly higher than rice husk treatment, which produced the lowest value (8.53 mg kg^{-1}) (Table 1). These results show that organic materials with different C/N ratios produce distinct patterns of soil N availability. This information is particularly relevant to coastal agriculture because N is readily lost by leaching from porous soils.

3.1.2. Soil Phosphorus (P)

Vegetable compost treatment produced the highest initial soil P concentration (36.10 mg 100 g^{-1}), whereas rice husk treatment produced the lowest (26.75 mg 100 g^{-1}) (Figure 1). At the second observation, soil P increased in nearly all treatments, reaching 41.20 mg 100 g^{-1} under treatment of cattle manure. By the third observation, however, P declined across all treatments to 28.92–31.97 mg 100 g^{-1}. This pattern demonstrates the dynamic availability of P and the need to maintain its supply during bulb formation.

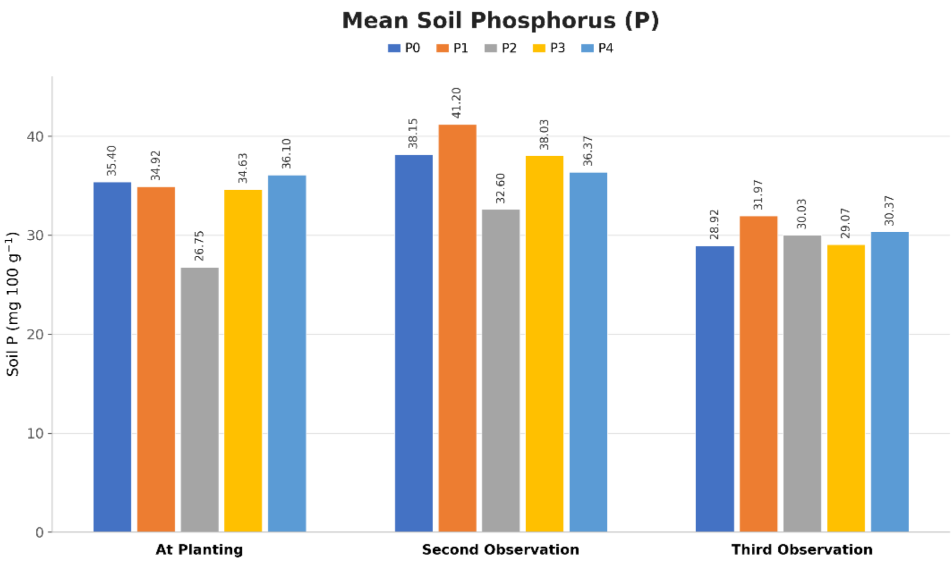

Figure 1. Mean soil phosphorus concentrations across treatments at three observation times.

3.1.3. Soil Potassium (K)

As shown in Fig. 2, initial soil K concentrations were approximately 34 mg 100 g^{-1} across most treatments, whereas rice husk produced the lowest value (25.37 mg 100 g^{-1}). At the second observation, soil K concentrations increased under all treatments, reaching the highest level under cattle manure treatment (40.65 mg 100 g^{-1}). However, by the third observation, the concentrations had declined to 28.40–31.45 mg 100 g^{-1}. This temporal pattern may reflect the combined effects of K release from the organic amendments, plant uptake, and nutrient loss from the growing medium. Given the essential role of K in assimilate translocation, bulb initiation, and bulb development, maintaining adequate K availability throughout the growing period is important for sustainable shallot production in coastal soils.

