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Optimizing Organic Liquid Fertilizer for Hydroponic Grown-Leafy Vegetables

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Abstract
Organic fertilizers are gaining popularity due to health and environmental concerns; however, their use in hydroponic systems remains limited, primarily due to challenges in nutrient availability and microbial activity. This study aimed to optimize organic liquid fertilizer formulations for the hydroponic cultivation of Brassica juncea, using two systems: the Kratky and Nutrient Film Technique (NFT) systems. Four formulations were tested over a two-month period, assessing seven key growth and physiological parameters. In the Kratky system, formulation T3 yielded the highest plant weight (0.64 ± 0.05 g) and chlorophyll content (SPAD 46.10). In the NFT system, T2 and T3 showed superior plant height (23.50 ± 1.00 cm and 16.80 ± 3.02 cm, respectively). Overall, NFT outperformed Kratky, likely due to better oxygenation and nutrient flow, enhancing microbial activity and nutrient uptake. These results highlight that the performance of organic fertilizers is system-dependent and support the use of NFT for more efficient organic hydroponic farming.

Keywords: Organic liquid fertilizers, Hydroponic systems, *Brassica juncea*, Kratky method, NFT

Introduction
In recent years, increasing global food demand has placed immense pressure on agriculture, leading to the excessive use of chemical fertilizers and pesticides (Santos *et al*., 2012). This overuse has led to environmental pollution, particularly through the accumulation of nitrogen (N), phosphorus (P), and potassium (K) in soil and water, which threatens both ecosystems and human health (Bhardwaj *et al*., 2014). For instance, the continuous application of ammonium sulphate can reduce soil fertility by lowering soil pH, while excessive nitrogen and phosphate use may cause eutrophication and oxygen depletion, harming aquatic life. Since only 10–40% of fertilizers are absorbed by plants, a large portion is wasted, highlighting the need for integrated nutrient management through microbial inoculation to promote sustainability (Adesemoye *et al*., 2009).

Organic fertilizers, especially bio-fertilizers derived from animal waste and natural materials, offer a promising solution. These fertilizers support plant growth by enhancing soil fertility and microbial activity (Raja *et al*., 2013). Liquid bio-fertilizers are particularly advantageous as they improve nutrient content and have a longer shelf life compared to solid forms (Brar *et al*., 2012). Alongside this, hydroponics is emerging as an efficient and space-saving agricultural method that utilizes nutrient-rich water instead of soil. It enables precise nutrient and water management, supporting the year-round cultivation of crops such as leafy vegetables in Malaysia's tropical climate (Chow *et al*., 2017). Despite the popularity of chemical-based Cooper AB formulations in hydroponics, improper fertilization can still result in water pollution and reduced plant health (Fatahian *et al*., 2012; Kano *et al*., 2021). Therefore, integrating organic fertilizers into hydroponic systems could provide a sustainable and eco-friendly alternative (Reddy *et al*., 2010; Dubey *et al*., 2020).

However, organic fertilizer application in hydroponics faces several challenges, such as unpleasant odours, inconsistent nutrient composition, and limited research on their performance compared to chemical fertilizers. Moreover, organic fertilizers made from animal waste, such as chicken feces, are underutilized due to concerns about odour and handling. This study was conducted to explore the feasibility of using organic liquid fertilizers in hydroponics by formulating various mixtures using chicken dung, molasses, and microbial inoculants. The research aimed to determine the pH, electrical conductivity (EC), and available NPK values of each formulation to ensure balanced nutrient supply. Additionally, the study assessed the growth and yield of *Brassica juncea* cultivated with organic versus chemical fertilizers, focusing on plant height, biomass, and overall health.

The research was conducted using two hydroponic systems, Kratky and NFT and tested four different organic fertilizer formulations. The scope included chemical analysis of the nutrient solutions and assessment of plant growth parameters, such as plant height, leaf area, and biomass. While the study acknowledged limitations, such as variability in waste-based nutrients and microbial interactions, it provided practical insights into standardizing organic fertilizer use in hydroponics.

Overall, the findings of this research hold potential for transforming hydroponic farming by reducing reliance on synthetic inputs and promoting circular economy practices. Using organic fertilizers in hydroponics may reduce environmental impact, support organic certification, and enhance food security by providing a cleaner, more sustainable method of production (Gaikwad *et al*., 2022; Kannan *et al*., 2022). This research aims to contribute toward more resilient agricultural systems by aligning efficient crop cultivation with environmental stewardship.

