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COMPARATIVE EFFECTS OF GROWING MEDIA AND STARTER NITROGEN FERTILIZATION ON THE GROWTH AND NUTRIENT UPTAKE OF LETTUCE (*LACTUCA SATIVA* L.) SEEDLINGS

Abdulrahman B. Lawan, Mustapha Fadil and Mustapha A. Aishat*

Department of Soil Science, Faculty of Agriculture, Bayero University Kano, Kano State, Nigeria

Abstract: The growth and nutrient uptake of lettuce (*Lactuca sativa* L.) are strongly influenced by the choice of growing medium and nitrogen fertilization strategy. This study investigated the comparative performance of soil, coco peat, and hydroponics under different starter nitrogen regimes using a completely randomized design (CRD) with six treatments and four replications. Data on seedling emergence, chlorophyll content, plant height, root number, dry weight, and nutrient concentrations (N, P, K) were collected. The results revealed significant differences ($p < 0.001$) across the treatments. Hydroponics supported the fastest seedling emergence (2 days), the highest chlorophyll content (0.632 at week 2), the tallest plants (5.53 cm at week 3), and the greatest biomass (1.31 g), while soil with NPK recorded the highest nitrogen concentration (7.17%). Hydroponic full-strength and half-strength nutrient solutions achieved the greatest phosphorus uptake (7.69 and 7.67 g kg^{-1}, respectively). Root number did not differ significantly among treatments. Overall, hydroponics demonstrated superior performance, with the half-strength nutrient solution offering a more economical approach without compromising growth. These findings highlight the potential of hydroponics and coco peat as sustainable alternatives to soil-based systems for lettuce production in resource-limited environments.

Key words: lettuce, growing medium, hydroponics, coco peat, soil, nitrogen fertilization, seedling emergence, chlorophyll content, nutrient uptake.

Introduction

Lettuce (*Lactuca sativa L.*) is a globally significant leafy vegetable valued for its nutritional content, low caloric value, and economic importance. As a rich source of vitamins A, C, and K, folate, and dietary fiber, lettuce contributes significantly to human health, especially in urban diets. Its cultivation supports food security and income generation, making it a preferred crop for smallholder

*Corresponding author: e-mail: aamustapha.ssc@buk.edu.ng

farmers and urban agriculture in many parts of the world (Gonzaga et al., 2018; Nyam et al., 2021).

In Nigeria, lettuce is increasingly grown in urban and peri-urban settings, supported by the rise in demand for fresh vegetables. However, the diverse soil conditions pose challenges to its cultivation. Nigerian soils, particularly those in the southeastern and savanna regions, are often characterized by low fertility, acidity, and nutrient imbalances. These issues include deficiencies in essential nutrients such as nitrogen, phosphorus, and potassium, and poor organic matter content, which limits their suitability for optimal lettuce production (Mustapha et al., 2022a; Mustapha and Muhammad, 2023). Additionally, soil erosion and soil degradation further reduce productivity, emphasizing the need for alternative solutions to improve crop yields (Mustapha and Idris, 2023).

Alternative growing media, such as coco peat and hydroponics, have gained traction as sustainable methods to address soil-related limitations of lettuce cultivation. Coco peat, derived from coconut husks, is known for its excellent water retention capacity, aeration, and pH stability. Its use has proven to be particularly beneficial in seedling production, offering uniform growth conditions and improved root establishment (Fathidarehnijeh et al., 2023). In Nigeria, coco peat is increasingly being integrated into urban farming practices due to its affordability and ease of use, particularly for high-value vegetables such as lettuce and tomatoes, due to its affordability and ease of use (Mensah et al., 2020; Ogunwole et al., 2001). Hydroponics, a soilless cultivation system that uses nutrient-enriched solutions, offers another viable alternative. It allows for precise control of nutrient delivery, leading to faster growth rates, higher yields, and reduced water usage compared to traditional soil-based systems. Hydroponics is especially effective in urban settings where space and soil quality are constraints, making it an attractive option for lettuce production in Nigerian cities (Alam et al., 2024; Raj et al., 2023; Sharma et al., 2018).

