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RESEARCH ARTICLE

Evaluation of different organic nitrogen nutrition for lettuce under hydroponic system

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Abstract

Effect of Different Organic Nitrogen Sources on Lettuce Growth in Hydroponics Hydroponics is one of the modern agricultural techniques applied in many countries of the world and some Arab countries such as Arab Gulf countries. Hydroponics comes as one of the proposed solution alternatives in Egypt in order to reduce the deficit in many strategic vegetable crops such as tomatoes, cucumbers, and leafy plants such as lettuce. Also, hydroponics technology allows for precise control over plant growth, particularly nutrition, by using nutrient solutions derived from chemical compounds. However, this poses significant disadvantages, including potential contamination of produce with trace elements and higher concentrations of chemicals in plants.. Also, health as well as environmental concern are considered important problems of this system. So, this study looked at the effect of various organic nitrogen sources in the cultivation of lettuce. The study tried to measure how these fertilizers compared against a complete mineral solution. The results of this study indicate that incorporating organic sources such as Moringa leaf tea and compost tea solution significantly enhances the growth and nutritional quality of lettuce under hydroponic systems. Moringa leaf tea recored high significant N-content and N-uptake of lettuce plants 43.73 g/kg dry weight and 749.77 mg/plant respectively during two seasons comparing with other treatments. Also, Moringa leaf tea recorded high shoot growth parameters followed by compost tea, vermicompost tea and control treatment (mineral fertilizer), respectively.

***Keywords*:** Hydroponic, Lettuce, Organic nitrogen nutrient, Compost

1. Introduction

Hydroponics is a contemporary agricultural system providing precise control over growing conditions, potentially enhancing productivity. Hydroponics, a relatively novel technology, has already demonstrated success in cultivating a variety of crops, including lettuce, tomatoes, and strawberries (Abbasi et al., 2022). The term "hydroponics," derived from the Greek words "Hydro" (water) and "Ponic" (labor), refers to the method of growing plants in various substrates such as sand, gravel, or water where nutrients are supplied without the use of soil (Savvas, 2003). Liquid organic fertilizers, which are derived from safe organic materials, can effectively substitute chemical nutrients in hydroponics. These fertilizers provide essential plant nutrients and beneficial microorganisms that aid in recycling or degrading the organic substrate (Upendri and Karunarathna, 2021). One of the foremost challenges in utilizing chemical nutrition in hydroponics is the potential contamination of products with heavy metals, which can pose significant health risks to consumers and contribute to environmental pollution. To mitigate the use of harmful chemicals in lettuce cultivation, explored the application of organic nutrition and will discuss the results obtained in the following sections. Assess the impact of organic nutrition on lettuce plant (*Lactuca sativa, L.)* nitrogen supplying and on the productivity of lettuce plants (*Lactuca sativa, L.)* under hydroponic systems. The organic nutrients of plants, particularly within hydroponic systems, has emerged as a vital area of research due to its numerous advantages. One of the most significant benefits is the production of healthy, safe organic food that is free from many pollutants.

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Additionally, organic produce is increasingly recognized for its health benefits and superior taste, which appeal to consumers. Also, to avoid problems of soil salinity and water deficiency (Youssef and Abou kamer, 2019). In hydroponic systems, a nutrient solution composed primarily of inorganic ions from soluble salts is essential for plant growth. This solution may also include organic compounds, such as iron chelates (Jamwal and Sharma, 2019). Basic nutrient solutions typically contain nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur, supplemented with micronutrients (Hira, 2014). Liquid organic fertilizers, which are derived from safe organic materials, can effectively substitute chemical nutrients in hydroponics. These fertilizers provide essential plant nutrients and beneficial microorganisms that aid in recycling or degrading the organic substrate (Upendri and Karunarathna, 2021). Nitrogen is an essential element for plants. In hydroponics, we can choose to provide it in three ways, as nitrate, as ammonium or as organic nitrogen. This last choice is the most complex one. It contains all possible nitrogen-containing organic molecules produced by organisms, such as proteins and nucleic acids. Since nitrate and ammonium are simple molecules, we know how plants react to them, but given that organic nitrogen can be more complicated, its interactions and effects on plants can be substantially harder to understand. In this post, we will take an evidence-based look at organic nitrogen, how it interacts in a hydroponic crop and how there is a proven way to use organic nitrogen to obtain great results in our hydroponic setups. Moringa leaves are rich in various macro and micro nutrients. Research shows that *Moringa Oleifera* leaf extract (MLE) is a potential bio stimulant that could improve product quality (El-Serafy et al., 2021). It produces plenty of biomass and its leaf contains numerous nutrients, vitamins, phytohormones, and secondary metabolites (Rehman et al., 2017). In modern terminology, compost tea (compost extract) produced from the fermented compost in water (Litterick et al., 2004) has been utilized in agriculture as a good source of organic matter and soil amendment that provide plants with mineral nutrients .Utilizing vermicompost in hydroponics has been shown to improve various growth parameters, with significant improvements in tomato and lettuce yields reported when grown with vermicompost tea (Jiang et al., 2023). This study aims to evaluate lettuce production under hydroponic systems utilizing natural, unprocessed organic nutrients. A key objective is to compare the yield of lettuce plants (Lactuca sativa L.) grown with organic nutrition against those grown with mineral nutrition.