Materials and methods

To assess the effectiveness of organic fertilizers, four distinct formulations were prepared and tested under controlled hydroponic conditions. These treatments included T1, which consisted of chicken dung combined with molasses alone; T2, which included chicken dung, molasses, and trypi; T3, containing chicken dung, molasses, and commercial Nitrobacter; and T4, which incorporated chicken dung, molasses, trypi, and commercial Nitrobacter. A liquid chemical fertilizer based on Cooper's formulation (Cooper, 1975) was used as the control. The preparation process began with the collection of chicken dung from local farms, followed by a decomposition stage where molasses was used as a sugar source to aid nutrient extraction. Each formulation was thoroughly mixed to ensure a consistent and balanced nutrient profile. As shown in Table 1, the ratio used in each formulation consisted of 120 grams of chicken dung, 80 millilitres of molasses, six grams of Trypi, one milligram of Nitrobacter and diluted in two litres of water. To ensure experimental reliability, each mixture was prepared in triplicate.

Table 1: Amount of ingredients in each formulation

Formulation	Chicken Dung (g)	Molasses (mL)	Trypi (g)	Commercial Nitrobacter (mg/L)
T1	120	80	0	0
T2	120	80	6	0
T3	120	80	0	1
T4	120	80	6	1

The formulation process began with the mixing of chicken dung and water in Schott bottles. Agitation helped separate solid particles, and after allowing the mixture to settle for 24 hours, filtration was performed repeatedly over the following days to remove residual impurities and obtain a purified solution. On the third day, molasses was added to the refined mixture until it turned a brownish-black colour, indicating sufficient sugar enrichment. The containers were then sealed to promote fermentation over several days. This step was essential for converting ammonia and extracting nutrients from organic materials. The final fermented organic liquid fertilizers were later used in hydroponic systems to test their effectiveness in promoting plant growth and yield (Fu et al., 2022).

To evaluate the formulated fertilizers, their pH, EC, and nutrient composition were measured. A pH meter was used to assess the acidity or alkalinity of each solution, ensuring compatibility with hydroponic systems. EC was measured using a conductivity meter to determine the concentration of dissolved salts and overall nutrient strength. Notably, a higher nitrogen-to-potassium ratio was observed to correspond with lower EC values, which reflect the total solute concentration without distinguishing individual nutrients. Nutrient analysis was conducted using standard laboratory methods to quantify the NPK contents, thereby helping to characterize the nutrient profiles of each fertilizer.

The hydroponic experiment was conducted to evaluate the growth and yield of *Brassica juncea* under both organic and chemical fertilization. Seeds from the Green World brand were germinated in seedling trays filled with peat moss and regularly watered to maintain optimal moisture. After two weeks, when the seedlings reached the four-leaf stage, they were considered ready for transplanting. Two hydroponic systems were employed in this study: the Kratky method and the NFT. These systems allowed for comparison between static and circulating nutrient delivery environments.

In the Kratky method, plants were grown in plastic containers measuring 16 cm in height, 18 cm in width, and 26 cm in length, each fitted with six holes for holding net pots. Approximately two liters of liquid fertilizer were added to each container, and the roots were partially submerged in the nutrient solution without any mechanical aeration. This passive system relied on gradual nutrient uptake and evaporation, allowing researchers to assess plant responses to a stable, non-circulating nutrient source.

Conversely, the NFT system consisted of five separate channels equipped with 24 Hygrow pots each, resulting in a total of 120 planting points. In this system, both organic and chemical nutrient solutions were circulated continuously using a solar-powered pump. This ensured a constant flow of oxygenated nutrient solutions to the plant roots, creating a dynamic environment for nutrient absorption. The experiment was conducted over a four-week period, with six replications for each treatment across both hydroponic systems. During this time, multiple growth parameters were monitored, including plant height, stem diameter, number of leaves, leaf length, leaf width, and total biomass. These data were recorded weekly to observe the developmental progress and health of the plants. Chlorophyll content was measured using a SPAD meter (Konica Minolta SPAD-502), which provided a non-destructive, quantitative assessment of chlorophyll levels, reflecting photosynthetic efficiency and plant health.

Statistical analysis was conducted using one-way Analysis of Variance (ANOVA) with a significance threshold of $p \leq 0.05$. Where significant differences were observed, Duncan's post-hoc test was employed to identify specific group differences. Pearson correlation analysis was also performed to examine relationships between variables, such as chlorophyll content and biomass. This comprehensive analytical approach provided valuable insights into the performance of organic fertilizer formulations and their potential as sustainable alternatives in hydroponic crop production.