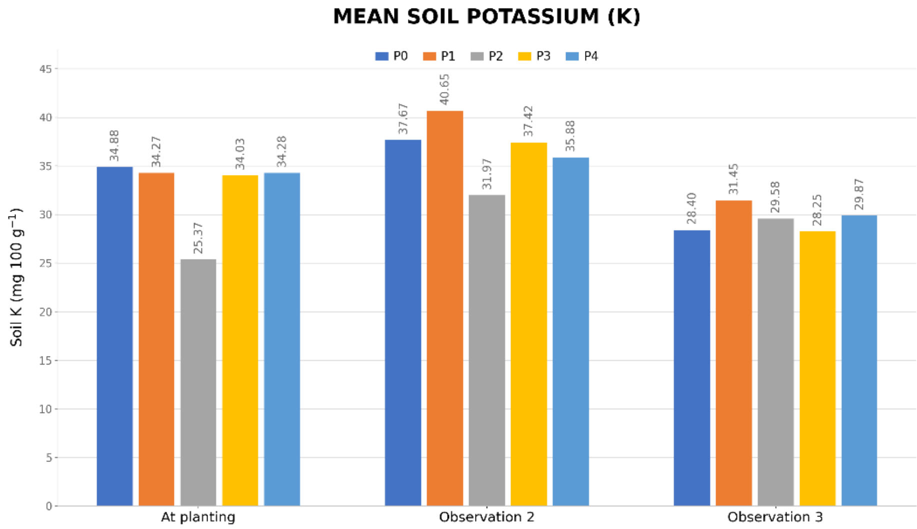

Figure 2. Mean soil potassium concentrations across treatments at three observation times.

3.1.4. Fresh Weight of Shallot Plants

Cocopeat tended to produce greater total shoot fresh weight and bulb fresh weight than the other organic amendments (Fig. 3).

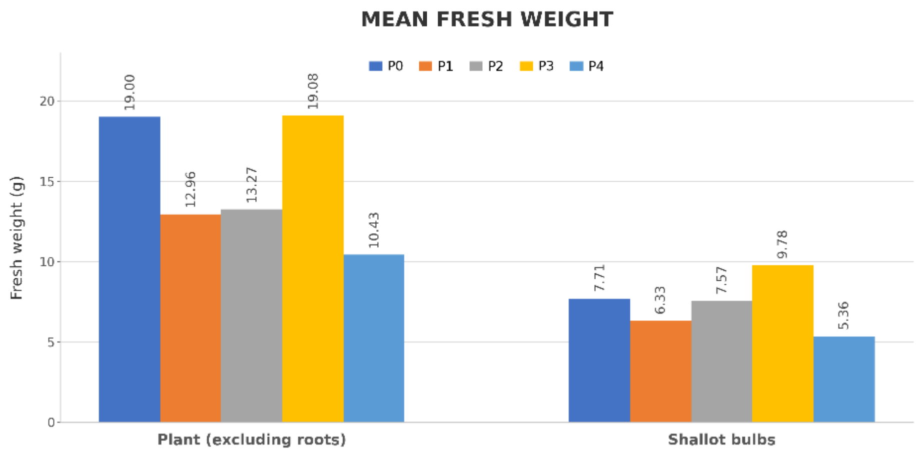

Figure 3. Mean fresh weights of shallot plants (excluding roots) and bulbs under different organic-amendment treatments

This response suggests that improving the physical condition of the growing medium can promote plant growth, particularly where water retention and adequate root space are essential.

3.1.5. Oven-Dry Weight of Shallot Plants

The oven-dry weights of shallot plants and bulbs were measured to assess dry-matter accumulation under the different organic-amendment treatments. As presented in Table 2, cocopeat produced the highest oven-dry plant and bulb weights, whereas vegetable compost resulted in the lowest values.

Table 2. Mean oven-dry weights of shallot plants and bulbs under different organic-amendment treatments

Treatment	Plant dry weight (g)	Bulb dry weight (g)
Control	0.11	0.06^{ab}
Cattle manure (C/N 19.8)	0.10	0.05^{b}
Rice husk (C/N 40.7)	0.10	0.06^{ab}
Cocopeat (C/N 90.6)	0.13	0.09^{a}
Vegetable compost (C/N 13.5)	0.06	0.04^{b}
LSD ($\alpha = 0.05$)	—	0.04

Note: Within the bulb dry-weight column, means followed by the same superscript letter are not significantly different according to the LSD test at α = 0.05.