2. Materials and Methods

Two cycles of the experiment were run: the first took place in November 2023, and the second took place at the end of January 2024., in a controlled greenhouse environment at the farm of the Horticultutre Department, vegetable crops section, Faculty of Agriculture, South Valley University, Qena, Egypt. The primary objective of this research was to evaluate the effects of various organic amendments, specifically Moringa leaves (*Moringa oleifera*), compost, and vermicompost, on the growth and nitrogen content of lettuce (*Lactuca sativa* L.) In addion, the organic treatments were compared to a conventional mineral fertilizer.

2.1. Treatments and experimental design

The experiment was carried out in a randomized complete block design (RCBD), included four treatments with three replicates.

2.2. Nutrient Solutions. The experiment treatments consisted of four treatments as follows

- Mineral Nutrition (Nutrient Solution): A balanced nutrient solution tailored for hydroponic growth according to lettuce requirements.
- Compost (Compost tea): A liquid fertilizer prepared by steeping compost in water.
- Vermicompos (Vermicompost tea): A nutrient-rich liquid prepared by steeping vermicompost in water.
- Moringa tea (Moringa leaves): A nutrient solution derived from steeped Moringa leaves.

2.3. Experimental hydroponic unit

The hydroponic culture unit had a U-shape flat system (Width :High: 100*100 mm, Wall thickness 2.5mm) and consisted of 8 pipes of PVC with a diameter 5 inch that filled with different studied growing solution. The PVC pipes were holed every 30. cm net pots cultivated with lettuce plants using a density of 30 plants per an experimental unit were put in plant holes. A foam boards were made to install the seedlings in holes, pH and EC devices were used to adjust the acidity and salinity of the solutions. Each unit was supplying with a water as well as 50 liter tank with a 50 liters capacity. For aeration, different studied nutrient solutions were pumped via a submersible pump (40 watt, maximum flow of 1800 l/h and maximum head of 2.2 m) To adjust the time to pump the amount of nutrient solution in tank, a timer set at 10 min/2 h was used. The different substances which tested and their description can be found in Table (1).

Table 1. Identity of the tested substances using in this study

Tested Materials	Component	Treatments concentration	Application Rates
Control (Cooper nutrient solution)	The chemical nutrition solution was prepared in laboratory of soil and water department	Using one liter of diluent for 25 liters of water. Because the barrel holds 50 liters, 2 liters	50 liters of water at pH= 5.5 and E.C = 1.5.
Compost tea	Was bought from the Vermi Company in Luxor.	Using a big container and a bag of gauze, add 1 kg of solid compost fertilizer to 5 liters of water over the course of 48 hours, agitating the mixture every hour to let oxygen in.	2 liters; A barrel is filled with 50 liters to supply the plant directly at E.C =1.6 and pH= 6.4.
Vermicompost tea	Was bought from the Vermi Company in Luxor.	After dilution, use liquid vermicompost fertilizer	500 ml to 50 liters at EC = 2 and pH= 6.5.
Moringa leaf tea	Faculty of Science farm, South Valley University	Leaf the moringa like and then add it to boiling water at 60:70 in a ratio of 1/5 kg to 5 L of water. For 24 hours, stir every 2 hours. The next day, dilute it with water and filter it once the consistency has increased.	1 liter, add it: 50 liters EC= 1.5 and pH= 6.3 in a 50-liter barrel.

