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The Effect of Use of Cow Manure on the Growth of Two Cultivars of *Glycine Max L.* Using a Verticulture Planting System

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Abstract

This study aims to provide data on the verticulture method planting and the use of cow manure to black soybeans (Glycine max L.). This study used a factorial Randomized Block Design (RAK) containing two factorials and four replications. K1 refers to the unit 1 soybean cultivar, while K2 stands for the pearl 2 cultivar. One of the cultivar factors is this (K). Inside the interval (P), we find three values: P1= 0 kg, P2= 0.18 kg, and P3= 0.32 kg. "Among the variables that underwent changes were plant height, leaf count, leaf area index, chlorophyll content, relative growth rate (LPR), net assimilation rate (LAB), and active root nodules. According to the results, there was no significant difference between using 0.16 kg/bed of organic fertilizer or no fertilizer at all when measuring plant height at 7, 14, 21, 28, 35, and 42 HST for Cultivar K1 (detam 1)". The availability of organic fertilizer at 0.32 kg/bed was significantly affected by manure at 7, 14, 21, 28, 35, and 42 HST at the third dosage. The results of this study show that neither cultivar 1 nor pearl cultivar 2 had any discernible impact on the vegetative development of black soybean plants when manure was applied at dosages of 0 kg, 0.16 kg, and 0.32 kg.

Introduction

In an era of rapid urbanization, the traditional agricultural landscape is undergoing significant transformation, particularly in densely populated regions like Indonesia, where arable land is becoming increasingly scarce. Amid these challenges, black soybeans (Glycine max L.) emerge as a critical crop due to their high protein content and rich nutritional value, making them an essential component of food security strategies in both rural and urban settings (Pudjihastuti et al., 2021; Rahmadina & Idris, 2022). However, the intensifying pressure on land resources necessitates the exploration of innovative agricultural techniques that can optimize crop production within limited spaces.

The verticulture planting system offers a compelling solution to these constraints by utilizing vertical space for crop cultivation (Yusoff et al., 2023; Safeyah et al., 2023). This method not only maximizes the use of available land but also aligns with the goals of sustainable urban agriculture, reducing the environmental footprint associated with traditional farming practices (Surahman et al., 2021). The integration of verticulture with organic fertilization strategies, particularly the use of cow manure, presents a promising approach to enhancing crop yields in space-constrained environments (Samoraj et al., 2024; Prain & De Zeeuw, 2007).

Cow manure is well-regarded for its ability to improve soil fertility and plant growth. It is rich in essential nutrients such as nitrogen, phosphorus, and potassium, which are vital for plant development (Bay'ul et al., 2021; Ling et al., 2024). Additionally, cow manure enhances soil structure, increases water retention, and promotes the activity of beneficial microorganisms, thereby contributing to a more robust and resilient crop growth environment (Safitri et al.,

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2023; Fahri et al., 2022). These attributes make cow manure a valuable resource for sustainable agriculture, particularly in systems like verticulture, where soil dynamics and nutrient availability are crucial to successful crop cultivation (Yusoff et al., 2023).

The potential benefits of combining verticulture with cow manure are particularly significant for crops like black soybeans, which have high nutritional demands. In a traditional farming setup, cow manure is distributed across a broad soil matrix, allowing for gradual nutrient uptake. However, in a verticulture system, the vertical arrangement of soil layers may influence nutrient distribution and absorption differently, potentially leading to enhanced or more efficient nutrient utilization by plants (Laksono & Fanata, 2022; Rendy Anggriawan et al., 2024). This could result in higher crop yields and better overall plant health, making the combination of verticulture and cow manure a promising strategy for urban agriculture.

Moreover, this approach supports broader sustainability goals by reducing the reliance on chemical fertilizers and promoting organic farming practices within urban environments (Gamage et al., 2023; Manna et al., 2021; Muhie, 2022). Urban agriculture, when integrated with organic methods, has the potential to significantly lower the environmental impact of food production, contributing to more sustainable and resilient food systems (Budi Kusumo et al., 2020; Wanantari et al., 2022). The use of cow manure in verticulture not only enhances soil health but also aligns with the growing movement towards sustainable urban living, where food production is closely integrated with ecological stewardship.

This study is thus important because it explores the synergistic effects of verticulture and cow manure on the growth and yield of black soybean cultivars, offering valuable insights into how these practices can be optimized for urban agriculture. The potential to improve crop yields in limited spaces through the strategic use of organic fertilizers within a verticulture system is both promising and relevant to contemporary agricultural challenges. As cities expand and the need for sustainable food production intensifies, this research offers a timely contribution to the development of innovative farming practices that can support urban food security and sustainability.

Methods

Research Design

The study was meticulously designed to investigate the effects of cow manure on the growth of two distinct cultivars of black soybean (*Glycine max L.*) within a verticulture planting system. The chosen design, a factorial Randomized Block Design (RBD), is particularly suitable for agricultural research as it allows for the examination of multiple factors simultaneously while controlling for variability among experimental units. This design was selected to ensure that the study could effectively isolate and examine the impacts of both the cultivar type and the dosage of cow manure on various growth parameters.

The first factor in this study was the cultivar of black soybeans, represented by the symbol "K." Two cultivars were carefully selected based on their known agronomic traits and potential performance under verticulture conditions. Cultivar K1 referred to Detam 1, a variety recognized for its robust growth characteristics, while Cultivar K2 was Pearl 2, known for its adaptability and yield potential.

The second factor, denoted by the symbol "P," was the dosage of cow manure applied as an organic fertilizer. Three distinct levels of cow manure were tested to evaluate their effects on the growth of the black soybean plants. P1 involved no cow manure application, serving as the control to compare with other treatments. P2 included a moderate application of 0.16 kg/bed,

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while P3 represented a higher dosage of 0.32 kg/bed. These dosages were selected based on existing agricultural practices and preliminary studies suggesting that they could influence plant growth without causing excessive nutrient loading, which might lead to diminished plant performance or environmental degradation.

The experiment was conducted with four replications for each treatment combination, ensuring that the data collected would be robust and statistically significant. The use of multiple replications also allowed for the reduction of experimental error, providing a more accurate representation of the treatment effects.

Location and Duration of the Study

The study was conducted over a period from June to August 2024, taking place in a specific urban agricultural setting at Jalan Binjai Km 10 Gg Damai Lorong Bengkel, Kec. Sunggal, Deli Serdang Regency. This location was selected for its relevance to urban agriculture, providing a realistic environment in which to test the efficacy of verticulture systems supplemented with organic fertilizers. The climate and soil conditions of this area were also conducive to soybean growth, further justifying its selection as the study site.