The treatment of cocopeat produced the highest bulb dry weight (0.09 g), which was significantly higher than those obtained with cattle manure treatment (0.05 g) and vegetable compost treatment (0.04 g), but not significantly different from the control and rice husk treatment (0.06 g each). Although cocopeat treatment also produced the highest plant dry weight (0.13 g), no mean-separation results were reported for this variable. Bulb dry weight reflects the accumulation and translocation of photosynthates into the harvested organ and is therefore an important indicator of shallot productivity in coastal farming systems.

3.1.6. Number of Shallot Bulbs

The number of bulbs per clump was evaluated to determine the effect of organic amendments with different C/N ratios on bulb formation. As presented in Table 3, cocopeat produced the highest mean number of bulbs, whereas vegetable compost produced the lowest.

Table 3. Mean number of shallot bulbs per clump under different organic-amendment treatments

Treatment	Number of bulbs (bulbs clump^{-1})
Control	7.75^{ab}
Cattle manure (C/N 19.8)	7.00^{b}
Rice husk (C/N 40.7)	7.50^{ab}
Cocopeat (C/N 90.6)	8.50^{a}
Vegetable compost (C/N 13.5)	6.67^{b}
LSD ($\alpha = 0.05$)	1.30

Note: Means followed by the same superscript letter are not significantly different according to the LSD test at α = 0.05.

The treatment of cocopeat produced the highest mean number of bulbs (8.50 bulbs clump^{-1}), which was significantly higher than those obtained with cattle manure treatment (7.00 bulbs clump^{-1}) and vegetable composttreatment (6.67 bulbs clump^{-1}). However, it did not differ significantly from the control (7.75 bulbs clump^{-1}) or rice husk treatment (7.50 bulbs clump^{-1}). These results suggest that the treatment of cocopeat provided favorable root-zone conditions for tiller development and bulb initiation.

3.1.7. Fresh and Oven-Dry Bulb Yield (t ha^{-1})

Fresh and oven-dry bulb yields were converted to a per-hectare basis to evaluate the productivity of Lembah Palu shallot under different organic-amendment treatments. As presented in Table 4,the treatment of cocopeat produced the highest numerical yields for both fresh and oven-dry bulbs.

Table 4. Mean fresh and oven-dry shallot bulb yields under different organic-amendment treatments

Treatment	Fresh bulb yield (t ha^{-1})	Oven-dry bulb yield (t ha^{-1})
Control	4.63	0.04^{b}
Cattle manure (C/N 19.8)	3.80	0.03^{b}
Rice husk (C/N 40.7)	4.54	0.03^{b}
Cocopeat (C/N 90.6)	5.87	0.05^{a}
Vegetable compost (C/N 13.5)	3.22	0.03^{b}
LSD ($\alpha = 0.05$)	—	0.02

Note: Within the oven-dry bulb yield column, means followed by the same superscript letter are not significantly different according to the LSD test at α = 0.05.

Cocopeat treatment produced the highest numerical fresh bulb yield (5.87 t ha^{-1}). However, because no mean-separation results were reported for fresh bulb yield, its apparent advantage should be interpreted as a numerical trend rather than a statistically significant difference. Cocopeat treatment also produced the highest oven-dry bulb yield (0.05 t ha^{-1}), which was significantly higher than those obtained under all other treatments. This result indicates that the treatment of cocopeat promoted greater dry-matter accumulation in the harvested bulbs and may therefore serve as a promising organic amendment for improving Lembah Palu shallot productivity in coastal horticultural systems.

3.1.8. Plant-Tissue Nitrogen (N), Phosphorus (P), and Potassium (K)

Plant-tissue N, P, and K concentrations were measured to evaluate nutrient accumulation under the different organic-amendment treatments. As presented in Table 5, the treatments produced distinct nutrient-concentration patterns.

