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The Effect of Organic Fertilizer on Nitrogen Mineralization, Nitrogen Uptake, and Protein Content of Mung Bean (Vigna radiata) in the Sandy Coastal Soil of Parangtritis, Yogyakarta, Indonesia

Yekti Maryani[1], Rembanang Anindita[2], Sekar Lananingrum[3], Driska Arnanto[4], Artita Devi Maharani[5]

Abstract

This research aims to examine the impact of organic fertilizer on nitrogen mineralization in the soil, nitrogen absorption, and the protein content of green bean seeds in sandy coastal areas. The study was carried out in the sandy coastal region of Parangtritis, Kretek, Bantul, Yogyakarta, Indonesia, at an altitude of approximately 10 meters above sea level, with a soil pH ranging from 5.6 to 6.0 and air humidity between 65% and 85%. The soil type is sandy. The experiment was based on a single-factor design, focusing on organic fertilizer, which included seven treatments: no organic fertilizer, cow manure, goat manure, chicken manure, compost, vermicompost, and guanophosphate. Data analysis was conducted using variance analysis at a 5% significance level, while differences between treatments were evaluated using the Duncan Multiple Range Test at the same significance level. The application of organic fertilizer enhances nitrogen mineralization, except in the case of guanophosphate fertilizer. Among the treatments, vermicompost fertilizer resulted in the highest nitrogen mineralization (NNH4) at 43.89 ppm. The application of nitrogen fertilizer also boosts nitrogen absorption and the protein content of green beans. The highest nitrogen absorption was observed with chicken manure at 2.13%, while the highest protein content in green beans was achieved with compost treatment at 22.33%. Additionally, organic fertilizer application contributes to an increase in green bean yield. The highest yields were obtained with compost fertilizer at 1.6 tons per hectare, followed by vermicompost at 1.541 tons per hectare, and guanophosphate at 1.554 tons per hectare.

Keywords: *Organic, Fertilizer, Mineralization, Nitrogen, Protein.*

Introduction

Indonesia has a coastline of 106,000 km and a potential land area of 1,060,000 hectares. The national land conversion rate reaches 50,000 hectares per year, making coastal sandy land a valuable alternative for agricultural use (Maryani et al., 2023). However, coastal sandy land presents complex challenges for agricultural cultivation. One approach to addressing these challenges is the application of organic fertilizers, which can help convert suboptimal land into a viable growing medium. Research has shown that chicken manure and tofu dregs compost can serve as effective organic fertilizers for green bean cultivation (Hajiz et al., 2018). In sandy soil, organic fertilizers enhance the soil's water-holding capacity and sustainably supply essential nutrients to plants through the mineralization process (Meena et al., 2015). Additionally, organic fertilizers improve soil structure, further increasing its ability to retain water (Sukmawijaya and Sartohadi, 2019). The repeated application of organic fertilizers also enhances soil fertility and boosts soil organic matter content (Geisseler et al., 2021).

Organic matter also plays a crucial role in increasing the population of microorganisms, which in turn enhances the mineralization of organic matter. The mineralization of organic fertilizers promotes root growth and improves nutrient absorption as a result of increased organic matter decomposition (Bengkele, 2018). Nitrogen mineralization influences nitrogen availability in the soil by transforming organic nitrogen into ammonium nitrogen, a process mediated by soil microorganisms. This process is affected by various

[1] Fakultas Pertanian, Universitas Sarjanawiyata Tamansiswa, Yogyakarta
[2] Postgraduate Environmental Science student at Gadjah Mada University.
[3] Food technology analyzer
[4] Fakultas Pertanian, Universitas Sarjanawiyata Tamansiswa, Yogyakarta, Email: driska.arnanto@ustjogja.ac.id (Corresponding author)
[5] Fakultas Pertanian, Universitas Sarjanawiyata Tamansiswa, Yogyakarta

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factors, including temperature, moisture content, soil characteristics, and the properties of soil organic matter (Geisseler et al., 2021).

Organic matter serves as a source of carbon, nitrogen, and other essential minerals while also fostering microbial activity. Microorganisms play a key role in the mineralization process, which enhances nutrient absorption in plants, including nitrogen, carbon, and other vital minerals (Bengkele, 2018). Nitrogen is an essential element for plant growth, yet its concentration in sandy soil is relatively low, ranging from 0.02% to 0.4%. Nitrogen also regulates the absorption of phosphorus, potassium, and other elements involved in photosynthesis (Anggraini et al., 2021). Research findings indicate that guanophosphate fertilizer provides the highest nitrogen absorption in green bean plants, reaching 2.597% per 100 g, followed by vermicompost fertilizer at 2.418% per 100 g and compost fertilizer at 2.089% per 100 g (Anggraini et al., 2021).