Results and discussion

The evaluation of different organic fertilizer formulations revealed a range of chemical and agronomic outcomes aligned with the study's objectives. The variation in nutrient profiles among the treatments highlighted the influence of specific additives like trypi and commercial Nitrobacter. The base formulation using chicken dung and molasses (T1) served as a foundation, while the addition of nitrogen-enhancing additives in T2, T3, and T4 aimed to boost nutrient availability through enhanced microbial activity during fermentation.

According to Dalorima et al. (2021), chicken dung is known for its rich composition of macro- and microelements, including nitrogen, phosphorus, potassium, magnesium, zinc, and boron, making it a valuable agricultural input. Qualitative observations during fermentation indicated active microbial activity, as evidenced by colour changes and odour transformation, especially in T3 and T4. Wu *et al*. 2020) describe such shifts as signs of two-step nitrification, conversion from ammonia to nitrate, which plays a central role in nitrogen availability for plants. Ammonia, being highly soluble, is a common nitrogen source but requires microbial conversion to nitrate for optimal plant absorption (Tiwari *et al*., 2023; Shilpha *et al*., 2023). The fermentation process, enhanced by additives, appeared to promote this conversion while minimizing nitrogen loss (Shan *et al*., 2021). As such, the formulated fertilizers not only provided accessible nutrients but also offered an environmentally friendly alternative by reducing reliance on chemical nitrogen sources.

The analysis of pH, electrical conductivity (EC), and available NPK values in the formulated organic liquid fertilizers revealed that these fertilizers generally had optimal pH levels between 5.5 and

6.5 and adequate EC values, indicating a sufficient concentration of nutrients for hydroponically grown leafy vegetables.

Table 2 pH values for all formulations

Formulation	Day 3	Day 6	Day 7	Day 8
T1: chicken dung + molasses	6.07	5.21	5.37	5.49
T2: chicken dung + molasses + trypi	6.39	5.33	5.54	5.55
T3: chicken dung + molasses + Nitrobacter	6.16	5.23	5.43	5.51
T4: chicken dung + molasses + trypi + nitrobacter	6.24	5.18	5.38	5.54

As shown in Table 2, all treatments (T1 to T4) experienced a drop in pH by Day 6, which can be attributed to microbial conversion of ammonia into nitrate a process that releases acid (Bernal et al., 2009). The final pH ranged between 5.49 and 5.55, which falls within the ideal range for hydroponics. Maintaining this pH range is important because it directly affects the solubility and availability of nutrients. If the pH is too low or too high, it can cause nutrient imbalances for example, reduced availability of phosphorus, iron, and zinc or lead to aluminum toxicity under highly acidic conditions. An optimal pH ensures nutrients stay in plant-available forms, supporting healthy growth (Carmo et al., 2016).

Regarding electrical conductivity (EC), as shown in Table 3, all treatments recorded high EC values (above 9.0 mS/cm) by Day 8. Initially, EC levels were lower because microbial activity was still breaking down the nutrients. As the nitrification process progressed, more nitrate and salts were released, causing EC and salinity levels to rise. EC reflects the concentration of dissolved ions in the solution and is a key indicator of nutrient availability and potential salt stress (Mehboob et al., 2019). While low EC can indicate nutrient deficiency, excessively high EC typically above 3,500 µS/cm can lead to salt stress, nutrient imbalance, and root damage. In this study, the organic fertilizers were prepared as concentrated stock solutions, which were later diluted to bring EC levels down to safe and effective ranges for plant absorption.

In terms of plant growth under the Kratky system, as shown in Table 4, T3 and T1 showed the best overall growth performance. T3 recorded the highest average plant height (4.93 cm), which, though moderate, is notable given the use of organic inputs. Compared to studies using inorganic fertilizers like Trisnawati and Suparti (2023), who reported 14 cm with AB. It also had the thickest stem (1.45 mm), five leaves per plant, and the highest plant weight (0.65 g). Chlorophyll content under T3 was also the highest (46.10 SPAD), comparable to values from other organic fertilizer studies (Kano *et al*., 2021).

T1 also performed well, with the second-highest plant height (4.17 cm), the thickest stem (2.25 mm), and the highest number of leaves. However, despite its high NPK content, elevated sodium levels may have reduced its effectiveness, leading to slightly lower chlorophyll content and leaf weight compared to T3. Overall, T3 stood out as the most balanced and effective formulation, particularly for the Kratky system, where nutrient availability relies heavily on microbial activity and stable solution conditions.