To ensure precise and reliable measurement of one of the key plant physiological traits, chlorophyll content, laboratory analyses were conducted at the University of North Sumatra (USU) Agricultural Laboratory. The choice of this facility was based on its state-of-the-art equipment and expertise in plant physiological studies, ensuring that the chlorophyll content data would be accurate and scientifically valid.

Materials and Equipment

The materials used in this study were carefully selected to support the experimental objectives and to ensure the relevance and reproducibility of the results. The black soybean seeds for the Detam 1 and Pearl 2 cultivars were sourced from certified suppliers to guarantee the genetic purity and quality of the plants.

The planting medium consisted of a carefully prepared mixture of soil and cow manure, tailored to the specific requirements of each treatment group. The soil used was sieved to remove large particles and debris, ensuring a consistent and homogenous planting medium across all experimental units. The cow manure, obtained from local organic sources, was air-dried and pulverized before being mixed into the soil. This preparation ensured that the nutrients were evenly distributed within the planting beds, facilitating uniform plant growth.

The equipment utilized throughout the experiment included:

Hoe and wooden boards

These tools were essential for the manual preparation of the planting beds. The hoe was used to break up and aerate the soil, while the wooden boards ensured that each bed was of uniform size and depth, critical for maintaining consistency across treatments.

50 kg hanging scale

Precision in manure application was achieved using this scale, which allowed for the accurate measurement of cow manure for each treatment. The scale was calibrated regularly to maintain accuracy throughout the experiment.

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Label paper and stationery

To avoid any confusion during data collection and analysis, each bed and plant were clearly labeled according to their treatment group. This labeling system was crucial for tracking the progress of individual plants and ensuring the integrity of the data.

Ruler and meter

Plant height, a key growth parameter, was measured using a ruler and meter, ensuring precision to the nearest millimeter. These tools were also used to maintain consistent plant spacing, which is essential in studies where plant competition can influence growth outcomes.

Experimental Procedures

The experiment commenced with the thorough preparation of the planting beds. Each bed was carefully measured to dimensions of 20 cm by 20 cm, providing adequate space for the growth of black soybean plants while ensuring the efficient use of vertical space in the verticulture system. The soil in each bed was loosened and mixed with the appropriate dosage of cow manure according to the treatment group, ensuring that the nutrients were well-integrated and accessible to the plant roots.

Once the beds were prepared, black soybean seeds from the Detam 1 and Pearl 2 cultivars were sown at a uniform depth across all beds. The sowing depth was standardized to promote consistent germination and early growth, reducing variability in the initial stages of the experiment.

After planting, the beds were watered regularly to maintain optimal soil moisture levels, a critical factor in the verticulture system where soil volume is limited. Watering was done with care to avoid waterlogging, which could adversely affect root development and nutrient uptake.

Throughout the growing period, the plants were closely monitored, with regular data collection occurring at key growth stages (7, 14, 21, 28, 35, and 42 days after planting). This data collection focused on several growth parameters, each providing insights into the effects of the different treatments.

Data Collection and Measurement

Plant height was measured at the specified intervals using a ruler, from the base of the stem to the tip of the highest leaf. Plant height is a direct indicator of vegetative growth and was carefully recorded to assess how the different treatments influenced vertical growth in the verticulture system. The number of fully expanded leaves was counted for each plant at regular intervals. Leaf number serves as an indicator of the plant’s ability to photosynthesize and accumulate biomass, both of which are crucial for overall growth and yield.

The Leaf area index (LAI) was calculated based on the total leaf area relative to the ground area occupied by the plant. This index is critical for understanding the plant's efficiency in intercepting light, which directly influences photosynthetic activity and biomass accumulation. Samples of leaf tissue were collected and analyzed for chlorophyll content at the USU Agricultural Laboratory. Chlorophyll content is a key indicator of the plant’s photosynthetic capacity and overall health, reflecting the efficacy of the treatments in promoting robust vegetative growth.

The Relative growth rate (RGR) was determined by calculating the rate of increase in plant biomass over time. This parameter provides insights into the plant’s growth efficiency and its ability to convert nutrients and light into new biomass. The Net assimilation rate (NAR) was calculated as the rate of biomass accumulation per unit of leaf area, providing a measure of the

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plant's photosynthetic efficiency and nutrient use. The number of active root nodules was counted to assess the symbiotic nitrogen fixation capability of the plants. Root nodules are essential for legumes like soybeans, as they enable the plant to access atmospheric nitrogen, a critical nutrient for growth.

Data Analysis

The data collected from the experiment were subjected to rigorous statistical analysis using Analysis of Variance (ANOVA). ANOVA was chosen for its ability to handle the complexity of factorial experiments, allowing the researchers to discern the main effects of the cultivar type and cow manure dosage, as well as their interaction effects on the growth parameters.

Upon identifying significant effects through ANOVA, Duncan's Multiple Range Test (DMRT) was applied as a post-hoc analysis. DMRT provided a detailed comparison between the treatment means, identifying which specific treatments led to statistically significant differences in growth outcomes. This analysis was crucial for drawing precise conclusions about the efficacy of different manure dosages and the suitability of the cultivars in a verticulture system.

Results and Discussion

Based on Table 1, it shows that measurements for plant height at the ages of 7, 14, 21, 28, 35 and 42 HST of Cultivar K1 (detam 1) had no significant effect on organic fertilizer with a dose without fertilizer, and a fertilizer dose of 0.16 kg/bed . Meanwhile, manure at the age of 7, 14, 21, 28, 35 and 42 HST has a significant effect on the application of organic fertilizer of 0.32 kg /bed at the third dose on the growth of black soybean plants, so it is necessary to carry out the Duncan test with K1P3 results (detam 1 fertilizer 0 .32 kg/bed) and K2P2 (Mutiara Detam 2 fertilizer 0.32 kg/bed) had no significant effect on the application of 0.32 kg manure/bed and the growth of black soybeans.