Table 5. Mean N, P, and K concentrations in shallot plant tissue under different organic-amendment treatments

Treatment	Tissue N (%)	Tissue P (%)	Tissue K (%)
Control	3.25	0.34	4.68
Cattle manure (C/N 19.8)	3.37	0.26	3.39
Rice husk (C/N 40.7)	3.30	0.36	3.45
Cocopeat (C/N 90.6)	3.57	0.22	3.64
Vegetable compost (C/N 13.5)	3.33	0.33	2.10

The treatment of cocopeat produced the highest tissue N concentration (3.57%), whereas the control produced the lowest (3.25%). Tissue P concentration was highest under rice husk treatment (0.36%) and lowest under cocopeat treatment (0.22%). In contrast, the control produced the highest tissue K concentration (4.68%), while the treatment of vegetable compost produced the lowest (2.10%). These results indicate that each organic amendment generated a distinct pattern of nutrient accumulation in shallot tissue, potentially reflecting differences in nutrient release, root-zone conditions, and plant nutrient acquisition. However, because no statistical test results are reported in Table 5, these differences should be interpreted as numerical trends rather than statistically significant treatment effects.

3.1.9. Nitrogen (N), Phosphorus (P), and Potassium (K) Acquisition

Consentrations of N, P, and K in shallot plant tissues were measured to evaluate nutrient acquisition or nutrient accumulation under the different organic-amendment treatments. As presented in Table 6, the treatments produced distin`ct nutrient-concentration patterns.

Table 6. Mean N, P, and K concentrations in shallot plant tissue under different organic-amendment treatments

Treatment	Tissue N (%)	Tissue P (%)	Tissue K (%)
Control	3.25	0.34	4.68
Cattle manure (C/N 19.8)	3.37	0.26	3.39
Rice husk (C/N 40.7)	3.30	0.36	3.45
Cocopeat (C/N 90.6)	3.57	0.22	3.64
Vegetable compost (C/N 13.5)	3.33	0.33	2.10

The treatment of cocopeat produced the highest tissue N concentration (3.57%), whereas the control produced the lowest (3.25%). Tissue P concentration was highest under rice husk treatment (0.36%) and lowest under cocopeat treatment (0.22%). In contrast, the control produced the highest tissue K concentration (4.68%), while vegetable compost treatment produced the lowest (2.10%). These results indicate that each organic amendment generated a distinct pattern of nutrient accumulation in shallot tissue, potentially reflecting differences in nutrient release, root-zone conditions, and plant nutrient acquisition. However, because no statistical test results are reported in Table 5, these differences should be interpreted as numerical trends rather than statistically significant treatment effects.

3.2. Discussion

3.2.1. Effects of Amendment C/N Ratio on Soil N Dynamics

The C/N ratio of an organic amendment strongly influences microorganism decomposition and soil N dynamics. Carbon-rich materials generally promote temporary N immobilization, whereas amendments with lower C/N ratios or higher N contents tend to decompose more rapidly and release plant-available N. This process is particularly important in coastal agriculture because N can be readily lost through leaching from porous, coarse-textured soils.

However, the results presented in Table 1 indicate that crop response was not determined solely by the amendment C/N ratio. Despite having the highest C/N ratio (90.6), cocopeat did not suppress shallot productivity. Instead, it produced favorable responses in bulb number, bulb dry weight, and converted yield (Tables 2–4). This response may be associated with gradual nutrient release and improved root-zone conditions, which could enhance root development and nutrient acquisition. Previous studies have similarly demonstrated that N mineralization and immobilization depend on interactions among amendment type, C/N ratio, application rate, crop condition, and observation time [4], [5].

3.2.2. Physical Role of Cocopeat as an Organic Amendment

Cocopeat treatment produced the highest bulb number, averaging 8.50 bulbs $clump^{-1}$ (Table 3). This value was 21.4% higher than that obtained with cattle manure and 27.4% higher than that obtained with vegetable compost. Cocopeat treatment also produced the highest numerical fresh bulb yield of 5.87 t ha^{-1} (Table 4), representing increases of 26.8%, 54.5%, and 82.3% relative to the control, cattle-manure, and vegetable-compost treatments, respectively. However, because no mean-separation results were reported for fresh bulb yield, these differences should be interpreted as numerical trends rather than statistically significant treatment effects.

The oven-dry bulb yield under cocopeat treatment reached 0.05 t ha^{-1} and was significantly higher than those under the other treatments (Table 4). This result is consistent with the higher bulb dry weight recorded under cocopeat treatment (0.09 g; Table 2). The fresh-weight pattern presented in Fig. 3 also shows that cocopeat tended to support greater plant and bulb biomass.