Nitrogen is a key macronutrient that plays a critical role in lettuce growth and yield. It is essential for chlorophyll synthesis, leaf area development, and overall plant biomass. However, excessive nitrogen application can result in nitrate accumulation in the leaves, posing health risks to consumers and contributing to environmental pollution through leaching (Hong et al., 2022; Mensah et al., 2020). Starter nitrogen fertilization, which involves applying nitrogen during the early growth stages, has been shown to enhance seedling establishment and improve nitrogen use efficiency. This approach is particularly relevant in resource-constrained environments, where efficient nutrient management is essential (Al-Taey et al., 2018; Alam et al., 2024).

Despite the growing interest in soilless systems and advanced fertilization strategies, there is limited research on the comparative effects of soil, coco peat, and hydroponics under varying nitrogen fertilization regimes on lettuce growth in

Nigeria. This study seeks to evaluate the influence of these growing media on lettuce seedling growth, focusing on germination time, chlorophyll content, plant height, root development, and nutrient uptake. The findings will contribute to identifying sustainable and efficient practices for lettuce cultivation in diverse agro-ecological zones, particularly in regions with degraded soils or limited resources.

Material and Methods

Study location

The greenhouse experiment was conducted at the Center for Dryland Agriculture, Bayero University Kano. Laboratory analyses were carried out at the Research and Experimental Laboratory of the Department of Soil Science, Faculty of Agriculture, Bayero University Kano.

Growing media

Three different growing media were used in this study: soil, coco peat, and hydroponics. The soil was collected from the research farm of the Center for Dryland Agriculture. Coco peat and hydroponic materials were sourced from certified commercial suppliers.

Experimental design and treatments

The experiment followed a completely randomized design (CRD) with six treatments. The treatments included three growing media (soil, coco peat, and hydroponics) combined with two fertilizer doses: zero fertilizer dose (no fertilizer applied), and complete fertilizer dose (for hydroponics, half the recommended fertilizer rate was used in the zero-dose treatment).

Urea, single super phosphate (SSP), and muriate of potash (KCl) were used as fertilizers. The fertilizer was applied based on the standard recommendations for lettuce: 30 kg N ha^{-1}, 15 kg P_2O_5 ha^{-1}, and 10 kg K_2O ha^{-1}.

Collection of agronomic data

The agronomic data collected included chlorophyll content, plant height, and root characteristics.

1. Chlorophyll content and plant height: Measurements were recorded at 9, 18, and 27 days after sowing (DAS). Chlorophyll content was assessed using a

GreenSeeker™ handheld optical sensor (Model 505, NTech Industries, Ukiah, CA, USA).

2. Root samples: Root samples were collected from each treatment at the end of 27 DAS for further analysis of root growth parameters.

3. Dry weight: Plants were harvested at 27 DAS, dried at room temperature for three days, and weighed using a precision balance.

This approach ensured a comprehensive evaluation of the effects of the growing media on the growth and development of the lettuce seedlings.

Laboratory analysis

The soil and the coco peat were analyzed for their basic properties as follows:

- Soil texture was determined using the Boyoucous hydrometer method (Bouyoucous, 1962);
- The electrical conductivity and pH were measured using a pH meter with a glass electrode based on the method outlined by Mclean (1982);
- Organic matter was determined using the Walkley-Black wet oxidation method as described by Mustapha et al. (2022a);
- Total nitrogen was determined by the micro-Kjedhal digestion method (Bremmer, 1996);
- Available phosphorus was determined using the Bray method as outlined by Mustapha et al. (2022b), while total P was determined using the procedure of Malá and Lagová (2014);
- Exchangeable bases were determined as described by Silva et al. (2010).

