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RESEARCH ARTICLE

Effect of Liquid Organic Fertiliser Produced from Organic and Fish Wastes on the Growth and Yield of Tomato

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ABSTRACT

The use of inorganic fertilisers poses significant environmental and public health risks. This study evaluated the effects of liquid organic fertilisers (LOFs) produced from waste materials, including fish waste, molasses, wood ash, cow dung, goat manure, cow urine, poultry manure, rice bran, and nitrogen-rich plants, on the growth and yield of tomato plants. Four LOF formulations were prepared by combining fish waste with various plant materials (Gliricidia sepium, Sesbania grandiflora, Leucaena leucocephala, Tithonia diversifolia) and agricultural byproducts (goat manure, cow urine, poultry manure, rice bran). The experiment was conducted in a protected house using a completely randomised design (CRD) with five treatments evaluated: a control (Albert's solution; T0) and four organic formulations (T1–T4) comprising fish waste, wood ash, molasses, and cow dung, each supplemented with different plant residues and organic amendments—Gliricidia sepium with goat manure (T1), Sesbania grandiflora with cow urine (T2), Leucaena leucocephala with poultry manure (T3), and Tithonia diversifolia with rice bran (T4) with each treatment having six replicates. Growth parameters recorded included plant height, number of leaves, number of branches, number of flowers, flowering time, dry weight, number of fruits, and total yield. Results showed that T0 (Albert's solution) achieved the highest growth and yield. Among the LOFs, T1 (fish waste, wood ash, molasses, cow dung, Gliricidia sepium, and goat manure) demonstrated growth performance comparable to T0. However, fruit number and yield in T1 were significantly lower than T0. The highest average yield per plant was recorded in T0 (1796.8 g), followed by T1 (1246.3 g), representing approximately a 30% reduction compared to the control. These findings indicate the potential for developing LOFs that perform similarly to Albert's solution using the raw materials in T1. Future research should focus on optimising the composition of T1-based LOFs to achieve yields closer to those of conventional fertilisers, thereby supporting sustainable tomato cultivation.

Keywords*: Fish waste, Organic farming, Liquid organic fertiliser, Tomato, Yield*

INTRODUCTION

Organic food production is a more sustainable agricultural practice that produces food of improved quality while safeguarding the environment and human health, as opposed to inorganic farming (Narmilan and Amuthenie, 2015). The use of chemical fertilisers in agriculture is one of the major threats to the environment and a significant contributor to the accumulation of inorganic pollutants in the soil, water, air, and even plants, thereby posing negative impacts on human health (Savci, 2012). In agricultural areas, chemical fertilisers became widely used after the green revolution. Large amounts of chemical fertilisers have been shown to present substantial dangers to society, including environmental pollution (Sharma and Singhvi, 2017). In order to maintain agricultural output throughout time, it is essential to promote the use of organic fertilisers and reduce the reliance on synthetic fertilisers to safeguard both human health and the environment.

Both the total population and the daily needs of people have increased significantly after the Industrial Revolution. Industrial processes designed to meet human needs have led to the emergence of large commercial enterprises. Among these, the fishing industry has developed into a major part of the global market (Aranganathan and Radhika, 2016). Fish is regarded as a nitrogen-rich food because it makes up around 65% of animal protein consumption and has the capacity to provide protein. The seafood and aquaculture industries of Sri Lanka are key sectors with distinctive cultural value, yielding about 410,760 metric tons of fish in 2023, mainly from inland, marine, and aquaculture (EDB, 2025). A considerable quantity of fish waste is generated in these industries, creating disposal challenges and associated costs. According to Ahuja *et al.* (2020), the generation of fish waste varies with the level of processing, ranging from 30–10% of the original fish. Therefore, a substantial amount of fish waste is expected to be generated in Sri Lanka.

The improper disposal of fish waste, such as illegal open dumping, can cause environmental problems, including the generation of methane and other harmful gases, contamination of soil, surface water, and groundwater, and disturbance of natural ecological balance (Aranganathan and Radhika, 2016; Sahu *et al.*, 2016). However, fish waste is rich in beneficial minerals, enzymes, and nutrients. Moreover, it is a source of high-quality protein, which can contribute to increasing the Nitrogen content of organic fertiliser produced from the waste (Ahuja *et al.*, 2020). Therefore, converting fish waste into organic liquid fertiliser for crop production has enormous potential to improve both the yield quantity and quality. According to Shaji *et al.* (2021), the organic fertiliser produced from fish waste exhibits the slow-release nature of nutrients with non-toxic properties, which help increase the nutrient use efficiency of the crops. Therefore, it is important to investigate the use of fish waste in the production of organic fertiliser, in combination with other agricultural byproducts, to determine whether it can enhance the quality of the fertiliser.

In this study, we attempted to: (1) produce an organic liquid fertiliser from fish waste mixed with different organic substrates, (2) analyse selected nutrients in the produced liquid organic fertiliser, and (3) determine the effects of organic liquid fertiliser on tomato crop growth and yield.

MATERIALS AND METHODS

Preparation of liquid organic fertiliser

A total of 2 kg of fish waste was collected from the local fish market (Kamburupitiya, Matara). The collected waste was ground into small parts, including fish bones, heads, guts, viscera, scales, and fins, and added to a 25 L plastic container. Subsequently, 1 kg of molasses, wood ash, cow dung, leaves (*Gliricidia sepium, Sesbania grandiflora, Leucaena leucocephala,* and *Tithonia diversifolia*), animal excreta (goat manure, cow urine, poultry manure) and, rice bran were added separately according to the treatments (Table 1). The contents of the container were thoroughly mixed and supplemented with clean water until they were completely submerged. The container was then sealed with a lid and maintained under anaerobic conditions for 14 days. Cow dung served as the source of inoculum for the anaerobic digestion process. After 14 days, 1 kg of molasses was added again, and the mixture was stirred properly before being left to ferment for an additional 7 days. At the end of 21 days, the mixture was filtered and used as a liquid fertiliser. The final product of LOF was stored in a dark and cool environment in the refrigerator until use.