Methodology

The research was conducted on the sandy land of Parangtritis Beach, Kretek District, Bantul Regency, D.I. Yogyakarta, at an altitude of approximately 10 meters above sea level. The soil had a pH ranging from 5.6 to 6.0, with air humidity between 65% and 85%. The soil type was sandy. The experiment was designed using a completely randomized block design. The organic fertilizer treatments included no organic fertilizer, compost, vermicompost, guanophosphate, cow manure, goat manure, and chicken manure.

Soil sampling was conducted before land use to analyze the characteristics of coastal sandy soil. The collected soil samples were analyzed for various parameters, including water content using the 100°C 3-hour IK.5.4.c temperature method, pH (H_2O) using the 100°C 3-hour IK.5.4.c method, pH (KCl), N-NO_3 using the Morgan-Wolf spectrophotometer method, N-NH_4 using the Morgan-Wolf spectrophotometer method, available K using the Olsen IK.5.4.h method, P_2O_5 using the Olsen IK.5.4.h method, cation exchange capacity (CEC) using the IK.5.4.f distillation method, and bulk volume (BV) using the ring printing method.

The analysis of soil nitrogen content was conducted by collecting soil samples from all fertilizer treatments, including organic fertilizers, when the plants were five weeks old after planting. The N-NO_3 content was analyzed using the Morgan-Wolf spectrophotometer method, while the N-NH_4 content was also determined using the same method. The analysis of plant tissue nitrogen content was performed to assess nitrogen absorption by plants. This process involved wet ashing with H_2SO_4 and selenium, followed by nitrogen measurement using a spectrophotometer at a wavelength of 693 nm. The protein content of green bean seeds was analyzed using the UV-Vis spectrophotometry method with Lowry reagent.

Results and Discussion

Soil Characteristics

Coastal sandy land is a type of dry, suboptimal land with extremely low soil water content, measuring just 0.50% (Table 1). The soil consists of uniformly sized grains composed of non-cohesive particles, which lack the ability to bind together effectively. This results in a loose inter-granular structure, significantly reducing the soil's water-holding capacity. As a result, coastal sandy soils dry out quickly, making it difficult for plants to access sufficient moisture. Additionally, the lack of cohesion between soil particles contributes to high permeability, allowing water to drain rapidly through the soil.

The rapid drainage characteristic of coastal sandy soils further complicates water retention, particularly during dry periods, when plants struggle to obtain adequate moisture. In addition to water loss, the soil's structure also affects its ability to retain essential nutrients, limiting its overall fertility. This poor nutrient-holding capacity makes it challenging to support plant growth and agricultural productivity. Given these constraints, effective management strategies are necessary to improve soil fertility and moisture retention, ensuring the land becomes more suitable for cultivation. Coastal sandy land presents several environmental challenges that make it difficult for plant growth. These challenges include high infiltration and evaporation

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rates, low nutrient content, high temperatures, and exposure to strong salty winds (Rajiman, 2014). The soil in these areas has a very low water retention capacity, making it prone to drought. Additionally, wind speeds can reach up to 50 km per hour, further exacerbating moisture loss and soil instability.

The harsh conditions of coastal sandy land are further characterized by extreme soil temperatures, ranging from 26.9°C to 31.5°C, as well as a loose soil structure that contributes to poor fertility (Maryani et al., 2023). Due to these limitations, the land is considered suboptimal for agricultural use. To enhance its suitability for cultivation, the application of ameliorants is necessary to improve soil structure, increase nutrient availability, and promote better water retention.