Table 1. Plant Height 7, 14, 21, 28, 35 and 42 HST

Treatment	**Average**					
	7 HST	**14 HST**	**21 HST**	**28 HST**	**35 HST**	**42 HST**
Cultivars						
Soy Detam 1	9.73 a	20.60 a	31.83 a	39.56 a	50.60 a	65.23 a
Pearl Soy 2	9.90 a	20.96 a	31.50 a	37.90 a	51.90 a	60.66 a
Manure Dosage						
No Fertilizer	9.35 a	18.75 a	29.00 a	36.50 a	48.35 a	57.00 a
Fertilizer 0.16 kg/bed	11.75 a	23.10 a	36.25 a	41.35 a	58.40 a	68.35 a
Fertilizer 0.32 kg/bed	8.35 b	20.00 b	29.75 b	38.35 b	47.00 b	63.50

This table displays the progression of plant height over time, reflecting how different treatments (cultivar types and manure dosages) impacted vertical growth. Both cultivars (Detam 1 and Pearl Soy 2) showed comparable growth rates across all time points, indicating that the inherent genetic differences between the cultivars had minimal influence on height under the conditions of this study. This suggests that in a verticulture system, where space is limited, both cultivars can perform similarly, allowing for flexibility in cultivar choice depending on other desired traits.

The application of cow manure at 0.16 kg/bed (P2) significantly increased plant height at all measured intervals compared to no fertilizer (P1) and the higher manure dosage (0.32 kg/bed,

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P3). Interestingly, the highest dosage (P3) did not produce the tallest plants, which might indicate a diminishing return or even a negative effect at higher manure levels. This could be due to nutrient imbalances or excess nitrogen leading to suboptimal growth conditions, such as excessive vegetative growth at the expense of root development or other physiological processes (Bay'ul et al., 2021; Darma et al., 2021). This interpretation aligns with findings from other studies where optimal growth was achieved at moderate levels of organic fertilizer, suggesting that more is not always better in constrained agricultural systems (Fahri et al., 2022).

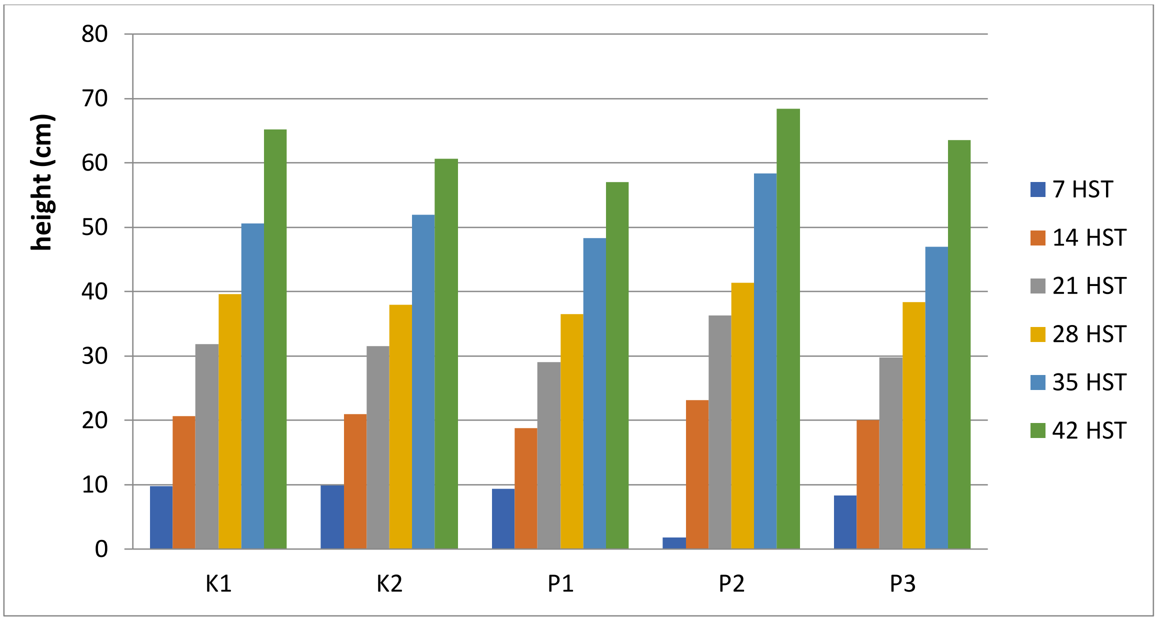

Figure 1. Plant Height 7, 14, 21, 28, 35, and 42 HST

The graphical representation of plant height over time visually underscores the trends observed in Table 1. The figure reveals that plants treated with 0.16 kg/bed of cow manure consistently outperformed the other treatments in terms of height. This supports the hypothesis that moderate fertilization is more beneficial in verticulture systems, where nutrient distribution and absorption may differ from traditional farming setups. The graph also highlights a plateau in height for all treatments as the plants approached maturity (42 HST). This plateau suggests that while early growth was influenced by manure dosage, the effect tapered off as the plants reached their maximum potential height, a common phenomenon in legume crops where vegetative growth stabilizes as the plant shifts resources towards reproductive development (Widyastuti et al., 2015). Table 2 findings from the leaf number study show that cultivar had no significant effect on cow dung application on two black soybean plant cultivars or on applications of 0.16 and 0.32 kg of fertilizer, with an average of 27 and 19, respectively, during plant vegetative growth.

Table 2. Average Number of Leaves

Treatment	**Average**
Cultivars	
Soy Detam 1	20.00 a
Pearl Soy 2	20.66 a
Manure Dosage	
No Fertilizer	15.00 b
Fertilizer 0.16 kg/bed	27.00 a
Fertilizer 0.32 kg/bed	19.00 a

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Both cultivars produced a similar number of leaves, which is consistent with the finding that cultivar type had little impact on plant height. This suggests that the photosynthetic capacity, as reflected by leaf number, is not significantly different between the two cultivars when grown under the same verticulture conditions. The treatment with 0.16 kg/bed of cow manure (P2) resulted in a significantly higher leaf count compared to the other treatments, reinforcing the conclusion that moderate manure application optimizes vegetative growth. The lower leaf number in the 0.32 kg/bed treatment (P3) compared to P2 may again point to nutrient overload or possible imbalances, which could inhibit leaf production by stressing the plants (Surahman et al., 2021). The substantial increase in leaf number under the P2 treatment also suggests improved photosynthetic potential, which is crucial for the overall biomass accumulation and yield of the crop. This aligns with research indicating that optimal levels of organic fertilizers can enhance leaf production by improving nutrient availability and soil structure (Safitri et al., 2023).