Table 2. Chemical composition of compost, vermicompost, and moringa fertilizer used in the experiment

Characteristic	Compost Tea	Vermicompost Tea	Moringa Leaf Tea
Total N (%)	1.71	1.35	4.70
Total P (%)	2.83	0.99	3.90
Total K (%)	0.67	0.33	2.00
pH	6.50	6.90	6.40
EC (dS/m)	1.60	2.10	1.23

3. Plant measurements during vegetative growth and after harvest:

3.1. Vegetative Growth Characteristics

- Plant heights (cm), number of leaves per plant, root length, stem diameter, and roots diameter.
- The plant was harvested and taken to the college department to weigh the entire plant on a scale. In order to measure each plant's growth independently, the rooted plant was then separated from the rest of the plant.

- A ruler was used to measure the length of the plant roots. Measure the diameter of the plant stem and use the foot to measure the roots. To ensure that the diameter numbers do not overlap and that the measurement is taken correctly, the foot is reset to zero between readings.
- Plant leaves were separated from each other to ascertain the number of plant leaves. The number of the plant's huge outer leaves was counted.

3.2. Chemical content analysis

- Vitamin C Content (Ascorbic Acid) determined by using 2, 6-dichloro phenol indophenol method. Silva et al., (2004).
- A level-3 heading must be indented, in Italic and numbered with an Arabic numeral followed by a right parenthesis. The level-3 heading must end with a colon. The body of the level-3 section immediately follows the level-3 heading in the same paragraph. For example, this paragraph begins with a level-3 heading.
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- The body of the level-3 section immediately follows the level-3 heading in the same paragraph. For example, this paragraph begins with a level-3 heading. Total Nitrogen by using the micro-Kjeldahl method (Jackson, 1973).

3.3. Relative chlorophyll content

- We measured chlorophyll with the SPAD_502 Puls instrument. An average was calculated by taking two leaves from the outside of the plant and one leaf from the inside. Each plant underwent this procedure independently. Relative Cholorpphyll content (SPAD) measured using a Minolta Chlorophyll Meter (SPAD-502 plus). Richardson et al., (2002).

4. Results

4.1. Growth parameters

The shoot growth parameters (plant height, number of leaves/plant, relative chlorophyll, content SPAD stem diameter and leaf area) of lettuce plants statistically showed in most treatment significant increases with all organic nutrient solutions (Table 3).

Table 3. Effects of different organic nutrient solutions on lettuce growth characteristics growing in hydroponic during two growing cycles.

Treatment	Plant height (cm)		Fresh biomass (g\plant)		Dry biomass (g\plant)	
	2023	2024	2023	2024	2023	2024
T_0	23.00[a]	23.33[a]	73.20[b]	94.13[a]	12.96[c]	12.97[c]
T_1	24.33[a]	26.00[a]	93.30[a]	99.51[a]	14.32[ab]	14.32[ab]
T_2	23.66[a]	25.33[a]	93.30[b]	95.50[a]	13.37[bc]	13.37[ac]
T_3	24.66[a]	26.33[b]	93.41[a]	103.87[a]	14.47[a]	14.47[a]
LSD	2.1	1.82	13.8	15.2	0.97	0.97

T_0= Cooper nutrient solution, T_1= compost tea, T_2 = Vermicompost tea and T_3=Moringa leaf tea

4.1.1. Plant height

Data in Table 3. Show no significant differences were observed for plant height (cm) between the control and the various organic treatments during the first cycle. However, in the second cycle, only the moringa leaf tea treatment led to a significant increase in plant height compared to the control (T_0). Specifically, plants in the control group reached a height of 23.33 cm, while those treated with moringa leaf tea (T_3) attained a height of 26.33 cm

4.1.2. Fresh biomass (g per plant)

In the first growing cycle, both compost tea and moringa leaf tea treatments significantly enhanced fresh weight compared to the control (T_0). The control treatment recorded a fresh weight of 73.20 (g), while moringa leaf tea and compost tea (T_3) achieved 94.41 and 93.30, (g) respectively. On the other side, no significant differences was obtanied in the second growing cyclefresh weight emerged between the organic treatments and the control. The control (T_0) recoded 94.13(g), whereas moringa leaf tea produced a higher fresh weight of 103.87 (g).