Table 1. Soil Characteristics

Soil Characteristics	Value
H_2O* (%)	0.50
pH (H_2O)*	7.35
PH (KCl)* (ppm)	6.98
N-NO_3 (ppm)	Not detected (very low)
N-NH_4 (ppm)	21.37
K available (ppm)	13
P_2O_5* (ppm)	19
KTK* (Cmol(+)kg^{-1})	1.81
BV* (V g/cc)	1.65

One of the most effective ameliorants is organic fertilizer. Organic fertilizers improve the soil structure, enhancing its ability to retain water. The addition of organic materials transforms the soil from single grains to clumps, thereby increasing its structural integrity and water-holding capacity (Priyadi et al., 2018). Organic compost, in particular, plays a direct role in improving the soil's physical quality by acting as a binding agent for sand particles. This process forms soil aggregates and makes the soil structure more crumbly (Pangaribuan et al., 2020). Soil structure significantly influences the arrangement of micro- and macro-pores. Micro-pores are crucial for water retention, and by adding organic fertilizers, the number of micro-pores increases, which improves the soil's ability to hold water. In sandy soils, macro-pores contain more air than micro-pores, leading to a low water-holding capacity. Organic matter helps bind soil particles together, forming aggregates that increase water retention (Nurhuda et al., 2021). Moreover, soil structure plays an essential role in drainage, aeration, and the overall health of the soil (Meli et al., 2018).

Soil, Growth and Yield

Organic fertilizers play a crucial role in improving soil moisture and enhancing the availability of N-NH_4 compared to soils without organic amendments (Table 2). Among various organic fertilizers, compost provides the highest soil moisture, demonstrating its effectiveness in increasing the soil's water retention capacity. By improving moisture levels, organic fertilizers create a more favorable environment for plant growth, reducing the risk of drought stress. Additionally, they contribute to the increase of N-NH_4 content in the soil, which is essential for plant nutrition and overall soil fertility.

However, the transformation of NH_4^+ in the soil is influenced by nitrification, a process where NH_4^+ is converted into NO_3^-. As NH_4^+ decreases, the NO_3^- concentration rises due to this transformation. Not all NH_4^+ is oxidized to NO_3^- during nitrification; some is lost as nitrous oxide (N_2O) during the oxidation of hydroxylamine (NH_2OH) to nitroxyl (HNO). The presence of decomposing litter can slow down the conversion of NH_4^+ to NO_3^-, affecting nitrogen availability in the soil. An increase in NO_3^- concentration may also indicate that nitrification has not yet occurred, as there is no significant transformation of NH_4^+ to NO_3^-. These complex nitrogen dynamics highlight the need for careful soil management to optimize nutrient retention and minimize losses.

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Tabel 2. Soil Moisture and Nitrogen Contant

Ameliorant	Variables		
	Soil moisture (%)	N-NH_4 of soil (ppm)	N-NO_3 of soil (ppm)
Non organic fertilizer	0.53 d	20.03 d	0.00 c
Cow manure	2.17 c	29.55bc	1.09 c
Goat manure	2.43 bc	26.14 c	0.00 c
Chicken manure	2.17 c	28.67 c	5.07 a
Compost	3.03 a	33.05 b	0.00 c
Vermicompost	2.57 b	43.89 a	2.66 b
Guanophosphate	2.30 bc	21.25 d	0.00 c

Description: The everage number followed by the same letter in the column indicates there is no significant difference at 5% level

Organic fertilizers also enhance the soil's capacity to provide essential nutrients to plants, particularly nitrogen, through the mineralization of organic materials (Meena et al., 2015). The mineralization process involves converting organic nitrogen into ammonium (NH_4^+) and nitrate (NO_3^-), which are forms of nitrogen readily available for plant uptake. The higher the rate of nitrogen mineralization, the more fertile the soil becomes, as it can provide plants with the necessary nutrients for growth (Toan, 2024). During the mineralization of organic fertilizers, organic matter is broken down into N-NH_4 and N-NO_3. While not all NH_4^+ is converted into NO_3^- (Table 1), the rate at which organic nitrogen is mineralized into inorganic nitrogen determines its availability in the soil. This process includes aminization (conversion of protein to R-NH_2), ammonification (conversion of R-NH_2 to NH_4^+), and nitrification (conversion of NH_4^+ to NO_3^-) (Azahra, 2021).

The application of organic fertilizers has been proven to enhance plant dry weight, nitrogen uptake, yield, and protein content in green beans. Organic fertilizers, such as compost and manure, break down into nitrogen compounds, thereby improving nitrogen availability in the soil. Since soil nitrogen levels directly influence plant nitrogen absorption, an increase in nitrogen content leads to higher nitrogen uptake by plants, ultimately promoting better growth (Maftu'ah and Nursyamsi, 2019). This improvement in plant growth is particularly important for achieving higher yields and better-quality produce.