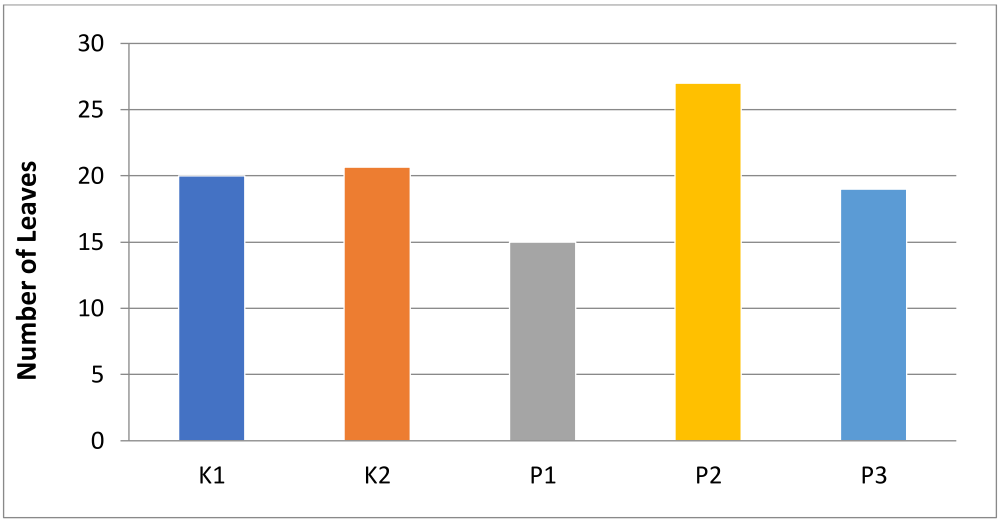

Figure 2. Number of Leaves

The figure complements Table 2 by visually illustrating the pronounced difference in leaf number between the treatments. It highlights the effectiveness of the 0.16 kg/bed manure dosage in promoting leaf production, a critical factor in the overall growth and yield of the plants. The figure also visually underscores the relatively poor performance of the control and high manure dosage treatments, reinforcing the interpretation that balance is key in nutrient management within verticulture systems.

The test results on the leaf area index treatment of two cultivars, as shown in Table 3, show that there is a real influence of the technique of applying cow manure on the vegetative development of black soybean plants. Duncan's test on treatments of 0 kg, 0.16 kg, and 0.32 kg of cow manure on two black soybean cultivars showed no significant differences at means of 1, 2.9, and 1.5.

Table 3 Average Leaf Area Index

Treatment	**Average**
Cultivars	
Soy Detam 1	1.03 a
Pearl Soy 2	1.03 a
Manure Dosage	
No Fertilizer	1.00 a

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Fertilizer 0.16 kg/bed	2.09 a
Fertilizer 0.32 kg/bed	1.05

Leaf Area Index (LAI) is a critical parameter that reflects the ability of the plant canopy to intercept sunlight, which directly influences photosynthetic efficiency and, ultimately, crop yield. The identical LAI values for both cultivars further reinforce the earlier finding that cultivar type did not significantly affect the growth parameters measured in this study. This suggests that under the conditions tested, both cultivars have similar capabilities in terms of canopy development and light interception. The significant increase in LAI under the 0.16 kg/bed treatment (P2) indicates that this manure dosage optimally supports canopy development, enhancing the plant's ability to capture light and convert it into biomass. The relatively low LAI in the control (P1) and high manure dosage (P3) treatments suggests that either insufficient or excessive nutrients can limit canopy development, potentially reducing the plant’s photosynthetic efficiency (Bay'ul et al., 2021). This result emphasizes the importance of precise nutrient management in verticulture systems, where the limited soil volume makes plants particularly sensitive to both deficiencies and excesses in nutrient supply.

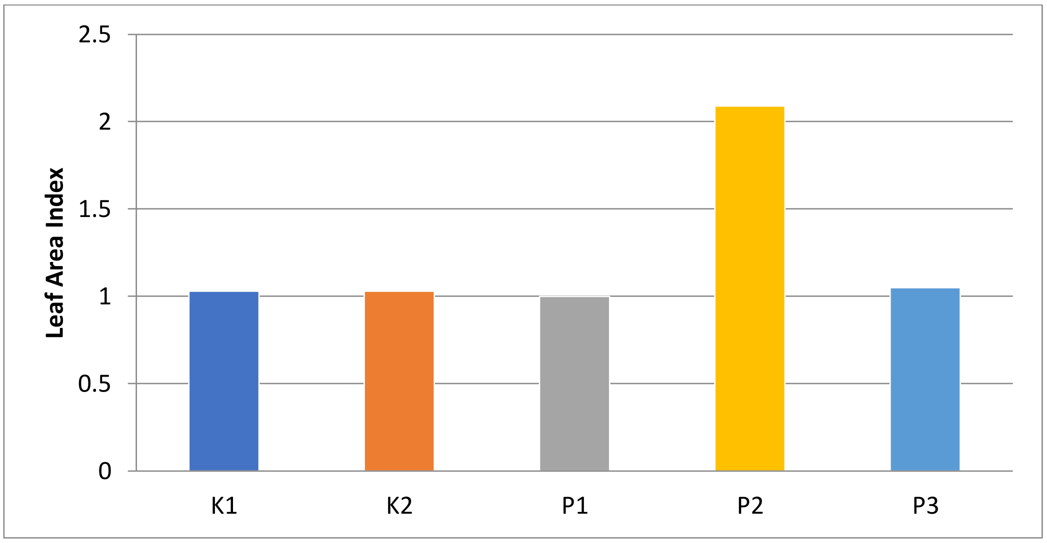

Figure 3. Leaf Area Index

The graphical representation of LAI further highlights the superiority of the 0.16 kg/bed manure treatment in promoting canopy development. The figure clearly shows the enhanced LAI under this treatment, which is crucial for maximizing photosynthetic activity in the constrained environment of a verticulture system. The graph also visually reinforces the underperformance of the other treatments, suggesting that both too little and too much manure can hinder optimal leaf area expansion.

Complete treatment of cultivars K1 and K2, as well as analysis of variance in chlorophyll a and b measurements, showed no significant effect, with averages of 0.4, 1.4, and 8.8 mg/g, according to Table 4.