4.1.3. Dry biomass (g per plant)

In the first cycle, the control treatment recorded a dry weight of 12.96, while the moringa leaf tea treatment (T_3) recorded a dry weight of 14.47(g) and the compost tea (T_1) treatment 14.32(g). These data in the table for lettuce plants grown in the hydroponic system demonstrated highly significant differences between the two treatments in terms of the plant's dry weight. When it came to dry weight, the organic therapies also outperformed the control treatment in the second cycle. The difference was noteworthy, with the Moringa leaf tea treatment (T_3) recording 14.47(g) and the control treatment (T_0) recording 12.97(g).

4.1.4. Chlorophyll Content

The chlorophyll content, measured in SPAD units, showed increases in relative chlorophyll content. The highest chlorophyll values were recorded only in the moringa leaf tea treatment (T_3) which recorded significant increase reached to 29.14% than mineral control treatment (Fig, 1).

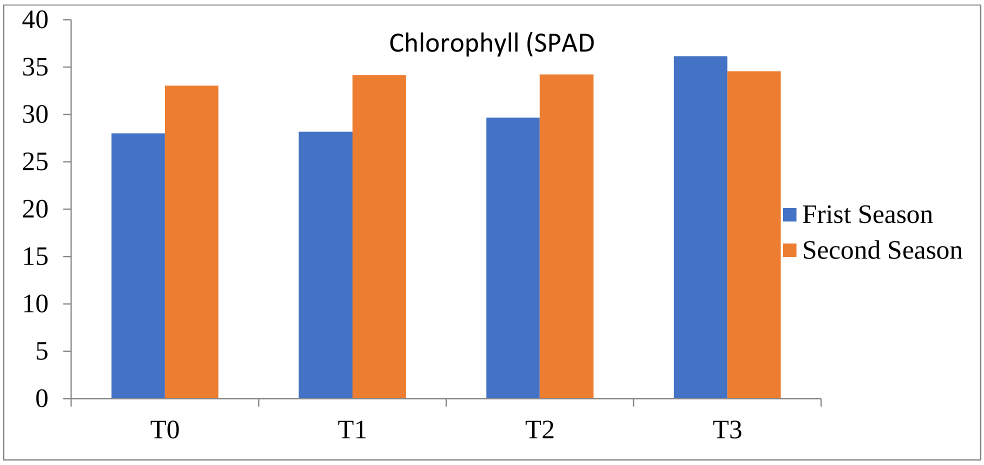


Figure (1): Effects of different organic nutrient solutions on Chlorophyll-content in leaves of lettuce growth in hydroponic during two seasons.

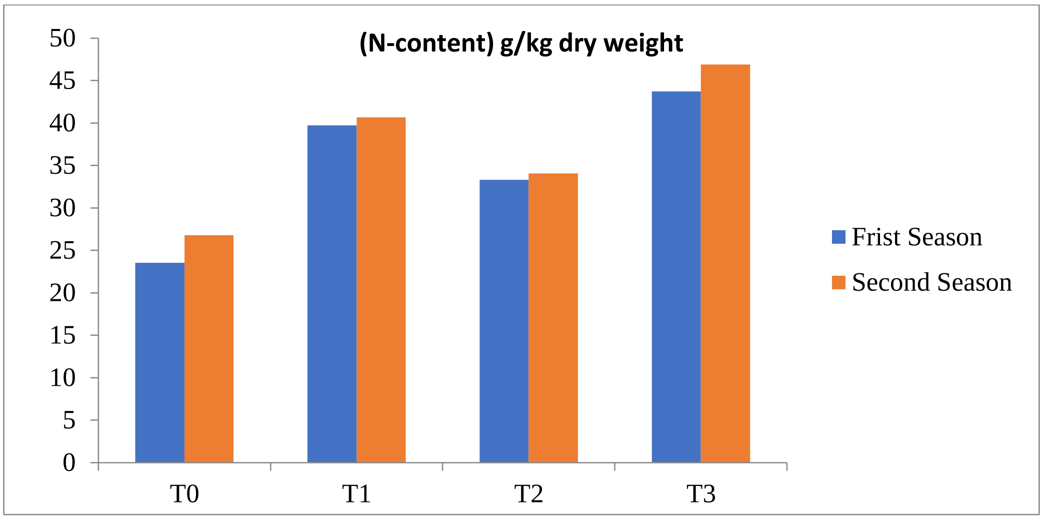
4.2. Nitrogen contents and nitrogen uptake of plants