Statistical analysis

The results of soil physical and chemical properties were analyzed using descriptive statistics, while analysis of variance was used to evaluate the response of lettuce to different growing media and fertilizers. Means were separated using the Fisher's protected least significant difference. All analyses were carried out using the JMP version 16 statistical package.

Results and Discussion

Soil and coco peat characterization

The results of the physical and chemical properties of the soil and the coco peat are shown in Table 1. The soil used was classified as sandy loam, a common soil type in the Nigerian savannah, which is often classified as nutrient-deficient and requires fertilization for optimal vegetable production (Mustapha et al., 2022a; Nyam et al., 2021). These characteristics make coco peat particularly effective in supporting seedling growth in environments with inconsistent water availability.

Cahyo et al. (2019) and Abad et al. (2002) highlighted the ability of coco peat to provide a stable water supply, promoting uniform germination and root development. Both media displayed slightly acidic pH values within the optimal range for lettuce cultivation (5.5–6.8), with coco peat having a slightly higher pH (6.70 and 5.90) than soil (6.50 and 5.60) in both water and CaCl2, respectively. These pH levels enhance nutrient solubility and availability to plants (Amran et al., 2024).

Table 1. Characterization of the soil and the coco peat.

Property	Soil	Coco peat
Texture (%)	Clay loam	
Sand	40.24	
Silt	31.28	-------
Clay	28.48	
pH		
Water	6.50	6.70
$CaCl_2$	5.60	5.90
Electrical conductivity (dsm-^{1})	0.14	0.17
Exchangeable bases ($cmol_{(+)}kg^{-1}$)		
Na	0.14	14.13
Mg	1.11	14.37
Ca	3.16	2.61
K	0.42	0.41
Exchange acidity	0.67	----
Organic carbon (%)	1.06	2.37
Total nitrogen (%)	0.28	4.37
Available P (mg kg^{-1})	4.09	8.82

Electrical conductivity values for both media were low (soil: 0.14 dS m-1, coco peat: 0.17 dS m-1), indicating minimal salinity stress, which is critical for optimal lettuce growth (Sublett et al., 2018). Organic carbon plays a crucial role in improving soil structure, water-holding capacity, and nutrient availability. Coco peat had a higher organic carbon content (2.37%) compared to soil (1.06%). The higher organic carbon content of coco peat aligns with its use as an effective growing medium for crops that require consistent moisture and nutrient availability during germination and early growth stages (Cahyo et al., 2019). In contrast, the lower organic carbon content in the soil may limit its ability to retain nutrients and water, potentially impacting seedling development. Coco peat exhibited significantly higher levels of exchangeable bases, particularly magnesium (14.37 cmol kg-1) and sodium (14.13 cmol kg-1), compared to soil. These findings support the use of coco peat as a medium for maintaining a balanced nutrient supply as reported by Amran et al. (2024). However, the soil had a higher calcium concentration (3.16 cmol kg-1), which is beneficial for plant structural development. Despite this, the overall nutrient retention capacity of coco peat, credited to the high amounts of cations observed (Na (14.13 cmol(+)kg-1); Mg (14.37 cmol(+)kg-1); Ca (2.61 cmol(+)kg-1) and K (0.41cmol(+)kg-1)), makes it a more reliable medium for nutrient delivery. Coco peat contained significantly higher nitrogen (4.37%) and phosphorus (8.82 g kg-1) levels than soil (0.28% nitrogen and 4.09 g kg-1 phosphorus). Nitrogen is essential for chlorophyll synthesis and leaf growth, while phosphorus supports root development and energy transfer. The higher nutrient content in coco peat highlights its suitability for promoting rapid seedling growth (Asiah et al., 2004). Conversely, the lower nutrient levels in the soil underscore the need for supplemental fertilization to support healthy lettuce growth.

Effect of different growing media and fertilizer rates on the chlorophyll content of lettuce

The chlorophyll content of lettuce as affected by different growing media and fertilizer rates are as shown in Table 2. The chlorophyll concentration represents the production of energy nutrition in plants and an indication of the sufficiency of required nutrients, especially N (Sandadevani et al., 2025).