Table 4. Average Chlorophyll Content

Treatment	**Average**		
	Chlorophyll a	**Chlorophyll b**	**Total chlorophyll**
Cultivars			
Soy Detam 1	0.436 a	1,250 a	8,830 a
Pearl Soy 2	0.444 a	1,459 a	9,026 a

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Manure Dosage			
No Fertilizer	0.372 a	1,548 a	7,545 a
Fertilizer 0.16 kg/bed	0.483 a	1,638 a	9,790 a
Fertilizer 0.32 kg/bed	0.466 a	1982 a	9,450 a

Chlorophyll content is a direct indicator of the plant's photosynthetic capacity and overall health. Both cultivars exhibited similar chlorophyll levels, consistent with the earlier findings that cultivar type had minimal impact on other growth parameters. This suggests that, in terms of photosynthetic pigment concentration, both cultivars are equally capable of thriving in the verticulture system when provided with adequate nutrition. The application of cow manure at 0.16 kg/bed (P2) resulted in the highest total chlorophyll content, which aligns with the superior growth observed in other parameters under this treatment. This increase in chlorophyll content indicates that the plants were better equipped for photosynthesis, supporting more vigorous growth and higher biomass accumulation. The slight drop in chlorophyll content at the 0.32 kg/bed dosage (P3) might suggest that excessive nutrient levels can lead to stress, potentially disrupting chlorophyll synthesis or leading to the degradation of chlorophyll molecules (Widyastuti et al., 2015). The elevated chlorophyll levels in P2-treated plants suggest that moderate manure application enhances photosynthetic efficiency, crucial for maximizing yield in verticulture systems where nutrient management is critical.

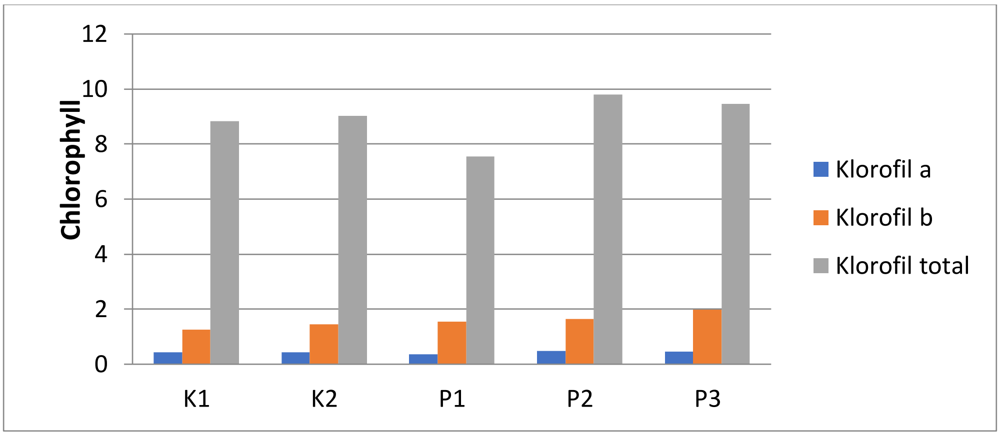

Figure 4. Chlorophyll content

The graphical representation of chlorophyll content across treatments visually emphasizes the positive impact of the 0.16 kg/bed manure dosage on photosynthetic capacity. The figure clearly shows the elevated chlorophyll levels in this treatment group, reinforcing the conclusion that optimal manure application can significantly enhance the physiological health of plants in a verticulture system.

Table 5 and analysis of variance show that manure significantly changed the relative growth rates of Detam 1 and Mutiara 2 cultivars. Duncan's additional test found no effect of manure on the dose of black soybeans.

Table 5. Average Relative Growth Rate

Treatment	Average		
	21 HST	28 HST	35 HST
Cultivars			
Soy Detam 1	1.66 a	1.76 a	2.62 a
Pearl Soy 2	2.02 a	2.10 a	1.73 a
Manure Dosage			

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No Fertilizer	1.03 a	1.57 a	2.06 a
Fertilizer 0.16 kg/bed	1.75 a	2.37 a	2.35 a
Fertilizer 0.32 kg/bed	2.73 a	1.85 a	2.11

Relative Growth Rate (RGR) provides insights into how efficiently the plants are converting absorbed resources (nutrients, light, water) into biomass over time. The RGR data shows that while both cultivars performed similarly at certain growth stages, Pearl Soy 2 (K2) exhibited a higher RGR early in the growth period (21 HST and 28 HST), indicating a more rapid initial growth phase. This suggests that Pearl Soy 2 may be better suited for environments where rapid early growth is advantageous, such as in competitive planting systems or short growing seasons.

The highest RGR was observed in plants treated with 0.32 kg/bed of manure at 21 HST, which suggests that at this early stage, a higher nutrient supply can accelerate growth. However, by 35 HST, the RGR of plants treated with 0.16 kg/bed (P2) was comparable to or slightly exceeded that of plants treated with the higher dosage (P3), indicating that while higher initial manure levels might boost early growth, moderate levels sustain growth more effectively over time (Fahri et al., 2022). This result supports the idea that while higher manure levels can stimulate early growth, they may not necessarily translate into sustained or improved long-term growth, potentially due to nutrient imbalances or other physiological stresses induced by excessive fertilization.

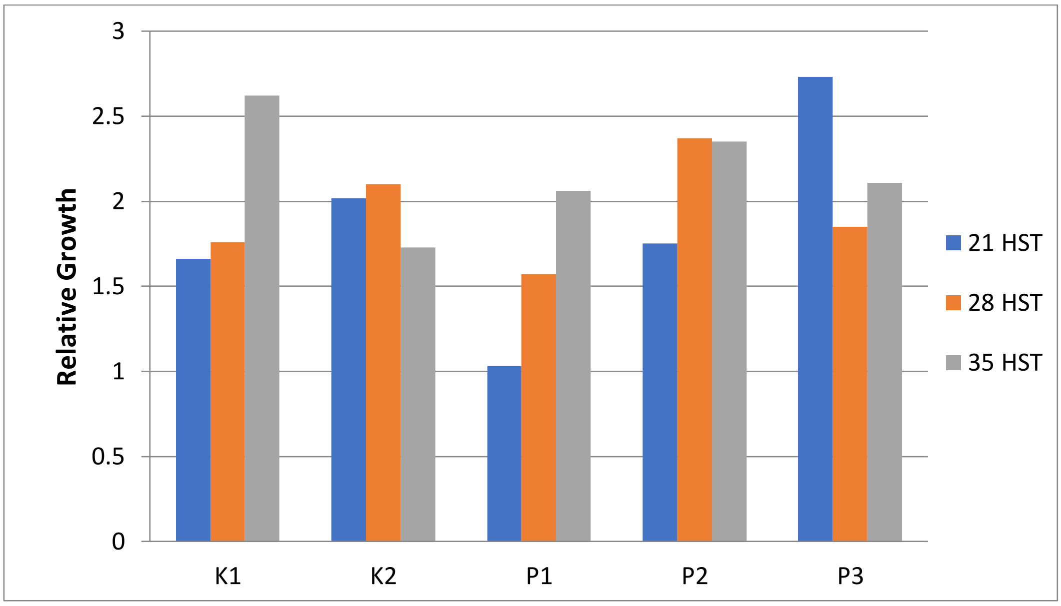

Figure 5. Relative Growth Rate

The figure illustrates the changes in RGR across the different treatments, clearly showing the initial boost in growth provided by the higher manure dosage (P3). However, the convergence of RGR values between P2 and P3 by 35 HST suggests that the moderate manure dosage (P2) provides a more balanced growth environment over time, likely supporting both vegetative and reproductive growth phases more effectively.