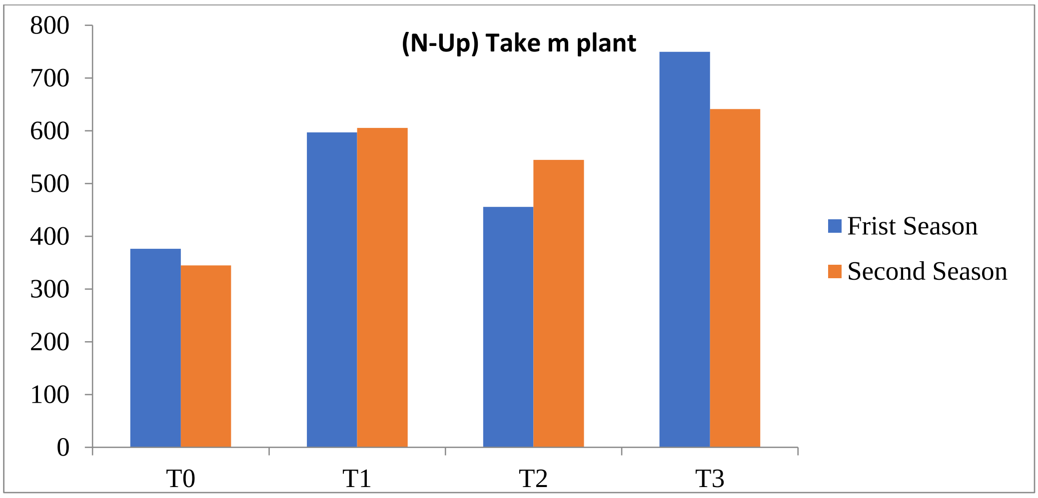
Nitrogen content and nitrogen uptake of lettuce plants showed significant increases by using all nutrient solutions treatments (Table, 4). In the first cycle, the highest values for N content and uptake of lettuce plants 43.73 g/kg dry weight and 749.77 mg/plant respectively, were obtained with using T_3 treatment (moringa leaf tea), with an increment of 85.85 % in the nitrogen content compared to T_0 mineral control treatment (Table, 4).

Table 4. Effects of different organic nutrient solutions on nitrogen content and uptake of lettuce plant growing in hydroponic during two growing cycle

Treatment	N-content (g/kg dry W.)		N-uptake (mg plant^{-1})	
	2023	2024	2023	2024
T_0	23.53^{c}	26.77^{b}	376.75^{c}	345.15^{c}
T_1	39.73^{ab}	40.67^{a}	597.23^{b}	605.62^{ab}
T_2	33.3^{b}	34.07^{ab}	455.7^{c}	545.25^{b}
T_3	43.73^{a}	46.90^{a}	749.7^{a}	641.66^{a}
LSD	5.42	9.48	78.63	65.02

T_0= Cooper nutrient solution, T_1 = compost tea, T_2 = Vermicompost tea and T_3=Moringa leaf tea.





The T_3 treatment recoded the hifhest values of N content (43.73 and 46.9 g/kg dry weight) and uptake (749.77 and 641.7 mg/plant), in both two growing cycles, Additionly, the data showed T_3 surpassing the control treatment by 85.85% and

99.0%, and 85.91%, in both two growing cycles, respectively.