The favorable response to cocopeat may be primarily associated with its physical properties. Cocopeat can improve water retention, aeration, pore structure, and root penetration, thereby supporting water availability, root development, and nutrient acquisition. These properties are particularly beneficial in coastal soils, which commonly have limited water- and nutrient-retention capacities [3]. Improved root growth and a larger root–soil contact area may also partly compensate for temporary N immobilization associated with high-C/N materials and enable plants to use available nutrients more efficiently [9].

3.2.3. Relationships among Soil Nutrients, Tissue Nutrient Status, and Bulb Yield

The temporal patterns of soil N, P, and K presented in Table 1 and Figs. 1 and 2 demonstrate that nutrient availability changed during the growing period. Nevertheless, higher soil nutrient concentrations did not always correlate linearly with bulb yields. For example, the treatment of cocopeat had a moderate initial soil N concentration of 13.07 mg kg^{-1} but produced the highest numerical fresh bulb yield of 5.87 t ha^{-1}. Conversely, vegetable compost treatment had the highest initial soil N concentration of 14.05 mg kg^{-1} but produced the lowest fresh bulb yield of 3.22 t ha^{-1}.

The tissue nutrient data presented in Table 5 also indicate that yield was not governed by a single nutrient concentration. Cocopeat treatment produced the highest tissue N concentration (3.57%) and an N/K ratio close to 1:1, with N and K concentrations of 3.57% and 3.64%, respectively. By comparison, vegetable compos treatment produced tissue N and K concentrations of 3.33% and 2.10%, respectively, corresponding to an N/K ratio of approximately 1.6:1. Although this pattern suggests that a more balanced tissue N/K status may have supported bulb production, this interpretation remains preliminary because statistical comparisons and established critical nutrient-ratio thresholds were not reported for the tissue data.

The favorable performance of cocopeat may therefore reflect the combined effects of nutrient retention, gradual nutrient release, water availability, aeration, and root development rather than total nutrient concentration alone. In porous coastal soils, rapid nutrient release may increase the risk of nutrient loss from the root zone, whereas a gradual release pattern may improve synchronization between nutrient availability and crop demand. Recent studies likewise indicate that plant-available nutrients and nutrient-acquisition efficiency may explain crop productivity more effectively than total soil nutrient concentrations [10].

3.2.4. Plant-Tissue N, P, and K and Their Relationship with Bulb Productivity

As shown in Table 5, the treatment of cocopeat produced the highest tissue N concentration (3.57%). This value was 9.8% higher than that of the control, 5.9% higher than that under cattle manure treatment, 8.2% higher than that under rice husk traetment, and 7.2% higher than that under vegetable compost treatment. Tissue P was lowest under cocopeat treatment (0.22%), whereas tissue K remained relatively high at 3.64%.

The higher tissue N concentration under cocopeat treatment was accompanied by the highest numerical fresh bulb yield and the highest oven-dry bulb yield (Table 4). Nitrogen supports vegetative growth, photosynthetic activity, and assimilate production. Nevertheless, tissue N concentrations varied only moderately among treatments, ranging from 3.25% to 3.57%. Therefore, the yield response under cocopeat treatment cannot be attributed solely to tissue N concentration.

Improved root-zone aeration, water availability, nutrient retention, and nutrient translocation to the bulbs may have contributed simultaneously to the observed response. This interpretation is consistent with van der Sloot et al. [4], who emphasized the importance of growing-medium properties and root–microbe interactions in plant nutrient acquisition. However, because Table 5 does not report inferential statistical results, differences in tissue nutrient concentrations should be interpreted as numerical trends.

3.2.5. Role of Rhizosphere Microorganisms

The microorganism colony numbers presented in Table 6 indicate that organic-amendment type and C/N ratio influenced the abundance of culturable rhizosphere microorganisms. The treatment of rice husk produced the highest microorganism population, followed by vegetable compost treatment, whereas cocopeat treatment produced the lowest. Rhizosphere microorganisms contribute to organic-matter decomposition and the transformation and cycling of N, P, and K in agricultural soils.