Table 3 EC values for all formulations

Formulation	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8
T1: chicken dung + molasses	9.625	9.681	9.348	9.184	9.656	9.217
T2: chicken dung + molasses + trypi	0.036	4.850	9.596	6.418	9.535	9.338
T3: chicken dung + molasses + Nitrobacter	6.598	9.121	9.596	9.797	9.515	9.260
T4: chicken dung + molasses + trypi + Nitrobacter	0.016	8.770	9.596	9.555	9.651	9.083

Table 4 Mean comparison of plant growth and yield for each formulation in the Kratky method

Parameters	Height (cm)	Stem Diameter (mm)	No of Leaves	Leaf Length (cm)	Leaf Width (cm)	Weight (g)	Chlorophyll content (SPAD)
T1	4.17 ± 0.07[c]	2.25 ± 0.19[b]	5.33 ± 1.20[b]	3.14 ± 0.03[b]	1.70 ± 0.15[c]	0.64 ± 0.05[b]	44.33 ± 0.56[a]
T2	3.00 ± 0.11[d]	2.12 ± 0.24[b]	5.00 ± 1.00[b]	3.54 ± 0.24[b]	1.77 ± 0.12[c]	0.71 ± 0.01[b]	43.87 ± 0.52[a]
T3	4.93 ± 0.31[b]	1.45 ± 0.18[c]	4.67 ± 1.20[b]	2.19 ± 0.08[c]	2.53 ± 0.24[b]	0.65 ± 0.04[b]	46.10 ± 2.07[a]
T4	2.00 ± 1.00[d]	1.31 ± 0.06[c]	2.00 ± 1.00[b]	2.34 ± 0.29[c]	1.31 ± 0.06[c]	0.33 ± 0.02[b]	11.40 ± 11.40[b]
AB fertilizer	12.20 ± 0.10[a]	7.67 ± 0.16[a]	18.00 ± 1.15[a]	10.18 ± 0.92[a]	7.17 ± 0.03[a]	33.26 ± 0.02[a]	46.00 ± 1.96[a]

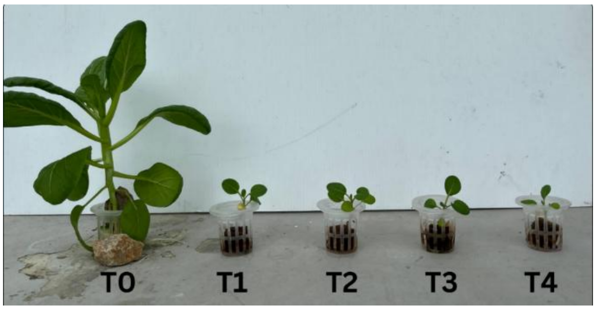

Figure 1 The plant growth performance in the Kratky method

In the NFT system, plant growth was more vigorous overall due to continuous oxygen and nutrient delivery As shown in Table 5, T2 performed best under the NFT system, producing the tallest plants (23.50 cm), the highest leaf count (16), and the greatest leaf weight (41.49 g). Its chlorophyll content (37.93 SPAD) reflected good photosynthetic activity, though slightly lower than other studies using higher-nitrogen inputs. These results suggest that T2 provided a well-balanced nutrient supply, supporting strong vegetative growth. T3 also showed solid performance, with the longest leaves (11.43 cm), thickest stem, and high chlorophyll content (41.40 SPAD). Although it had fewer leaves and slightly lower biomass than T2, it still indicated healthy growth and good nutrient uptake. In contrast, T1 recorded the weakest results, shortest plant height, lowest leaf weight (19.67 g), and the lowest chlorophyll content (35.63 SPAD) despite having the highest NPK levels. This suggests nutrient imbalances, such as high sodium, may have hindered plant health in the NFT system.

Figure 2 The plant growth performance in the NFT method

These findings mirror those of Phibunwatthanawong et al. (2019), who noted strong vegetative outcomes with organic treatments in lettuce. T3 also performed well in NFT, particularly in leaf length and stem diameter. Conversely, T1 performed the weakest, despite its high NPK value. This anomaly may be explained by salt imbalances or pH-related nutrient lockout (Qadeer *et al.*, 2019).