Nitrogen plays a vital role in plant development, especially in chlorophyll formation, which is essential for photosynthesis. Through photosynthesis, plants produce carbohydrates that fuel growth and contribute to increased yields. Additionally, nitrogen is a crucial component in seed protein synthesis, directly impacting the nutritional quality of the harvested crop (Patti et al., 2013). Ensuring sufficient nitrogen supply during the generative phase is also important for delaying leaf aging, maintaining active photosynthesis during the grain-filling period, and ultimately enhancing protein content in the grains. Proper nitrogen management through organic fertilization is therefore essential for optimizing both plant productivity and crop quality.

Table 3. Growth, Yield and Protein Contant Mung Bean

Ameliorant	Variables				
	Dry plant weight (g)	Nitrogen uptake (%)	Yield (t ha^{-1})	Protein contant (%)	Water content of seeds (%)
Non ameliorant	1.59 d	1.77 d	0.706d	18.02 g	10.11 a
Cow manure	7.06 c	1.92 b	1.140 c	21.33 b	10.51 a
Goat manure	6.46 c	1.93 b	1.175 c	20.18 e	10.43 a
Chicken manure	8.91 b	2.13 a	1.320b	21.10 c	10.32 a
Compost	8.53 b	1.93 b	1.600 a	22.33 a	10.22 a
Vermicompost	8.34 b	1.87 bc	1.541 a	20.64 d	10.35 a

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Guanophosphate	13,80 a	1.87 c	1.554 a	19.87 f	10.18 a

Description: The everage number followed by the same letter in the column indicates there is no significant difference at 5% level

Regression Correlation

The relationship between plant dry weight and protein content exists but is weak, as indicated by an R^2 value of 0.209 (Figure 2). An R^2 value below 0.5 suggests that plant dry weight is not strongly correlated with protein content. Similarly, the relationship between soil N-NH_4^+ content and plant yield is also weak, with an R^2 value of 0.302 (Figure 3), indicating that variations in soil N-NH_4^+ levels do not significantly influence yield. Likewise, the relationship between nitrogen uptake and protein content is weak, with an R^2 value of 0.3696 (Figure 5). The correlation between soil N-NH_4^+ levels and protein content follows a similar pattern, with an R^2 value of 0.3334 (Figure 6), suggesting that soil ammonium levels have a limited impact on protein formation in plants.

In contrast, some relationships show stronger correlations. The connection between plant dry weight and plant yield is significant, with an R^2 value of 0.718 (Figure 1), indicating that higher plant biomass strongly contributes to increased yield. Similarly, the relationship between plant yield and protein content is relatively strong, with an R^2 value of 0.4922 (Figure 4), showing that higher yields tend to be associated with higher protein levels. Meanwhile, the relationship between soil moisture and seed water content remains weak, with an R^2 value of 0.178 (Figure 7), suggesting that soil moisture has minimal influence on the water content of seeds. These findings highlight the varying degrees of correlation between different agronomic factors, emphasizing the importance of plant biomass and yield in determining overall protein content.