However, the highest microorganism population under rice husk treatment did not correspond to the highest bulb yield (Table 4). Microorganism abundance alone should therefore not be regarded as a direct predictor of crop productivity. Microorganism-community composition, functional activity, enzyme production, and synchronization between nutrient release and plant demand may be more important than the total colony numbers. Organic amendments have been reported to increase microorganism biomass, soil-enzyme activity, and nutrient-processing functions in agricultural ecosystems [10], [11].

3.2.6. Integrated Mechanisms Underlying the Benefits of Cocopeat

The results suggest that cocopeat improved shallot performance through interacting physical and nutritional mechanisms. As shown in Fig. 3 and Tables 2–5, the treatment cocopeat produced the highest tissue N concentration (3.57%), bulb number (8.50 bulbs clump^{-1}), bulb dry weight (0.09 g), numerical fresh bulb yield (5.87 t ha^{-1}), and oven-dry bulb yield (0.05 t ha^{-1}).

The principal statistically supported advantage of cocopeat treatment was observed for oven-dry bulb yield, which differed significantly from those under the other treatments (Table 4). The treatment of Cocopeat also produced significantly higher bulb dry weight than cattle manure and vegetable compost (Table 2) and a significantly higher bulb number than those two treatments (Table 3). However, its fresh bulb yield should be interpreted as a numerical advantage because no significant mean separation was reported for that variable.

From an application perspective, cocopeat may provide a useful means of recycling coconut residues while improving root-zone conditions in coastal soils. Its use may contribute to the productive cultivation of marginal sandy land, diversification of coastal livelihoods, increased local production of Lembah Palu shallot, and reduced dependence on mineral inputs. Nevertheless, regional cocopeat availability, potential reductions in fertilizer requirements, economic feasibility, and residual benefits over successive cropping seasons require field-scale validation before broad recommendations can be made.

3.2.7. Statistical Interpretation

The mean-separation letters and LSD values reported in Tables 1–4 identify treatment differences at the 5% significance level. In Table 2, cocopeat produced a significantly higher bulb dry weight than cattle manure and vegetable compost but did not differ significantly from the control or rice husk. In Table 3, the number of bulbs under cocopeat was significantly higher than those under cattle manure and vegetable compost but was comparable to those under the control and rice husk treatments.

For oven-dry bulb yield, the LSD value of 0.02 t ha^{-1} indicates that cocopeat differed significantly from all other treatments (Table 4). By contrast, no inferential statistical results were reported for fresh bulb yield or tissue nutrient concentrations. Consequently, differences in these variables should be described as numerical trends rather than statistically significant treatment effects.

3.2.8. Study Limitations and Recommendations for Coastal Application

This study had several limitations. First, soil nutrient concentrations were measured at only three observation times, and detailed measurements of mineral N forms (NH_4^+ and NO_3^-), plant-available P, and higher-resolution temporal nutrient dynamics were unavailable. Second, the total plate count method quantified only culturable microbial abundance and did not characterize microbial-community composition, functional groups, or enzyme activities involved in nutrient cycling. Third, important physical properties including field capacity, porosity, bulk density, and water-holding capacity were not measured quantitatively, although these properties are central to the proposed benefits of cocopeat. Fourth, the experiment was conducted in pots; therefore, the results may not fully represent nutrient movement, salinity, water dynamics, and root development under actual coastal-field conditions.

Future studies should evaluate cocopeat in combination with a readily available N source to improve synchronization between nutrient release and crop demand during early vegetative growth and bulb formation. Field trials on actual coastal soils should include measurements of salinity, NH_4^+, NO_3^-, plant-available P, exchangeable K, soil physical properties, and enzyme activities such as phosphatase, dehydrogenase, and urease. Microbial-community composition should also be characterized using appropriate molecular methods. Furthermore, different amendment rates and application times should be evaluated to align nutrient availability with critical crop-development stages, particularly the transition from vegetative growth to bulb initiation [5], [11].