5. Discussion

In this study, the obtained results showed the positive effects of all organic solutions treatment on shoot growth parameters and nitrogen contents and accumulation of lettuce plants compared to mineral solution treatment T_1. Result showed that Moringa leaf tea treatment and compost tea solution achieving the tallest plants in both season. This growth response can be attributed to the high nutritional potential of Moringa leaves, which contain essential macro elements such as magnesium (Mg), a key component of chlorophyll (Zaki and Rady, 2015). This suggests that the influence of Moringa leaf Tea (T_3) and compost tea (T_1) can lead to better lettuce growth and even to induce precocity in plant development. The also results indicate that Moringa leaf Tea and compost tea solution treatment consistently produced the highest biomass and strong performance. Fresh and dry biomass measurements reflected substantial growth improvements. These results corroborate findings by (Pahla *et al.,* 2013) and Umar (2014), which indicate that organic amendments can enhance vegetative growth and biomass accumulation in plants. The accompanying figure illustrates the nitrogen uptake across treatments. Moringa and compost treatments resulted in significantly higher nitrogen uptake compared to the control and vermicompost treatments, reinforcing the potential of organic nutrition to enhance nutrient absorption in hydroponically grown lettuce (Youssef and Abou kamer, 2019). Similar results have been recorded by Elsayed *et al.* (2023) they concluded that Moringa leaves serve as an effective nutrient source in hydroponic systems. Also, extracts from moringa leaves have demonstrated positive effects on plant growth and can be integrated into hydroponic systems as a foliar spray or nutrient solution (Elsayed *et al.,* 2023). Notably, moringa improves nitrogen use efficiency by supplying and enhancing nutrient uptake and reducing nitrate accumulation in plants, which is critical in hydroponic systems where precise nutrient management is essential (Mashamaite *et al.*, 2022). Also, these results are in with line with those of Adiaha, (2017) who observed that Moringa acts as a natural fertilizer, enriching the growing medium with essential nutrients. Its application has been shown to increase the availability of critical minerals such as nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg) in plants compared to untreated controls. He added that, the presence of various bioactive compounds, including vitamins, amino acids, and secondary metabolites, enhances physiological processes in plants, promoting better nutrient absorption and overall growth (Youssef and Abou kamer, 2019). Furthermore, phytohormones like auxins and cytokinins found in moringa play a crucial role in stimulating root development and improving nutrient translocation within the plant (Yuniati *et al.*, 2022). This dynamic not only directly provides essential nutrients to plants but also improves their overall nutrient status, facilitating better nitrogen uptake (Hanafy, 2017). Also, Elbl *et al.* (2014) reported that, compost plays a significant role in enhancing nitrogen (N) uptake and overall nutrient content in plants. It typically contains a mix of organic and inorganic nitrogen, with approximately 85-90% of total nitrogen being organic and 10-15% being inorganic and readily available to plants. Regarding to the application of vermicompost extracts; the results showed that all plant growth parameters significantly increased when the lettuce plants were treated with vermicompost extracts nutrient solution which had a positive effect on the growth and nutrient contents of lettuce and found to be in the third arrangement after Moringa leaf Tea solution and compost tea nutrient solution. Studies have shown that vermicompost can significantly enhance nitrogen levels, correlating positively with plant growth and productivity (Rehman *et al.,* 2023).

6. Conclusions

The results indicate that incorporating organic sources such as moringa leaf tea and compost tea solution significantly enhances the growth and nutritional quality of lettuce in hydroponic systems. These treatments lead to improvement in growth and product were the use of these organic amendments represents a sustainable approach to crop production, promoting higher growth and improved nutritional value while reducing reliance on chemical fertilizers and by optimizing their application, hydroponic systems can achieve better nutrient availability, improved plant growth, and a reduced environmental impact. These findings demonstrate that organic nutrition significantly enhances both nitrogen content and biomass production in hydroponically grown lettuce, suggesting a viable alternative to chemical fertilizers and emphasizing the potential benefits of using organic treatments for improving crop yield and quality.

Declarations

Authors' Contributions:

All authors are contributed in this research. All authors reviewed and approved the final manuscript.

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Data Availability Statement

Data presented in this study are available upon reasonable request from the corresponding author.

Ethics Approval and Consent to Participate:

Not applicable

Consent for Publication:

All authors of the manuscript have read and agreed to the publication that all authors have agreed to the submission to the journal.

Conflicts of Interest:

The authors disclosed no conflict of interest from the study's conduct, data analysis, and writing until the publication of this research work.

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