Table 1: Composition of the control and treatment formulations with corresponding quantities of raw materials used

Treatments	Different materials
T0	Albert's Solution (Control)
T1	Fish waste (2 kg)+Wood ash (1 kg)+Molasses (2 kg)+Cow dung (1 kg)+*Gliricidia sepium* (1 kg)+Goat manure (1 kg)
T2	Fish waste (2 kg)+Wood ash (1 kg)+Molasses (2 kg)+Cow dung (1 kg)+*Sesbania grandiflora* (1 kg)+Cow urine (1 kg)
T3	Fish waste (2 kg)+Wood ash (1 kg)+Molasses (2 kg)+Cow dung (1 kg)+*Leucaena leucocephala* (1 kg)+Poultry manure (1 kg)
T4	Fish waste (2 kg)+Wood ash (1 kg)+Molasses (2 kg)+Cow dung (1 kg)+*Tithonia diversifolia* (1 kg)+Rice bran (1 kg)

The prescribed dose (10 g diluted in 4.5 L of water) of commercially available Albert's solution was used as the control treatment in the field evaluation of the LOF on tomato plants (Iqram and Seran, 2016).

Field experiments

The seeds of Thilina variety of tomato (certified by the Department of Agriculture in Sri Lanka) were used as the planting material in this study. Seeds were sown in a plastic tray filled with potting soil and irrigated daily. After 15 days, when the seedlings were mature enough, they were transferred to experimental polythene bags. No fertiliser was applied during this stage.

Seedlings were transferred into polythene bags (pots) within the protected house 15 days after sowing. Each pot contained one tomato seedling, and plants of the same age and size were chosen for transplantation.

The field experiment was conducted in a protected house (20×10 ft) located in the Low Country Wet Zone at the Faculty of Agriculture, University of Ruhuna, Sri Lanka (~6.060337° N latitude and 80.568148° E longitude) as a pot trial to evaluate the effect of LOF on the growth and development of tomato plants. A Completely Randomised Design (CRD) with six replications was employed. Five treatments were tested, consisting of four different liquid organic fertilisers and Albert's solution as the control, resulting in a total of thirty experimental units. Pots were arranged with 80×50 cm spacing. Polythene bags (20 cm diameter, 25 cm height) were used as pots and filled with a 1:1:1 mixture of topsoil, compost, and coir dust.

Fertiliser applications commenced after three days of transplanting and continued until the last harvest (Peiris and Weerakkody, 2015). LOF was applied to the soil of the pots twice per week, in the morning and afternoon. A total of 100 mL of fertiliser solution was applied per plant. For Albert's solution, 10 g was diluted in 4.5 L of water, and 100 mL of this solution was applied per plant (Tiwari *et al.*, 2023). To protect the crop from pest and disease attacks, Abamectin was used at recommended doses for the control of trips, mites, and aphids (Li *et al.*, 2020). The leaf curl complex caused by the fungi was managed with recommended fungicides (Captan, Chlorothalonil) (Dhananjani and Pakeerathan, 2023). The pesticide used for the control of pests and diseases was sprayed on all plants in the protected house to maintain similar treatments.

Data collection started five weeks after planting and continued weekly until the final harvest. The measured plant growth and yield parameters included plant height (cm), number of leaves, number of branches, days to first flowering, number of flowers per plant, number of fruits per plant, fruit weight per plant, and dry weight per plant.

Determination of the chemical and physical properties of the soil and fertiliser

Nitrogen (N), phosphorus (P), and potassium (K) contents were analysed to determine the nutrient composition of the LOF and soil. The nitrogen content of the soil and liquid fertiliser was determined using the Micro Kjeldahl method (Gunapala and Abeysingha, 2019). The phosphorus content of the LOF was determined using the Ascorbic acid method (Po *et al.*, 2018), whereas the plant available phosphorus content of the soil was ascertained using the Olsen method (Horta and Torrent, 2007). Potassium concentration in both the LOF and soil was determined using the flame photometric method (Po *et al.*, 2018). The pH and electrical conductivity of LOF and the soil were measured using a pH meter (HANNA-HI 98127) and an electrical conductivity meter (HANNA-HI 98130), respectively (Benhachem *et al.*, 2022; Machado *et al.*, 2021;

Mylavarapu *et al.*, 2020). Data were analysed using the IBM SPSS Statistics 25 software.

RESULTS AND DISCUSSION

Soil analysis

The soil was tested before transplanting the plants, and the results of the nitrogen, phosphorus, potassium contents, the pH and electrical conductivity (EC) of the soil are shown in Table 2. Some of the previous similar studies have shown that the high nutrient contents in the initial soil, while almost similar results for pH and EC (Sopha *et al.*, 2020). According to the data gathered, the nutrient content of the soil is comparatively low. Nitrogen, phosphorus, and potassium are major plant nutrients, of which nitrogen is regarded as an essential component of all proteins and enzymes and further participates in various metabolic processes of energy transformation, while phosphorus is involved in most growth processes and is an essential component of most organic compounds in the plant, including nucleic acids, proteins, phospholipids, sugar phosphates, enzymes, and energy-rich phosphate compounds, and potassium (K) plays an important role in many physiological processes vital to plant nutrient and water uptake, nutrient transport, and growth, especially under adverse conditions (Zewide and Reta, 2021). Soil pH and electrical conductivity (EC) are also important chemical indicators of soil health, as they directly influence nutrient availability and a plant's ability to absorb water. Maintaining these factors within optimal ranges is vital for crop growth and yield (Usha and Pandya, 2015). Although these factors can vary considerably depending on soil type, they are of less importance in this study, as the nutrients required for crop growth and development were supplied by the liquid organic fertiliser (LOF).