The overall contrast between Kratky and NFT methods can be explained by their differing nutrient dynamics. In static systems like Kratky, nutrient uptake depends heavily on microbial activity and oxygen availability. As Jones (2005) suggests, stagnant conditions may limit nutrient mineralization and lead to sediment accumulation, negatively impacting plant development. In contrast, the NFT's circulation ensures stable oxygen levels and continuous nutrient supply, mitigating such issues (Fu *et al.*, 2022). This was confirmed by the one-way ANOVA results (Table 6). In the Kratky method, significant differences were found across all growth parameters, indicating that fertilizer composition played a substantial role. In the NFT system (Table 7), however, not all parameters showed significant variation. Leaf count and chlorophyll content did not differ significantly among treatments, likely due to the system's efficiency in nutrient delivery, buffering minor formulation differences. This finding is consistent with previous studies, such as Kano *et al*. (2021), who noted stable chlorophyll levels across treatments in dynamic hydroponic systems.

Table 5 Mean comparison of plant growth and yield for each formulation in the NFT method

Parameters	Height (cm)	Stem Diameter (mm)	No of Leaves	Leaf Length (cm)	Leaf Width (cm)	Weight (g)	Chlorophyll content (SPAD)
T1	9.83 ± 0.20[c]	10.77 ± 0.92[b]	11.67 ± 0.88[a]	8.33 ± 0.23[c]	7.27 ± 0.82[b]	19.67 ± 0.76[d]	35.63 ± 1.95[a]
T2	23.50 ± 1.00[a]	9.63 ± 0.26[b]	16.33 ± 2.85[a]	10.50 ± 0.46[abc]	6.70 ± 0.15[b]	41.49 ± 5.58[b]	37.93 ± 1.67[a]
T3	16.80 ± 3.02[b]	10.60 ± 0.31[b]	12.00 ± 0.58[a]	11.43 ± 1.12[ab]	7.80 ± 0.69[b]	32.54 ± 3.07[bc]	41.40 ± 2.65[a]
T4	19.83 ± 0.55[a]	9.50 ± 1.01[b]	13.33 ± 0.67[a]	9.57 ± 0.15[bc]	6.57 ± 0.07[b]	26.58 ± 2.42[cd]	39.07 ± 2.28[a]
AB fertilizer	24.47 ± 1.24[a]	17.87 ± 0.54[a]	15.67 ± 1.76[a]	12.43 ± 1.34[a]	9.77 ± 0.07[a]	118.76 ± 2.93[a]	38.70 ± 1.42[a]

Table 6 One-Way ANOVA Interaction among fertilizer treatment cultivated using the Kratky method

Source of Variation	df	Height (cm)	Stem Diameter (mm)	No of Leaves	Leaf Length (cm)	Leaf Width (cm)	Weight (g)	Chlorophyll content (SPAD)
Treatments	4	48.963**	21.325**	118.667**	33.620**	17.729**	640.889**	683.341*
Error	10	0.671	0.093	3.733	0.095	0.060	0.145	83.185

Note:*significant at 0.05 probability level, **significant at 0.01 probability level, ns not significant

Table 7 One-Way ANOVA Interaction among fertilizer treatment cultivated using the NFT method

Source of Variation	df	Height (cm)	Stem Diameter (mm)	No of Leaves	Leaf Length (cm)	Leaf Width (cm)	Weight (g)	Chlorophyll content (SPAD)
Treatments	4	104.724**	36.912**	13.433ns	7.623*	5.041**	4912.405**	12.974ns
Error	10	7.190	1.382	7.467	1.999	0.742	33.373	12.496

Note:*significant at 0.05 probability level, **significant at 0.01 probability level, ns not significant

Conclusion

In conclusion, this study successfully achieved its objectives in formulating and evaluating organic liquid fertilizers for hydroponically grown leafy vegetables. The organic fertilizers, developed using a combination of chicken dung, molasses, and microbial additives such as Trypi and Nitrobacter, demonstrated their suitability for hydroponic applications. This formulation process highlights the potential of converting agricultural waste into value-added, nutrient-rich liquid fertilizers, offering a more sustainable and environmentally friendly alternative to synthetic fertilizers. Among the treatments, T3 and T4 stood out by producing noticeably less odor after fermentation, which indicated more efficient microbial activity and a more complete breakdown of organic material. This improvement in odor and clarity of the solution suggests a healthy fermentation phase, typically occurring within one to two weeks, during which beneficial microbes help transform ammonia into plant-available nitrogen forms like nitrite and nitrate.

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