Table 2. Effect of different growing media and fertilizer rates on the chlorophyll content of lettuce.

Growing medium	Chlorophyll w1	Chlorophyll w2	Chlorophyll w3
Hydroponics full	0.540a	0.632a	0.560a
Hydroponics half	0.520a	0.535a	0.565a
Coco peat	0.283b	0.310b	0.407a
Coco peat with NPK	0.253b	0.312b	0.362a
Soil	0.288b	0.335b	0.487a
Soil with NPK	0.355b	0.387b	0.502a
S.e.d	0.0575	0.570	0.0660
F probability	<0.001	<0.001	0.043

Means followed by different letters are significantly different at p<0.001, W1: week 1, W2: week 2, W3: week 3, NPK: nitrogen, phosphorus and potassium fertilizers.

Significant differences ($p < 0.05$) in the chlorophyll content were observed between the treatments, indicating that the different growing media and fertilizer regimes had an impact on the chlorophyll content of lettuce. The highest chlorophyll content (0.520 – 0.632) was observed with the use of the hydroponics which was attributed to optimal nutrient supply, excellent aeration essential for root respiration and nutrient supply as well as reduced or low competition with weeds and soil-borne pathogens (Çekin et al., 2025). The soil-based systems, both with and without NPK fertilizer, showed lower chlorophyll content (0.288–0.502) compared to hydroponics, with the lowest chlorophyll content of 0.288–0.407 recorded across the coco peat media.

The addition of fertilizer to soil-based systems was observed to significantly increase chlorophyll content by 3.08–23.03%, thus indicating the positive effect of NPK fertilizer and its ability to affect nutrient availability which may have an influence on the synthesis of chlorophyll (Rathnayaka et al., 2024). In contrast, the addition of NPK to coco peat-based systems did not significantly increase chlorophyll content. This suggests that the high nutrient-holding capacity of coco peat may already meet the crop requirements without additional fertilizer (Abad et al., 2002; Amran et al., 2024).

Generally, chlorophyll content increased over time in all treatments except for the full-strength hydroponics. The rate of increase was highest in the half-strength hydroponic systems followed by the soil-based systems with NPK.

Effect of different growing media and fertilizer rates on days to emergence, number of roots and dry weight of lettuce

The effect of different growing media and fertilizer rates on days to emergence, number of roots and dry weight of lettuce is shown in Table 3. The result showed highly significant differences (<0.001) in the days to emergence across the different media. The hydroponic systems, both with full and half-strength nutrient solutions, showed the fastest emergence time of 2 days, followed by the coco peat-based media (3 days) and finally the soil-based system of 5 days. Significant differences ($p<0.05$) in the number of roots among the different media were observed in the hydroponic systems, particularly the half-strength nutrient solution had significantly higher number of roots (20) compared to the full-strength solution (18). The soil-based and coco peat-based systems, both with and without NPK fertilizer, had a similar number of roots. The rapid emergence and higher root number in hydroponic systems can be attributed to the optimal nutrient and oxygen availability in the nutrient solution (Ahmed et al., 2021; Liu et al., 2014; Raj et al., 2023). The slower emergence and lower root number in soil-based and coco peat-based systems may be due to factors such as soil compaction, waterlogging, or nutrient deficiencies (Cahyo et al., 2019; Ogunwale et al., 2021; Olasupo et al., 2018).

Highly significant differences (<0.001) in the dry weight of lettuce were observed among the different media. Hydroponic systems, both with full and half-strength nutrient solutions, produced a significantly higher dry weight (1.308 and 1.258, respectively). The superior biomass production in hydroponics is a cumulative effect of early emergence, higher chlorophyll content, and increased root number. This reflects the efficient conversion of photosynthates into biomass under optimized nutrient and water conditions (Boroujerdnia and Ansari, 2007; Sandadevani et al., 2025). On the other hand, lower dry weights were observed in the soil-based and coco peat-based systems, with no significant weight increase with additions of NPK fertilizer. The addition of NPK fertilizer did not significantly improve weight, suggesting that other factors, such as soil structure and microbial activity, may limit plant growth (Nyam et al., 2021; Ogunwale et al., 2021; Olasupo et al., 2018).