Table 2: Nitrogen, phosphorus, and potassium contents, electrical conductivity (EC), and pH of the soil

Nutrients	Values (±Standard error)
Nitrogen	0.183% (±0.06)
Phosphorous	0.005% (±0.0002)
Potassium	0.038% (±0.001)
pH (29.3°C)	5.6 (±0.98)
EC (mS/cm) (29.3°C)	0.01 (±0.001)

Nutrient content of the liquid organic fertiliser

The Nitrogen (N), phosphorus (P), and potassium (K) contents of the produced LOF are shown in Table 3. According to the SLSI standard 1702:2021, the minimum required concentration of N, P, and K in liquid fertilisers are 1%, 0.5%, and 0.5% w/w, respectively (SLS, 2021). The nitrogen content of the LOF from all treatments exceeded the minimum requirement, likely due to the use of nitrogen-rich raw materials. However, since the fish waste was used as the primary P source, wood ash as the K source, the P and K content in the produced LOF in all treatments failed to meet the minimum requirements. The phosphorus content of most fish waste varies (0.1–0.5%) considerably, depending on the types of fish species (Palani *et al*, 2014). The relatively low quantity of P in the LOF produced in this study is attributed to the limited P quantities in the fish waste used. Nevertheless, fish wastes have been suggested and frequently utilised as a potential P source in the production of organic fertilisers (Ariyawansa and Arachchi, 2013). A higher P content can be expected when larger proportions of fish bones are used in the production of LOF. However, in this study, a mixture of fish wastes was used without particular attention to special components of the fish wastes, such as bones. The primary source of potassium in the production of LOF in this study was wood ash, which is frequently used as a K source (Ranasinghe *et al.*, 2021). However, the minimum required K (0.5%) content was not achieved in the LOFs produced by any of the treatments. This shortfall may be primarily attributed to the insufficient amount of wood ash used as the source of K in this study.

Table 3: Nitrogen, phosphorus, and potassium contents, and pH and electrical conductivity (EC) in the liquid organic fertilisers

Nutrient elements	T1	T2	T3	T4
N (%)	1.86 (±0.98)	1.49 (±0.16)	1.26 (±0.12)	1.31 (±0.13)
P (%)	0.08 (±0.002)	0.03 (±0.001)	0.04 (±0.001)	0.03 (±0.001)
K (%)	0.34 (±0.08)	0.29 (±0.006)	0.25 (±0.005)	0.24 (±0.004)
pH	6.7 (±0.07)	6.5 (±0.03)	7.1 (±0.10)	6.8 (±0.07)
EC (dS/m)	15.44 (±0.96)	20.00 (±1.26)	15.06 (±1.24)	15.68 (±1.28)

Standard errors (SE) are shown in parentheses for all values

pH and electrical conductivity (EC) of liquid organic fertilisers

According to the Sri Lankan standard 1702:2021, the accepted pH range for LOF is 6.0 to 8.5, while the EC should be less than 20 mS/cm (SLS, 2021). The values of those parameters in all produced LOF are within the recommended limit (Table 3). Within this pH range, the nutrients in liquid fertilisers remain soluble and available for plant absorption. If the pH is too high or too low, the nutrient availability of plants can be reduced, leading to a deficiency of nutrients and reducing plant growth (Peiris and Weerakkody, 2015). The electrical conductivity (EC) of liquid fertilisers reflects the concentration of dissolved salts in the solution. The optimal EC level depends on the growing environment and the specific requirements of the growing plants. However, for most crops, the EC should be around 20 mS/cm or slightly lower (Phibunwatthanawong and Riddech, 2019). It is important to note that different crops have varying pH and EC needs, which may also change depending on the growth stages of the plant (Sharma *et al.*, 2025).

Effect of treatments on the average height of the tomato

Figure 1 illustrates the changes in plant height under the different treatments during the study period. The Albert solution contains 10.6% N, 9.3% P, 16.3% K, and other micronutrients (Tiwari *et al.*, 2023), which are higher than the concentration found in the LOF produced in this study. As a result, treatment T0 recorded the highest average plant height (118.73±4.48 cm), whereas T4 showed the lowest (Figure 1b). The average plant height under T1 was 105.68±3.67 cm, which was slightly lower than that of T0. However, there was no significant difference in plant height between T0 and T1.