Based on Table 6, Manure application did not significantly change the vegetative development of the two black soybean plant cultivars, as indicated by measurements of the net absorption rate, which was independent of cultivar and organic fertilizer.

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Table 6. Average Net Assimilation Rate

Treatment	Average		
	21 HST	28 HST	35 HST
Cultivars			
Soy Detam 1	0.86 a	0.83 a	0.64 a
Pearl Soy 2	0.54 a	0.64 a	0.63 a
Manure Dosage			
No Fertilizer	0.57 a	0.54 a	0.70 a
Fertilizer 0.16 kg/bed	0.52 a	0.60 a	0.48 a
Fertilizer 0.32 kg/bed	0.57 a	0.62 a	0.41

Net Assimilation Rate (NAR) reflects the plant's ability to convert light energy into biomass, a crucial factor in determining overall productivity. The similar NAR values for both cultivars indicate that they have comparable efficiencies in biomass production per unit of leaf area, which suggests that other factors, such as leaf area and chlorophyll content, might be more critical in differentiating their performance in verticulture systems.

The NAR values across different manure treatments are relatively close, with no clear pattern of one treatment consistently outperforming the others. This might indicate that while manure dosage significantly impacts other growth parameters, it has a less pronounced effect on the efficiency of biomass production relative to leaf area. The slightly higher NAR observed in the control group at 35 HST might reflect a compensatory response, where plants with limited nutrient availability focus more on maintaining efficient biomass production rather than expanding leaf area or other growth parameters (Widyastuti et al., 2015). The close NAR values across treatments suggest that while nutrient availability (as influenced by manure dosage) is important, the overall environmental conditions and plant health also play significant roles in determining NAR.

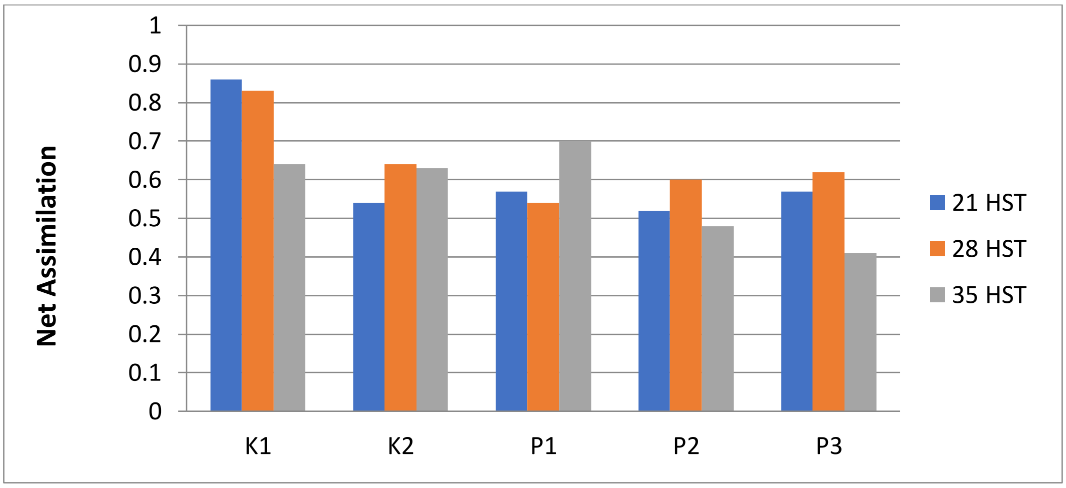

Figure 6. Net Assimilation Rate

The figure presents the NAR trends across treatments, reinforcing the observation that manure dosage does not drastically alter the NAR, particularly at later growth stages. This suggests that while nutrient management is crucial, other factors such as light availability, water management, and overall plant health are also critical in determining the efficiency of biomass production.

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According to Table 7. Measurement of root nodules shows that the use of manure does not significantly change the vegetative development of black soybean plants, nor does cultivar or organic fertilizer.

Table 7. Average Active Root Nodules

Treatment	Average
Cultivars	
Soy Detam 1	3.00 a
Pearl Soy 2	1.33 a
Manure Dosage	
No Fertilizer	1.50 a
Fertilizer 0.16 kg/bed	2.50 a
Fertilizer 0.32 kg/bed	2.50

Active root nodules are critical for nitrogen fixation in legumes, contributing to the plant's nitrogen supply and overall growth. Detam 1 (K1) exhibited a higher number of active root nodules compared to Pearl Soy 2 (K2), suggesting that K1 may have a greater inherent capacity for symbiotic nitrogen fixation. This could be an advantage in low-nutrient environments or in systems where organic inputs like manure are limited.

Both manure treatments (P2 and P3) significantly increased the number of active root nodules compared to the control (P1), indicating that manure application enhances the conditions for root nodule development and nitrogen fixation. However, the similar nodule counts between P2 and P3 suggest that beyond a certain point, additional manure does not further increase nodule formation, possibly due to nutrient saturation or the plant reaching a physiological limit in nodule production (Wanantari et al., 2022). This result emphasizes the importance of optimizing rather than maximizing manure application to enhance nitrogen fixation without risking nutrient imbalances or other growth issues.