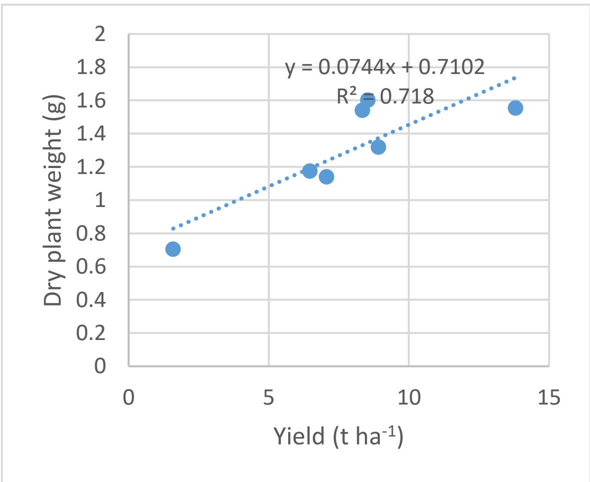

Figure 1. Relationship Between Plant Dry Weight and Plant Yield

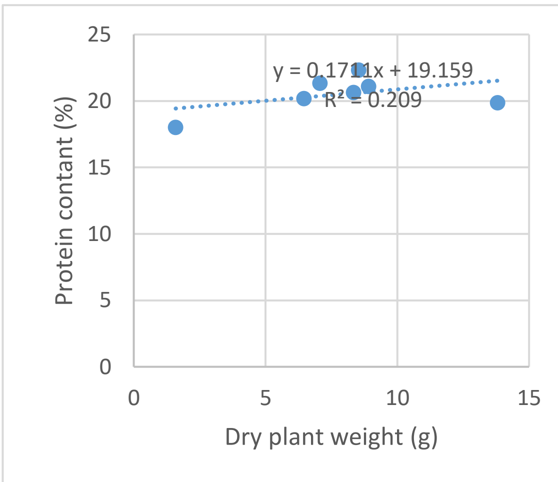

Figure 2. Relationship Between Plant Dry Weight and Protein Contant

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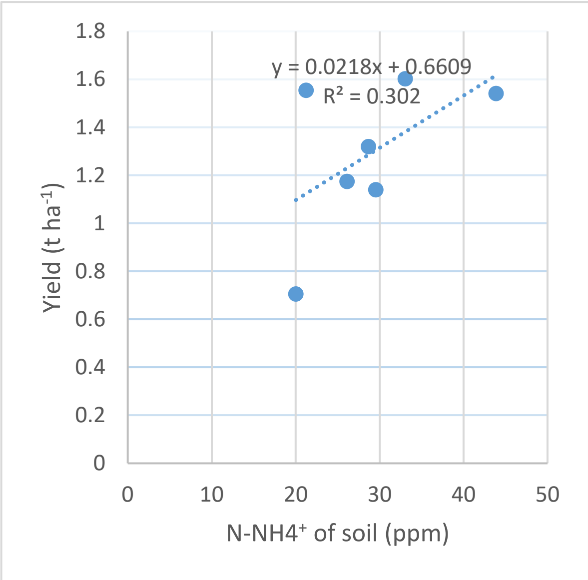