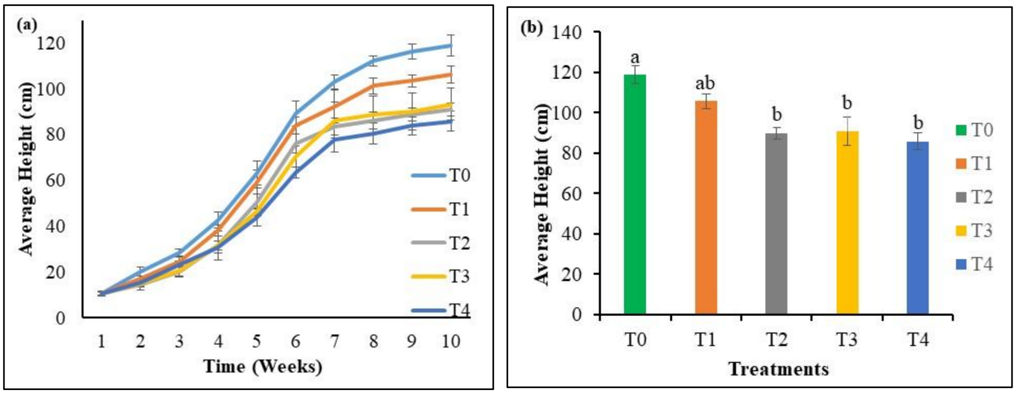

Figure 1: (a) Plant height of tomato over the study period and (b) plant height at the tenth week under different liquid organic fertiliser treatments. The bars with different letters indicate significant differences among the treatments at p=0.05

The plant height under T0 differed significantly from T2, T3, and T4, while there was no significant difference noted among the last three treatments. The similarity in the contents of nutrients in T2, T3, and T4 likely contributed to their lower plant height compared with T0 and T1 treatments.

These findings suggest that the height of tomato plants can benefit from the application of LOFs, providing vital nutrients in readily available form, supporting the rapid growth. Plant height is influenced not only by the type and rate of LOF applied but also by plant genetics, environmental conditions, and general plant management practices (Tripodi *et al.*, 2022).

Organic liquid fertilisers can help maximise nutrient availability in the soil when applied appropriately, thereby fostering healthier tomato plants that often attain greater average height. Studies of organic fertiliser use (including liquid forms) have shown improved growth parameters in many crops, including plant height, as a result of enhanced nutrient supply and soil conditions (Liu *et al.*, 2024). Nitrogen is especially critical for promoting vegetative (leafy) growth, which often correlates with increased plant height. Organic fertilisers typically release nitrogen more gradually than synthetic (mineral) fertilisers, providing a stable supply of nitrogen over time, which supports sustained growth. The differential release and mineralisation dynamics of organic nitrogen sources compared to synthetic forms have been documented (Dion *et al.*, 2020). Beyond nutrient supply alone, organic liquid fertilisers improve soil structure and stimulate microbial activity (including greater biomass and enzymatic activity). These changes in the soil environment enhance the plant's ability to absorb and utilise nutrients (Saikia *et al.*, 2015). By supporting improved nutrient uptake efficiencies, these biological and physical soil modifications may further contribute to increases in plant height and overall yield (Pan *et al.*, 2025).

One possible explanation for the good performance of T1 is that its nutrient solution provided a more balanced mix of macronutrients and micronutrients required for healthy tomato growth. In contrast, alternative LOFs (T2, T3, and T4) may not have contained all the necessary nutrients, resulting in suboptimal growth (Ali *et al.*, 2013). Furthermore, the favourable pH and EC level of the nutrient solution in T1 may have facilitated more efficient nutrient absorption by the plants, thereby supporting better growth (Palani, 2014).

Effect of treatments on the average number of leaves of the tomato

The average number of leaves of tomato plants varied among different treatments (Figure 2). The results of this study indicate that the five treatments influenced the average number of leaves of tomato plants. T0 recorded the highest average number of leaves, suggesting it was the most effective treatment for promoting leaf growth. However, there was no significant difference in leaves between T0 and T1 ($p<0.05$).

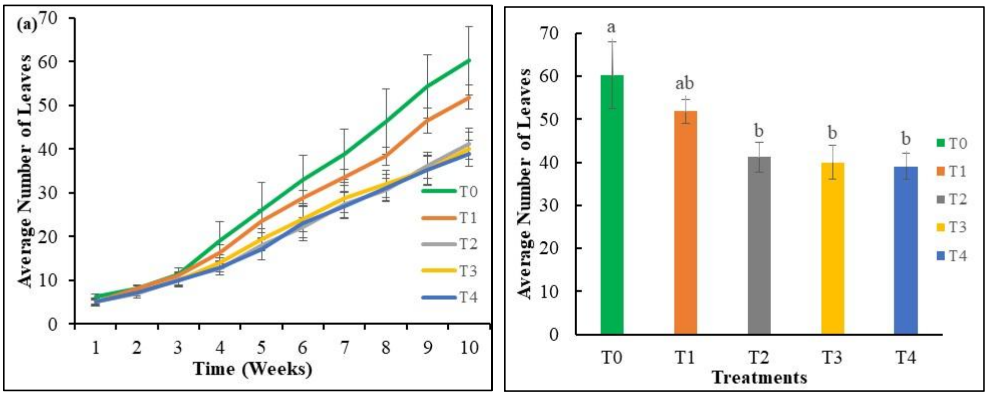

Figure 2: (a) Number of leaves of the tomato plants over the growth period and (b) number of leaves at the tenth week under different liquid organic fertiliser applications. The bars with different letters indicate significant differences among the treatments at $p=0.05$

Treatment four (T4) produced fewer leaves compared with the treatments and the control (Figure 2b), though no significant difference in the number of leaves was observed among the four treatments, where LOFs were applied (T1–T4). A possible explanation for these results is that T0 supplied tomato plants with a more balanced nutrient composition and favourable conditions, resulting in optimal leaf growth.