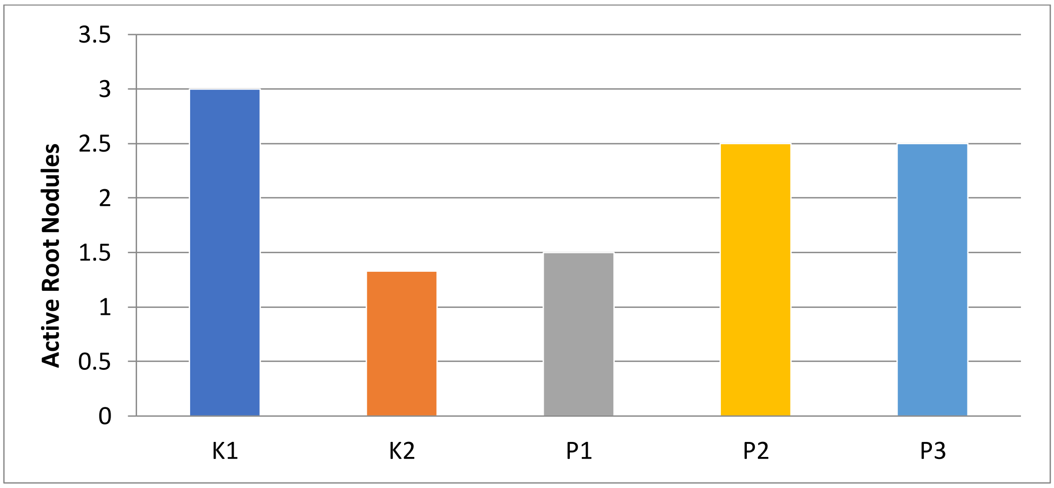

Figure 7. Active root nodules

The graphical representation of active root nodules clearly illustrates the positive effect of manure application on nodule formation, with both manure treatments showing significant improvements over the control. This visual aid reinforces the idea that organic fertilization not only supports general plant growth but also specifically enhances the symbiotic relationships that are crucial for legume crops like soybeans.

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Based on Table 1, it shows that measurements for plant height at the ages of 7, 14, 21, 28, 35 and 42 HST of Cultivar K1 (detam 1) had no significant effect on organic fertilizer with a dose without fertilizer, and a fertilizer dose of 0.16 kg/bed. However, it is different from giving fertilizer of 0.32 kg/bed which has a real effect. The best treatment was 0.18 kg/bed of cow manure with the black soybean cultivar Detam 1. Root growth and nutrient absorption are thought to be influenced by soil nutrient availability, structure and air quality. Nutrient absorption by roots, especially nutrients on the root surface, affects plant development, performance and growth. The nutrient N helps plants recover from stunted growth, phosphorus is essential for early plant development because it accelerates root growth, overall plant growth, and photosynthesis, and potassium helps plants grow stronger cell walls and wider leaf canopies (Setiono & Azwarta, 2020).

Table 2 shows that black soybean plants of all cultivars grew without significant influence from 0.16 kg or 0.32 kg of cow manure. This shows that the use of cow dung fertilizer is less effective and is because the nutrients contained in cow dung are insufficient and the nutrients from cow dung are not enough to stimulate plant growth, especially the number of leaves. This may be caused by the slow release of nutrients from organic material in cow dung at various doses used. In addition, it is suspected that the leaves lack nitrogen nutrients, causing the leaves to turn yellow and fall off. As a plant grows, it enlarges in every way: height, width and length of leaves, as well as the total mass of its organs and tissues. A plant's ability to absorb solar energy and carry out photosynthesis is directly correlated with the area of its leaves (Trisnawati et al., 2021).

Table 3 shows that the application of cow manure significantly affects the leaf area index. Fertilizer can increase photosynthetic activity to produce photosynthate, which develops leaf meristem tissue and increases the number of leaves. Nitrogen fertilizer in the medium increase’s growth and leaf area. N availability affects plant shape and number, leaves, and growth. Micronutrients improve soil conditions and aeration (Widyastuti et al., 2015).

Table 4 shows that there is no effect of chlorophyll on the two black soybean varieties. Shaded leaves use the results of photosynthesis from the leaves above them to meet the needs of photosynthesis and respiration. This situation reduces soybean growth and yield by reducing photosynthate, according to Anggraeni et al. (2020).

Table 5 displays the results of Duncan's further tests, which show that the relative growth rate of black soybean plants is not affected by the application of cow manure. Photosynthetic activity of black soybean plants reached its peak at 21 (DAP), 28 (DAP), and 35 (DAP) hours of light-dependent photosynthesis (LPR), because LPR growth was directly correlated with the amount of organic cow dung fertilizer given. In addition, nutrient availability increases as the dose of cow dung fertilizer increases. Compared with plants grown in a control environment, black soybean plants fertilized with cow dung had a faster average LPR. Among the cow manure doses tested, the third application of 0.32 kg /plant resulted in the largest increase in nutrient uptake. More nutrients are available in the planting medium when water is available (Kasim et al., 2017).

Table 6 shows that when black soybean plants were fertilized with cow manure, the net absorption rate assessment showed that neither the cultivar nor the organic fertilizer substantially affected the vegetative growth of the plants. The net assimilation rate and plant growth rate were found to be the same for all treatments. The biological and chemical properties of soil can be improved with organic amendments, which is why biomass does not undergo substantial changes under these conditions. Even in very salty soils, plants will benefit from increased water and mineral intake due to changes in chemical and biological characteristics.

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Because the RuBisCO enzyme increases temperature by binding oxygen, photorespiration is stimulated, and carbon and nitrogen are lost, growth is inhibited in hot areas (Nasrudin et al., 2021).

Table 7 shows that when black soybean plants were fertilized with manure, root nodule measurements showed that neither the cultivar nor the organic fertilizer affected the vegetative growth of the plants. When the plant is still young, when the main root hairs or branch roots have grown, the rhizobium will make root nodules. Soybean root nodules improve plant development and yield. Soil fertilization is another benefit, as it releases nitrogen into the soil and restores the use of NH3. Further benefits of adding cow manure to soil include increased physical productivity, greater water storage capacity, higher macro and micro nutrient content, and more microbial activity. Beneficial soil microbes help absorb nutrients and break down organic matter. Cow dung contains microbes that can help soybean plants create a symbiotic relationship that promotes root nodule growth (Wanantari et al., 2022).

Unsurprisingly, a crucial revelation noted by the study is the effects of the dosage and frequency of manure application on the height of the plants; it was found that while moderate application of manure (0. This is in consonance with what is referred to as nutrient toxicity, especially where nitrogen is in excess of what the plant needs, this has negative impacts to the plant's bio physics. According to the research by Bhardwaj et al. (2021), high N can increase the growth of tissues at the expense of [root growth] leading to tall plants that lack strength. This overemphasis on growth of the vegetative part of the plant can really hinder its productivity in relation to other factors such as water and nutrients which are important in the general growth process.