Figure 3. Relationship Between N-NH4+ of Soil and Yield

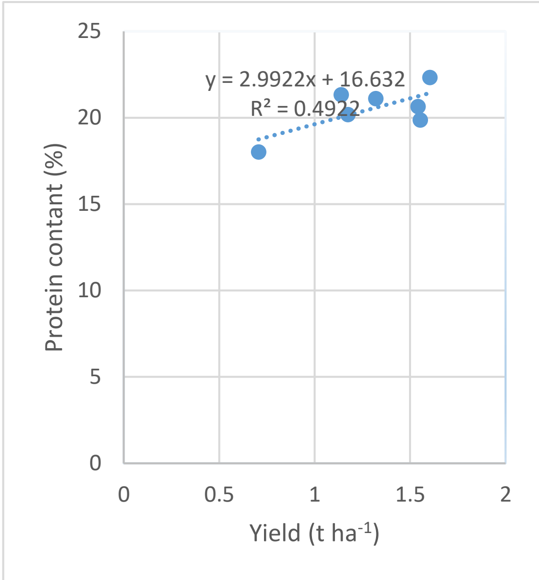

Figure 4. Relationship Between Plant Yield and Protein Contant

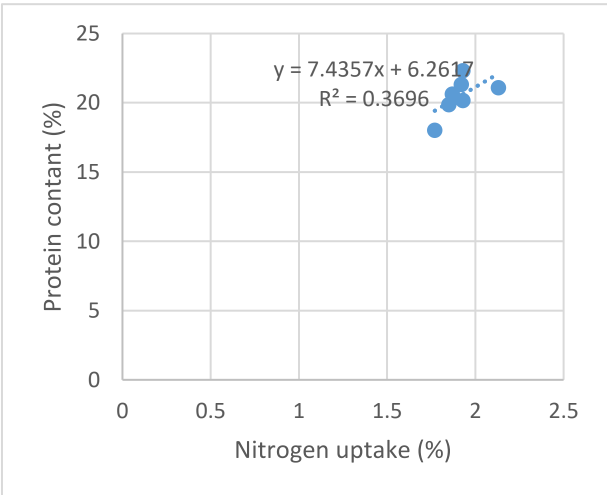

Figure 5. Relationship Between Nitrogen Uptake and Protein Content

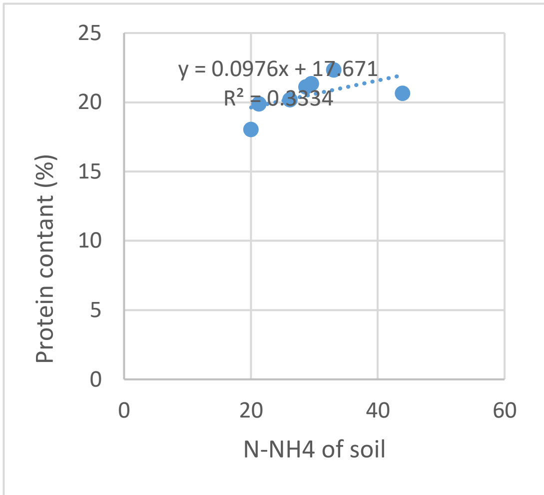

Figure 6. Relationship Between N-NH4+ of Soil and Protein Content

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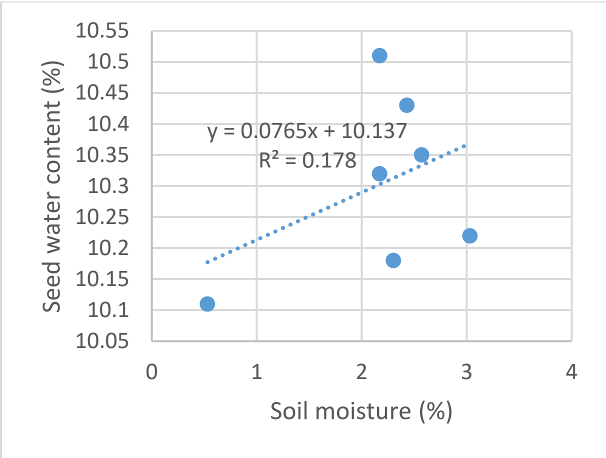

Figure 7. Relationship Between Soil Moisture and Seed Water Content

In support of this, Anggraini (2021) found that plants absorb nitrogen in the form of nitrate (NO_3^-) or ammonium (NH_4^+). Organic nitrogen in plants is converted into amino acids, which are then assembled into plant proteins. This process is reflected in the highest protein content of green beans achieved through compost fertilizer application. Furthermore, plant dry weight correlates positively with crop yields, as shown by the regression equation $y = 0.0744x + 0.7102$ ($R^2 = 0.718$). This positive correlation suggests that plant dry weight, which reflects plant growth, significantly influences green bean yields per hectare. Additionally, plant yields per hectare are positively correlated with green bean protein content, as indicated by the regression equation $y = 2.9922x + 16.632$ ($R^2 = 0.4922$). This means that organic fertilizer not only increases plant growth but also boosts green bean yields and protein content.

In conclusion, the application of organic fertilizers enhances nitrogen mineralization, with the exception of guanophosphate fertilizer. Among the different organic fertilizers tested, vermicompost provides the highest nitrogen mineralization (N-NH_4), reaching 43.89 ppm. Increased nitrogen availability in the soil improves plant nitrogen uptake, which in turn supports plant growth and productivity. The use of nitrogen fertilizers also plays a crucial role in boosting nitrogen absorption and enhancing the protein content of green beans. Chicken manure results in the highest nitrogen absorption at 2.13%, while compost treatment leads to the highest protein content, reaching 22.33%.

In addition to improving nitrogen dynamics, organic fertilizers contribute to increased green bean yield. Compost achieves the highest yield at 1.6 tons per hectare, followed closely by guanophosphate at 1.554 tons per hectare and vermicompost at 1.541 tons per hectare. These results highlight the effectiveness of organic fertilizers in promoting soil fertility, enhancing plant nutrition, and improving crop yield. The findings suggest that selecting the appropriate organic fertilizer can optimize nitrogen availability, leading to better growth and higher-quality green bean production.

Table 4. Regression Analysis

Variable	Dry plant weight	Yield	Nitrogen content of plant tissue	N-NH_4 of soil	Protein contant	Soil moisture	Water content of seeds

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Dry plant weight	1.00000 21	0.85523 **<.0001**** 20	0.27560 0.2266 21	0.12546 0.5879 21	0.44828 0.0415* 21	-0.04299 0.8532 21	0.05149 0.8246 21
Yield		1.00000 20	0.30257 0.1948 20	0.52368 **0.0178*** **20**	0.67349 **0.0011*** 20	-0.09718 0.6836 20	0.10378 0.6633 21
Nitrogen content of plant tissue			1.00000 21	0.22211 0.3332 21	0.59366 **0.0046*** 21	0.11278 0.6264 21	-0.08007 0.7301 21
N-NH4 of soil				1.00000 21	0.56200 **0.0080*** **21**	0.01670 0.9427 21	0.02036 0.9302 21
Protein contant					1.00000 21	0.09796 0.6727 21	-0.04653 0.8413 21
Soil moisture						1.00000 21	-0.99208 **<.0001*** **21**
Water content of seeds							1.00000 21

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