T1 may have been slightly less effective than T0 because it lacked some of the nutrients or conditions provided by the control treatment. This could be attributed to the rapid absorption and assimilation of macro and micronutrients present in Albert's solution, while the LOF (T1) may have enhanced metabolic activity, resulting in a relatively high number of leaves. Nitrogen, in particular, plays a key role in stimulating vegetative plant growth, including an increase in plant height and number of leaves (Ramesh *et a*l., 2020). The other treatments appear less effective, likely due to an even greater deficiency of these essential nutrients or unfavourable conditions. Previous studies have also demonstrated that organic fertilisers can influence tomato growth, with higher nitrogen contents being associated with improved vegetative growth (Lakmini *et al*., 2012).

Effect of treatments on average number of branches of the tomato

The results showed that tomato plants in T0 had a significantly higher average number of branches compared with other treatments ($p<0.05$; Figure 3).

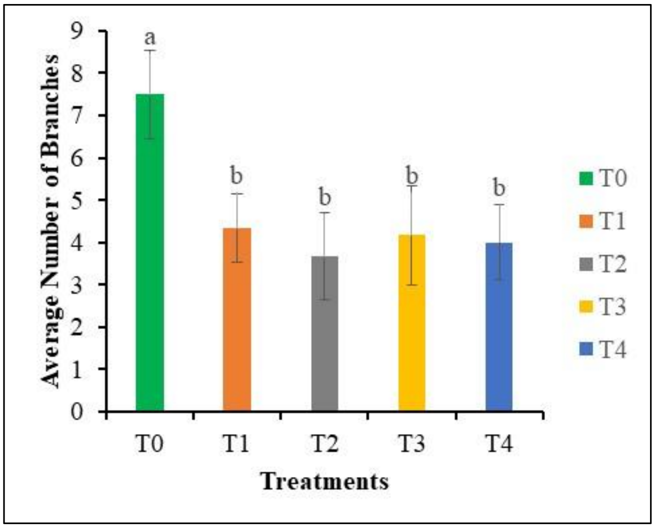

Figure 3: Average number of branches at the tenth week under different liquid organic fertilisers. The bars with different letters indicate significant differences among the treatments at $p=0.05$

The lowest number of branches was recorded from T2 (Figure 3); however, no significant difference in the number of branches among treatments with LOFs was observed (T1–T4), indicating a similar performance in terms of branch development in tomato plants. Micronutrients, particularly zinc (Zn) and boron (B) play a key role in the development of branches in tomato plants (Tiwari *et* *al.*, 2023). The lower number of branches of tomato plants treated with LOFs compared to the control may be due to the insufficient level of these micronutrients, especially Zn and B, in the LOFs.

Effect of treatments on time to first flowering in tomato plants

The time to first flowering under different treatments is presented in Figure 4. The longest period for first flowering (~54 days) was recorded in T4, while the shortest was observed in T0 (~36 days). The delayed flowering under T4 may be attributed to lower nutrient availability. Remarkably, no significant difference was found between T0 and T1 treatments in terms of flowering time (Figure 4). Similar to the plant height, number of leaves, and number of branches, no significant difference in flowering time was observed among the LOFs treatments (T1–T4; $p<0.05$).

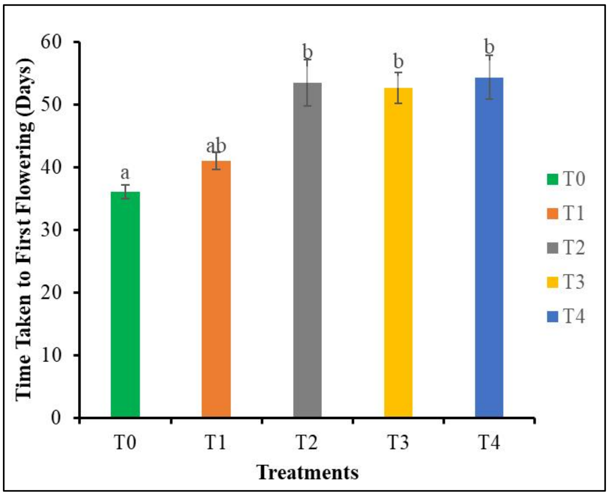

Figure 4: Number of days to the first flowering in tomato plants under different liquid organic fertiliser treatments. The bars with different letters indicate significant differences among the treatments at $p=0.05$

The effectiveness of LOFs and their impact on flowering time can vary depending on several factors, including plant species, fertiliser formulation, application rate, and overall growing conditions (Ye *et al.*, 2019). LOFs can promote earlier flowering when they supply sufficient nutrients; conversely, nutrient deficiencies can delay flowering and fruiting. In tomato crops, growth parameters such as plant height, number of leaves, leaf area, and stem diameter were reported to be lower under organic fertiliser application compared with inorganic fertilisers (Adekiya *et al.*, 2022). The same study also found that mineral content in tomato fruits was lower with organic fertilisers, likely due to slower nutrient release, lower availability, and reduced uptake compared with inorganic fertilisers. Therefore, the lower nutrient content of the LOFs produced in this study, relative to Albert's solution, may explain the extended time to first flowering. Adequate nutrient supply, in contrast, can encourage early flowering and fruit development.

Effect of treatments on the average number of flowers in tomato plants

The average number of flowers per plant was recorded, and the counts at the end of the tenth week are shown in Figure 5. No significant differences were found among T2, T3, and T4 treatments. T0 produced the highest average number of flowers (~45) while T3 had the lowest (~25). Although T1 (~35) resulted in fewer flowers than T0 (~45), the difference was not statistically significant ($p<0.05$). The results indicate that T0 had the greatest positive effect on flower development, likely balancing nutrient composition, which provided favourable conditions for tomato growth. T1 also positively influenced the number of flowers, suggesting that this LOF treatment can be beneficial for tomato plants.