Table 3. Effects of different growing media and fertilizer rates on days to emergence, number of roots and dry weight of lettuce.

Growing medium	Days to emergence	Number of roots	Dry weight
Hydroponics full	2b	18b	1.308a
Hydroponics half	2b	220a	1.258a
Coco peat	3b	16b	0.785b
Coco peat with NPK	3b	17b	0.808b
Soil	5a	15b	0.713b
Soil with NPK	5a	16b	0.758b
S.e.d	0.357	1.567	0.0591
F probability	<0.001	0.013	<0.001

Means followed by different letters are significantly different at p<0.001, NPK: nitrogen, phosphorus and potassium fertilizers.

Effect of different growing media and fertilizer rates on plant height

Table 4 presents the plant height of lettuce seedlings grown in various media and under different fertilizer rates over 3 weeks. Statistical differences ($p < 0.05$) in the plant height were observed among all the growing media. The tallest seedlings of 5.525 cm were observed in both the full-strength and the half-strength nutrient solutions of the hydroponic system. The plant height was observed to increase significantly over the time period. The excellent performance of the hydroponic system may be attributed to optimal nutrient supply, reduced competition as well as excellent aeration (Raj et al., 2023; Rathnayaka et al., 2024).

Table 4. Effect of plant height on lettuce seedlings grown on different media.

Growing medium	Plant height w1	Plant height w2	Plant height w3
Hydroponics full	1.800ab	3.450a	5.525a
Hydroponics half	2.250a	3.825a	5.525a
Coco peat	1.150c	2.150b	4.125b
Coco peat with NPK	1.150bc	2.200b	4.250b
Soil	0.850c	2.000a	3.950b
Soil with NPK	0.825c	1.950b	4.000b
S.e.d	0.3031	0.3432	0.2296
F probability	0.001	<0.001	<0.001

Means followed by different letters are significantly different at p<0.001, NPK: nitrogen, phosphorus and potassium fertilizers, W1: week 1, W2: week 2, W3: week 3.

On the other hand, the plant soil-based and coco peat-based systems were significantly shorter compared to hydroponic systems (3.95 cm and 4.125 cm, respectively). The low plant heights observed might be due to factors such as soil compaction, waterlogging, or nutrient deficiencies (Olasupo et al., 2018).

Effect of different growing media and fertilizer rates on the content of nitrogen, phosphorus and potassium

The nitrogen, phosphorus, and potassium content of lettuce grown under the various media is presented in Table 5. There were no significant differences in the content of nitrogen across the different growing media ($p = 0.963$) which is probably due to nitrification and other chemical changes within the environment of the growing media (Vought et al., 2024). Similar results were obtained for potassium. Significant differences ($p<0.001$) were found for phosphorous content across the different growing media. Hydroponic systems, both with full-strength (7.691 g kg^{-1}) and half-strength nutrient solutions (7.669 g kg^{-1}), had a significantly higher phosphorus content compared to soil-based (5.674 g kg^{-1}) and coco peat-based systems (5.660 g kg^{-1}). The enhanced phosphorus uptake in hydroponics underscores the efficiency of direct nutrient supply in soilless systems (Çekin et al., 2025). This aligns with Karimaei et al. (2004), who have highlighted that phosphorus availability is often constrained in soil-based systems but optimized in hydroponics systems.

Table 5. Effect of nitrogen, phosphorus, and potassium content on lettuce grown on different media.