However, to appreciate the impact of manure on the structure of the ground, other factors have to be put into account. Soil condition that contains large quantities of organic matter is desirable in moderate amount but when applied in large quantities, they cause compactness in the soil, which results to restriction of aeration and rigidity for root penetration. This is particularly relevant in verticulture systems, for which volume of soil is restricted anyway and roots play a fundamental role in the taking of nutrients. Literature by Bünemann et al (2018) explain that over application of organic fertilizers can result in compaction of the soil, which hampers root development and nutrient uptake partly in support of of the observed decline in growth at higher manure amounts found in this study.

The enhancement in LAI under moderate manure dosage is clear, which proves the principle of rationality of nutrient application for increasing photosynthesis. LAI is a direct measurement of the efficiency with which plants are intercepting sunlight and photosynthesizing, which determines biomass production. Though, the reduction in yields with increasing levels of manure that has been described above is also supported by the work of Poorter et al. (2019) which revealed that while the increased LAI is beneficial since it brings in more light to the canopy which is beneficial for the plant, it is also possible to over do it and end up with shading within the canopy which is not good.

By context, in such confined growing environments as verticulture, balancing nutrient levels therefore forms a most important element of a good strategy. In the same respect, nitrogen as a nutrient can cause an over growth of foliage and this may not be proportionately balanced with production, as extension might suggest. This phenomenon is explained by Zhang et al. (2020) noting that where planting densities are high, a crop develops a luxurious growth of vegetative parts which compete for light and thus the rate of photosynthesis is generally low and therefore the yields low as well.

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The concentration of Chlorophyll is one of the best known and most used parameters to determine the photosynthetic activity of plants, as well as their current condition. This goes in harmony with the findings that in this study chlorophyll content is relatively high under moderate application of manure since nitrogen encourage chlorophyll formation which is key to photosynthesis. Nevertheless, the decrease in the chlorophyll content at the highest level of manure can be attributed to nutrient stress which has been evidenced in the literature.

Research carried out by Egamberdieva et al. (2015) and Çakmakçı et al. (2017) show that Austin's claim is accurate since the abundance of nitrogen destabilises nutrients within the plant cells causing oxidative stress to the chlorophyll molecules. This stress can manifest in such a way that lower chlorophyll content is observed as done in this study and the reduction of photosynthetic efficiency. The results also indicated the importance of maximizing nutrient concentrations in verticulture systems but at the same time minimizing their concentration because excess nutrient concentration retards the growth of plants.

The initial increase in Relative Growth Rate (RGR) that is experienced when manure is applied is due to the direct utilizable nutrient that increases vegetation growth at the initial stages. Although the poor germination state of seeds is compensated at the beginning of the experiment by the plants under the moderate manure treatment, the manure TextAlign: LATER disadvantage becomes pronounced as the plants grow and need better balanced nutrients. This pattern of decrease in growth rate corresponds with the observations by Coutinho et al. (2019), wherein high nutrients have been noted for encouraging faster initial specimen growth, only it facilitates accrual of nutrient to the extent that uniform specimen development is slowed. The relative constancy of Net Assimilation Rate (NAR) of the plants in the different treatments indicates that, while nutrients gas has a role in early plant growth, other factors such as light receiving equipment and water control become more decisive as the plants grow. This is in tandem with Shao et al. (2009) observations on the need to strive for moderation in nutrient supply in systems such as verticulture, which tightens the connections between the environment.

Active root nodules necessary for nitrogen fixation in legumes were developed more actively when the dosage of manure reaches the moderate level. It therefore confirms the need to have a standard nutrient that is applied to the plants or soil so that it can improve the growth of the plants and other corollary associations that feed into sustainable agriculture. They cause root nodules, which is a feature that allows legumes to fix nitrogen from the air and therefore do not require inputs of nitrogen fertiliser. The result of this study corresponds to the study undertaken by Chaudhary et al. (2017) who revealed the fact that moderate nutrient availability of organic fertilizers improves root nodule formation and nitrogen fixing abilities but high nutrient nutrient levels suppresses formation. Understanding the outcomes of nutrient loading thus emphasizes the notion that nutrient existence is delicate to encourage ubuntu, friendly sycophancy; however, it is equally lethal as Socorrito's curse. In verticulture systems, particularly those confined by small volume of soil and influenced by poor availability of nutrients, it is important that this balance be sustained so as to enhance proper growth of the plants and health of the soil.

Conclusion

The experiment investigated impact of cow manure on germination and growth of two black soybean varieties under verticulture practice, thus providing useful information concerning the role of nutrient application on plant performance in limited space with high population density. Therefore, the outcomes stress the need to respect the rate of moderate manure application, such as 0. At 16 kg/bed, growth responses were always a cut above the corresponding

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optimums as measured by parameters such as plant height, leaf area index, chlorophyll content, and active root nodules. Surprisingly, while increasing the manure dosage to 0. 32 kg/bed, the result was not proportionate to the response obtained and sometimes a decline in the growth was seen. This is in agreement with nutrient saturation, an aspect stating that the availability of nutrients, especially nitrogen causes detonation of nutrients, distort the physical process of growth in plants. These results support findings availed in the literature on nutrient management in limited environment where precision is advocated in the use of fertilizer to counter the negative impacts of over fertilization. Morevover, results regarding chlorophyll content and root nodule formation presented in the study point out the effective of the balanced nutrients application not only for plants' growth but also for beneficial microbial relations that are significant for agricultural sustainability. The increased root nodule formation under moderate level of manure application give indication that proper nutrition can enhance nitrogen fixation that will eventually be beneficial to the ongoing cropping system and thus reduce on continuous use of nitrogenous fertilizers. Thus, analyzing the implications of the obtained findings, it is possible to note that the results obtained are not limited to the context of black soybean cultivation. They provide more general information on the control of nutrient inputs in verticulture systems; this is especially important in modern verticulture systems, where there is growing interest in obtaining high yields within limited space – such as cities. In a broader perspective, the focus that the study makes to apply moderate amounts of manure is actually a possible prescription that soils will follow in order to increase crop production without exacerbating the current environmental problems in the urban world. As for the further research, it is necessary to study the residues of these practices on the subsequent yields and the state of the soil, besides the possibilities for applying it to other crops and climate zones. As such, implementing these nutrient management strategies in conjunction with other sustainable practices could even more enhance verticulture systems become the foundation of urban agriculture.

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