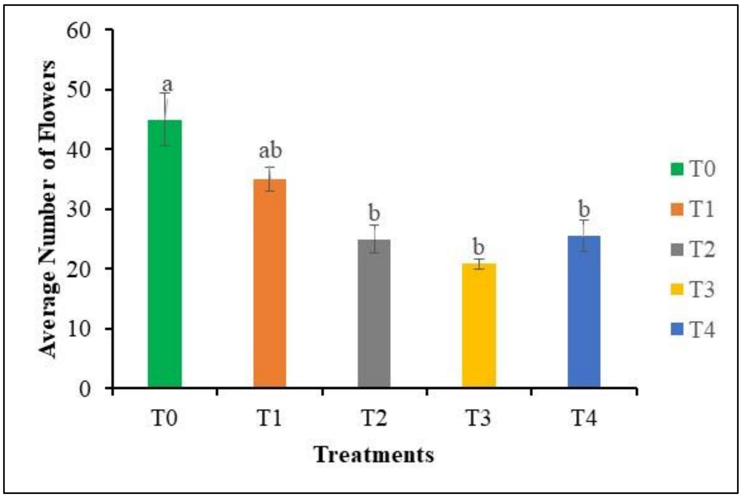

Figure 5: Effect of different liquid organic fertilisers on the number of flowers in tomato. The bars with different letters indicate significant differences among the treatments at p=0.05

The observed outcomes may vary depending on factors such as the type of organic fertiliser, application methods, nutrient content, and overall growth conditions (Kalbani *et al*., 2016). Overall, among the produced LOFs, T1 appears to be the most effective for enhancing the average number of flowers in tomato plants. Further research is suggested to identify the specific factors contributing to these effects and to assess their long-term impact on plant health productivity.

Effect of different LOFs on the shoot dry weight

The changes in the dry weight of the tomato plants under different treatments are shown in Figure 6. The highest dry weight was recorded by T0, likely because Albert's solution contains sufficient nutrients at recommended levels and has better solubility compared with LOFs (Ekanayake *et al*., 2020). The lowest dry weight was observed in T3 and T4, and these values were significantly ($p<0.05$) lower than those of the first three treatments (T0, T1, and

T2). However, no significant difference in dry weight was noted among T0, T1, and T2, indicating that T1 and T2 also had a positive effect on the dry matter accumulation in tomato plants. T1, which mainly consists of *Gliricidia sepium* and goat manure, appeared to contribute favourably to plant growth parameters. *Gliricidia sepium* leaves are rich in nutrients, containing approximately 3.82% nitrogen and 2.80% potassium (Budelman, 1989). In this study, the nutrient composition of the T1 treatment was 1.86±0.98% nitrogen, 0.08±0.002% phosphorus, and 0.34±0.08% potassium, which were higher than those of other LOFs (T2, T3, and T3). This may explain the relatively better performance of T1 in terms of dry weight gain compared with the other LOF treatments.

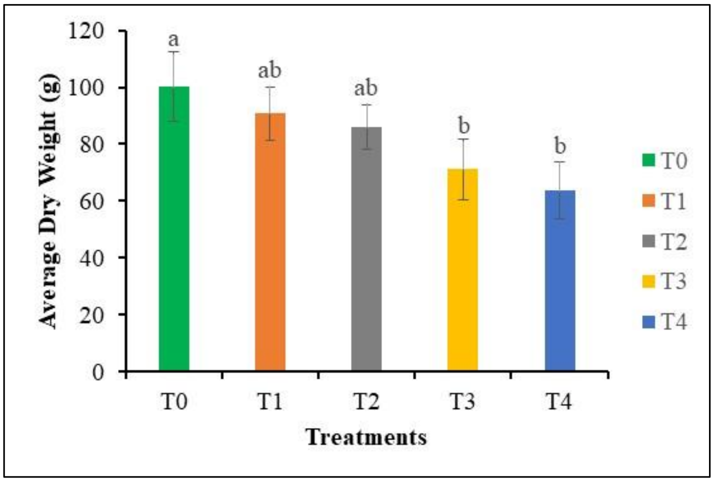

Figure 6: Dry weight of the tomato plants in the tenth week after planting under different liquid organic fertiliser applications. Mean values followed by different letters in the bar chart are significantly different at p=0.05

The findings of this study indicate that nitrogen fertilisation has a significant impact on the growth and development of tomato plants. Nitrogen is one of the essential macronutrients for plant growth, and its deficiency negatively affects yield, biomass accumulation, and overall quality of plant growth (Ranasinghe *et al.*, 2021). In this study, the application of T0 treatment significantly increased the shoot dry weight of tomato plants. This effect may be attributed to the role of nitrogen in the synthesis of proteins, chlorophyll, and other key biomolecules required for growth and development (Zewide and Reta, 2021).

Effect of different LOFs on the number of fruits

The number of fruits is an important parameter for evaluating the efficiency of fertilisers. The highest average number of fruits (~48) was observed in T0 (Figure 7). The number of fruits in T0 was significantly higher than those in LOF treatments (p<0.05). However, no significant differences were observed among the LOF treatments (T1–T4). Although the difference between T0 and T1 was not statistically significant, T1 produced the second highest numbers of fruits (~35).