4. CONCLUSION

Organic amendments with different C/N ratios influenced soil nutrient dynamics, rhizosphere microbial abundance, plant-tissue nutrient concentrations, and the growth and yield of Lembah Palu shallot. Among the amendments evaluated, cocopeat (C/N 90.6) produced the highest bulb number, bulb dry weight, numerical fresh bulb yield, and oven-dry bulb yield. Its statistically significant effects on several yield-related variables indicate its potential as an effective organic amendment for shallot cultivation.

The favorable performance of cocopeat may be associated with gradual nutrient release and improved root-zone conditions, particularly water retention and aeration, which can enhance nutrient acquisition in porous coastal soils. Because cocopeat is derived from locally available coconut residues, its use may also support agricultural-waste utilization and sustainable coastal farming. However, its capacity to reduce mineral-fertilizer requirements, improve farmers' livelihoods, and enhance regional food security requires further verification. Field trials on actual coastal soils are therefore recommended to determine appropriate application rates, evaluate economic feasibility, quantify soil physical improvements, and assess the long-term effects of cocopeat under different salinity and environmental conditions.

REFERENCES

[1] Rahim, "Productivity, quality, and agro-industrial development potential of Lembah Palu shallot in Palu, Central Sulawesi," Ph.D. dissertation, Universitas Hasanuddin, Makassar, Indonesia, 2012.

[2] Idris, M. Basir, and I. Wahyudi, "Effects of manure type and application rate on the growth and yield of Lembah Palu shallot," Jurnal Agrotech, vol. 8, no. 2, pp. 40–49, 2018.

[3] F. Minhal, A. Ma'as, E. Hanudin, et al., "Improvement of the chemical properties and buffering capacity of coastal sandy soil as affected by clay and organic by-product application," Soil & Water Research, 2020. [Online]. Available: http://swr.agriculturejournals.cz/pdfs/swr/2020/02/04.pdf

[4] M. A. van der Sloot, D. Kleijn, G. B. De Deyn, and J. Limpens, "Carbon to nitrogen ratio and quantity of organic amendment interactively affect crop growth and soil mineral N retention," Crop and Environment, vol. 1, no. 3, pp. 161–167, 2022, doi: 10.1016/j.crope.2022.08.001.

[5] P. Dalias and A. Christou, "Secondary immobilization as a phase of N mineralization dynamics of soil organic inputs," Nitrogen, vol. 3, no. 4, pp. 600–607, 2022, doi: 10.3390/nitrogen3040039.

[6] Pradiksa, "The C/N ratio of organic matter and its implications for soil nitrogen availability," Soil Science Journal, vol. 11, no. 2, pp. 55–64, 2022.

[7] Mautuka, "Role of the organic-matter C/N ratio in soil decomposition dynamics," Soil and Environment Journal, vol. 10, no. 2, pp. 67–75, 2022.

[8] N. Sasmita and T. Haryanto, "The C/N ratio and its implications for soil microbial activity," Jurnal Ekologi Tanah, vol. 9, no. 2, pp. 122–130, 2021.

[9] S. N. Gbollie, S. M. Mwonga, and A. M. Kibe, "Effects of calcium nitrate levels and soaking durations on cocopeat nutrient content," Journal of Agricultural Chemistry and Environment, vol. 10, no. 3, pp. 372–388, 2021, doi: 10.4236/jacen.2021.103024.
A. S. Ayangbenro, C. F. Chukwuneme, M. S. Ayilara, F. R. Kutu, M. Khantsi, B. S. Adeleke, et al., "Harnessing the rhizosphere soil microbiome of organically amended soil for plant productivity," Agronomy, vol. 12, no. 12, Art. no. 3179, 2022, doi: 10.3390/agronomy12123179.
[10] W. Liu, Z. Yang, Q. Ye, Z. Peng, S. Zhu, H. Chen, et al., "Positive effects of organic amendments on soil microbes and their functionality in agro-ecosystems," Plants, vol. 12, no. 22, Art. no. 3790, 2023, doi: 10.3390/plants12223790.