Growing medium	Nitrogen %	Phosphorus (g/kg)	Potassium (mg/kg)
Hydroponics full	6.30a	7.691b	0.580a
Hydroponics half	6.30a	7.669b	0.667a
Coco peat	6.30a	5.660a	0.384a
Coco peat with NPK	6.45a	5.843a	0.627a
Soil	7.00a	5.674a	0.661a
Soil with NPK	7.17a	5.07a	0.510a
S.e.d	1.291	0.1974	0.1449
F probability	0.963	<0.001	0.387

Means followed by different letters are significantly different at $p<0.001$, NPK: nitrogen, phosphorus and potassium fertilizers.

Conclusion

This study demonstrated that growing media and starter nitrogen fertilization significantly affected lettuce growth, development, and nutrient uptake. Hydroponics consistently outperformed soil and coco peat in terms of seedling emergence, chlorophyll content, plant height, and dry matter accumulation, confirming its efficiency as a high-performance cultivation system. Notably, half-strength hydroponic solutions produced results comparable to full-strength treatments, suggesting that input costs can be reduced without compromising productivity.

Coco peat proved to be a promising sustainable alternative to soil, with higher organic carbon and nutrient content, though its nutrient release dynamics require supplementation—particularly of calcium—to support structural development. Soil-based systems, while widely available, exhibited lower performance and highlighted the need for improved management practices such as fertilization or organic amendments to optimize productivity.

The findings emphasize the potential of hydroponics and coco peat to strengthen urban and peri-urban lettuce production in Nigeria and similar regions facing soil degradation. Future studies should focus on integrating coco peat with soil or other organic amendments, evaluating organic nutrient solutions, and assessing the environmental and economic sustainability of hydroponic adoption in resource-constrained settings.

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UPOREDNI EFEKTI SUPSTRATA I OSNOVNOG ĐUBRENJA AZOTOM NA RAST I USVAJANJE HRANLJIVIH MATERIJA KOD RASADA ZELENE SALATE (*LACTUCA SATIVA* L.)

Abdulrahman B. Lawan, Mustapha Fadil i Mustapha A. Aishat*

Department of Soil Science, Bayero University Kano

Rezime

Rast i usvajanje hranljivih materija kod zelene salate (*Lactuca sativa* L.) u velikoj meri zavise od izbora supstrata i načina đubrenja azotom. Ovim istraživanjem se ispitivao uporedni efekat zemljišta, kokosovog treseta i hidroponike u različitim režimima osnovnog đubrenja azotom, korišćenjem potpuno slučajnog rasporeda (engl. *completely randomized design – CRD*) sa šest tretmana u četiri ponavljanja. Prikupljeni su podaci o nicanju, sadržaju hlorofila, visini biljaka, broju korenova, suvoj masi i koncentracijama hranljivih materija (N, P, K). Rezultati su pokazali značajne razlike ($p < 0,001$) među tretmanima. Hidroponika je omogućila najbrže nicanje (2 dana), najveći sadržaj hlorofila (0,632 u 2. nedelji), najviše biljke (5,53 cm u 3. nedelji) i najveću biomasu (1,31 g), dok je kod zemljišta u kome je dodato đubrivo NPK zabeležena najviša koncentracija azota (7,17%). Hidroponski hranljivi rastvori sa punom i sa pola doze postigli su najveće usvajanje fosfora (7,69 odnosno 7,67 g kg^{-1}). Broj korenova se nije značajno razlikovao među tretmanima. U celini, hidroponika je pokazala najbolje efekte, pri čemu je hranljivi rastvor sa pola doze predstavljao ekonomičniji pristup bez ugrožavanja rasta. Ovi nalazi ističu potencijal hidroponike i kokosovog treseta kao održivih alternativa sistemima zasnovanim na zemljištu za proizvodnju zelene salate u okruženjima sa ograničenim resursima.

Ključne reči: zelena salata, supstrat, hidroponika, kokosov treset, zemljište, đubrenje azotom, nicanje, sadržaj hlorofila, usvajanje hranljivih materija.

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*Autor za kontakt: e-mail: aamustapha.ssc@buk.edu.ng