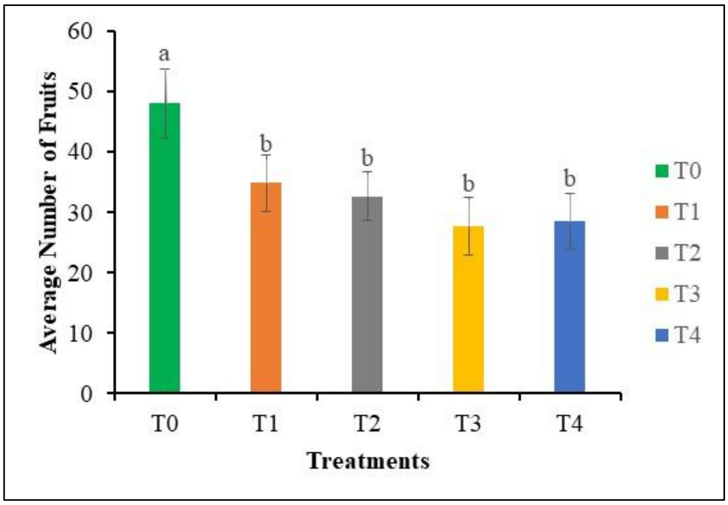

Figure 7: Number of fruits of the tomato per plant at the tenth week under different liquid organic fertiliser applications. Mean values followed by different letters in the bar chart are significantly different at p=0.05

Organic liquid fertilisers positively influence the number of fruits produced by tomato plants because they supply nutrients that are readily absorbed, promoting healthy growth and development. By providing both macro and micronutrients, OLFs can enhance plant vigour and ultimately increase fruit production (Fan *et al.*, 2023). The limited availability of these nutrients in the LOFs (T1–T4) used in this study is likely the main reason for the reduced number of fruits compared to T0. Khandaker *et al.* (2017) reported that increasing the nitrogen content of liquid fertilisers significantly raised the number of fruits per plant. The findings of the present s study are consistent with this observation, as the number of fruits per plant was closely related to the nitrogen content of the LOFs. The lowest number of fruits was reported in treatment T3, which also had the lowest nitrogen concentration. However, it is important to note that the benefit of organic fertiliser depends on applying it at recommended rates and schedules. Over-fertilisation can negatively affect plant health and fruit production (Sopha *et al.*, 2020).

Effect of treatments on the total yield of tomato

The most significant parameter for evaluating fertiliser efficiency is the yield (mass) per plant. The average yield per plant in T0 (1,796.8 g) was the highest compared to the other four treatments, and the yields of those treatments were significantly lower than T0 (Figure 8). The second-highest average yield per plant was observed in T1 (1,246.3 g), which is significantly lower than that of the control treatment. No significant difference in yields was recorded among LOFs (T1–T4). The tomato plants under T0 and T1 appeared healthier and more vigorous, as indicated by the higher average number of leaves. Increased leaf production can enhance photosynthetic activity, resulting in greater carbohydrate accumulation, larger yields, and better-quality fruit. Previous studies reported that the application of LOFs influences various physiological and enzymatic activities, leading to higher carbohydrates accumulation during the early stages of growth due to improved nutrient supply (Kalbani *et al.*, 2016).

Although plant growth parameters such as plant height, number of leaves, flowering time, number of flowers, and dry weight of plants were not significantly different between T0 and T1, the number of fruits and the overall yield per plant were significantly lower in T1 compared to the control (T0). This suggests that while LOFs used in this study can positively affect vegetative growth, their nutrient composition and release patterns may not be as effective as the balanced and readily available nutrients in T0 (Albert's solution) for maximising fruit production and yield.

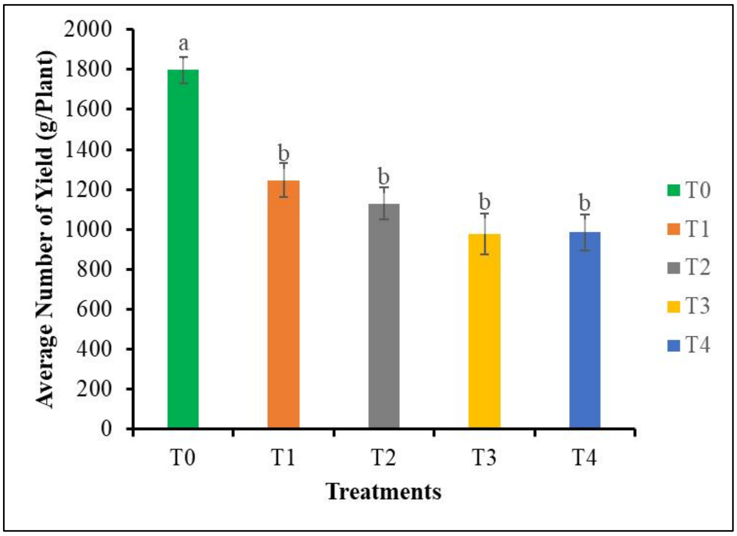

Figure 8: Total yield of the tomato plants under different liquid organic fertiliser applications. Mean values followed by different letters in the bar chart are significantly different at p=0.05

Effect of treatments on soil electrical conductivity variations

To assess the impact of liquid organic fertilisers (LOFs) on soil electrical conductivity (EC), it is important to monitor soil EC levels before and after fertiliser application. This ensures that EC remains within the optimal range for plant growth and that fertilisers are applied at appropriate rates (Mylavarapu *et al.*, 2020). Excessively high soil EC can indicate over-application or high soluble salt content, which may require adjustment of the fertiliser type or application rate.

EC is an important parameter for evaluating soil quality and productivity. The changes in soil EC under different treatments during the study period are shown in Figure 9. In the first four weeks, the EC of all treatments except T3 was relatively higher, reflecting the initial nutrient content in the soil. Later in the growth period, EC declined, indicating nutrient uptake by the tomato plants. The initial soil EC ranged from 10–20 mS/cm and decreased across all treatments over time.

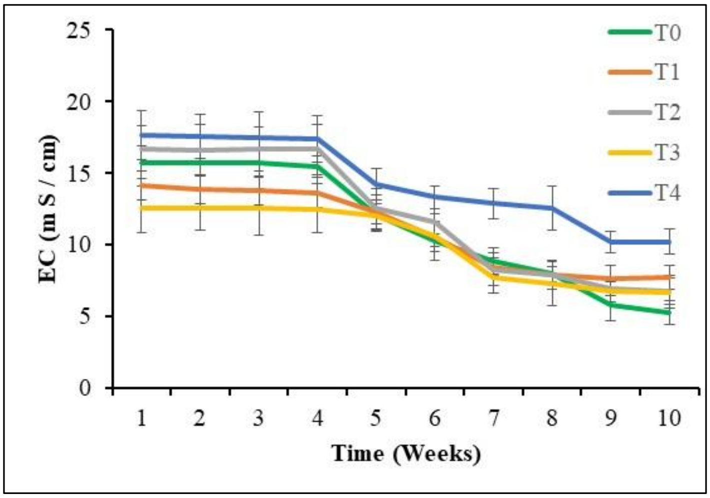

Figure 9: Electrical Conductivity variation of the soil over time under different liquid organic fertiliser applications

Increases in soil EC after fertiliser application can be attributed to the soluble salts and dissolved nutrients in the amendments. The level of EC change depends on factors such as the type and concentration of the organic fertiliser, soil type, and soil moisture (Phibunwatthanawong and Riddech, 2019). Organic fertilisers typically have lower EC values than inorganic fertilisers due to their lower soluble salt content, but high application rates or fertilisers rich in soluble minerals can still cause significant EC increases (Yu *et al.*, 2024).

In addition to influencing EC, organic fertilisers improve overall soil health and fertility. As the organic matter decomposes, it releases nutrients and beneficial compounds that enhance soil structure and water retention, supporting better plant growth and yield over time (Lubis *et al.*, 2021). However, excessive application can lead to salt accumulation, which may negatively affect soil quality and plant growth (Phibunwatthanawong and Riddech, 2019).

Effect of different liquid organic fertilisers on Soil pH variation

Soil pH has a significant impact on plant health and nutrient uptake, making it a critical factor in plant growth. While pH influences nutrient availability, other factors such as soil composition and overall fertility should also be considered. The initial soil pH ranged from 5.0 to 7.5 (Figure 10).

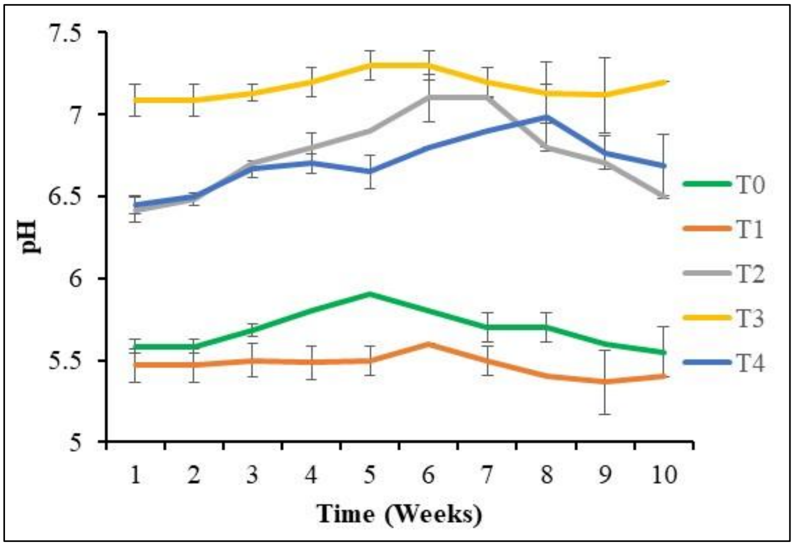

Figure 10: Changes in soil pH over time under different liquid organic fertiliser applications

The pH trends in T0 and T1 followed a similar pattern. In T0, soil pH remained nearly constant, while T1 showed a slight decrease from 5.46 to 5.40 by the end of the experiment. Other treatments exhibited a slight increase in pH over the same period, with T3 consistently showing comparatively higher pH values throughout the ten weeks. Overall, the changes in pH were minor during the later stages of plant growth. These results indicate that different treatments can influence soil pH. The slightly lower pH in T0 and T1 may be beneficial for crops that prefer acidic soil conditions. This experiment demonstrates that the choice of fertiliser and organic amendments can affect soil pH, with potential implications for nutrient availability and plant growth (Mylavarapu *et al.*, 2020).

CONCLUSION

This study evaluated the effects of different organic fertilisers on tomato growth and yield. The lowest performance was observed in T4, while Albert's solution (T0) and T1 showed the highest growth parameters and yields. T1, which included fish waste, wood ash, molasses, cow dung, *Gliricidia sepium*, and goat manure, demonstrated strong potential as an alternative to T0, achieving good vegetative growth and the second-highest yield, albeit with a ~30% reduction compared to T0. The significant differences in fruit number and total yield between T0 and T1 highlight areas for improvement. Overall, the results suggest that T1-based liquid organic fertiliser could serve as a viable organic alternative for the improvement of effective liquid fertiliser to replace conventional fertilisers. Future research should focus on improving the formulation of T1 by modifying its raw material composition and combining it with Albert's solution in different proportions to achieve performance comparable to that of Albert's solution, thereby supporting sustainable tomato cultivation.

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