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Research Article

Combination of Organic Liquid Fertilizer and Sea Weed Extract Enhances the Tomato Growth, Yield and Photosynthetic Attributes Under Hydroponic System

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ABSTRACT

Tomato is popular hydroponic crop cultivated predominantly with Albert solution. However, the recent trend in increased demand for organic agriculture warrants the need of alternative green liquid fertilizers as opposed to inorganic solution. Therefore, this study intended to investigate the effects of tomato photosynthetic, growth and yield performance supplemented with a simple and organic liquid fertilizer (OLF) prepared from home garden wastes through natural anaerobic fermentation using compost, goat manure, wild sunflower leaves, and banana peels supplemented with brown sugar (25 g/l). Anaerobic fermentation was allowed for up to 30 days. The prepared OLF was used to arrange five OLF treatments T1 (OLF, pH-5.5-6.5), T2 (OLF, pH-6.5-7.5), T3 (OLF, SWE, pH-5.5-6.5), T4 (OLF, SWE, pH-6.5-7.5), T5 (OLF, pH-5.5-6.5, MOP) and in addition, T6 - control (1000 ppm Albert solution, pH-5.5-6.5) with Albert solution were maintained in a plant net house facility. Tomato variety *cv. Platina* was used characterize the vegetative, floral, photosynthesis, and yield traits. Our results indicated that the nutrient levels were significantly higher at 15 days after fermentation, and highest nitrogen and phosphorus were obtained in the liquid solution. Tomato trial revealed that T6 (control) had significantly ($P<0.05$) increased performance on leaf area (372 cm^2), plant height (166cm) photosynthetic rates (18.9) and chlorophyll content (58.0 SPAD) and increased number of fruit set (13 fruits /plant) as opposed to other treatments. However, the T3 produced the highest performances among the OLF treatment. With those findings, T6 (Albert solution, control) produced highest total fruit yield (701g/plant) followed by T3 (557g/plant), suggesting that the treatments supplemented with Albert solution outperforms photosynthetic, growth and yield characters in tomato. However, the T3 showed the second highest performance among the treatments, Hence T3 can be proposed as an alternative organic liquid solution for cultivation of hydroponic tomato.

Introduction

Organic liquid fertilizer (OLF) has been extensively used in crop cultivation because it has an abundance of macro and micronutrients necessary for plant growth. Microorganism play a significant role during the fermentation procedure in which organic waste are broken down to create OLF. Since the nutrients from these fertilizers are released slowly, those are considered as a desirable option for hydroponic systems. Furthermore, many farmers are interested in employing organic fertilizers in vegetable plant cultivation (Hadad and Anderson, 2004).

Hydroponically growing tomato ensure the high crop yield, quality product and increased water use efficiency than conventional tomato growing system (Cardoso et al*.,* 2018). However, hydroponically growing tomato cultivation require high initial cost for the construction, maintenance and trained labor and also lead to environmental pollution (Velazquez–Gonzalez et al*.,* 2022). As a consequence, it is difficult to establish a commercial hydroponic unit by medium level farmers. Moreover, establishing a chemical based hydroponic tomato causes a serious issue on disposal of remaining nutrient to the terrestrial environment as it has more phosphate and nitrate content (Gagnon et al., 2010). In addition to these, organic food consumers less prefer to consume the chemical based product. Therefore, this warrants the development of an organic liquid fertilizer to serve as an alternative

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remedy to cater the organic farmer's needs. OLF could be formulated using different organic materials which mainly consist of animal or green house product wastes (Sonneveld and Voogt, 2009). Although, the nutrient concentration and method of production effect the final quality of the OLF product, depending on the material used, the level of nutrient concentration is determined in the final product. Hartz et al. (2010) stated that the nutrient level in OLF vary based on the type of biomass and production method. Hence, the concentration and nutrient content of OLF impact the crop yield and quality (Pokhrel et al., 2015). In many experiments, OLF was claimed to increase tomato fruit yield (Anila et al., 2019). As such it is presumed that liquid fertilizer made from animal and plant sources could replace chemical fertilizer in greenhouse conditions (Guajardo-Rios et al., 2018). Further, Pawar et. al., (2019) reported that various liquid fertilizer sources may have varying effects on tomato growth and output. Generally, anaerobic fermentation technique is used to prepare the OLF, where microorganism mainly bacteria form the final nutrient rich liquids. Sarker et al. (2019) reported that anaerobic fermentation of organic waste lead to produce biogas and release nutrient contents from the organic compounds. Moreover, Thanaporn and Nuntavun, (2019) suggested that simple fermentation of organic waste using microorganisms significantly enables the production of plant growth stimulants, organic acids, and phytohormones.

Shinohara et al. (2011) pointed out that the potential uses of organic hydroponics in vegetable cultivation faces many technical challenges that are related to pH fluctuation, limitation of nitrogen availability and other major and micro nutrients deficiency (Moller and Muller, 2012). Idealized pH level is crucial as it enable the nutrient availability to the hydroponically grown plant root zone. If the pH of the plant root zone is higher than 7, it causes less solubility of iron and H_2PO_4, precipitation of Ca and Mg, delaying the absorption of iron, boron, copper, zinc, or manganese. Further, if the pH<5, the absorption of nitrogen, phosphorus, potassium, calcium, magnesium, and molybdenum are restricted. Therefore, maintaining the proper pH (5.5-6.5) results in better growth performance. Singh et al. (2019) suggested that most of the hydroponically growing crops requires the pH of 5.5-6.5 at the root zone. However, the idealized pH of the organic liquid based hydroponic cultivations are poorly studied.

Moreover, supplementation of sea weed extract has importance as it provides ample of benefit (micronutrients) to the plants. Hernández-Herrera et al. (2022) proofed that sea weeds treated tomato showed early flowering, increase in fruit weight and quality and enhanced photosynthetic characters. Thereby, the objective of this study was to use agricultural and farmyard residues, such as plant and animal, to produce liquid organic fertilizer and evaluate its effects with supplement of sea weed extract (SWE) on different pH and subsequent effects on the photosynthetic, growth and yield of a hybrid tomato variety produced in a simple-portable hydroponic system.

Materials and Methods

Location of the study

The study was carried out in a plant net house facility at Agrotech Park in Malwatta, Faculty of Technology, South Eastern University of Sri Lanka, from January to December 2022. The experimental site is located at a latitude of 7.29° N and a longitude of 81.82° E, at a mean sea level of 20m in the agro ecological region of the low country dry zone (DL2b), in Sri Lanka (Mubarak et al., 2022).

Formulation of organic liquid fertilizer

Initially, the compost was prepared with the ratios of rice straw: cow dung: albizia leaves (1:3:1 w/w), and the red worm (*Eisenia foetida*) was introduced at a rate of 150 g / 25 kg of cow dung (Abul Hashem et al., 2020) subsequently allowed decomposing for three months. Thereafter, the natural compost was sieved to obtain homogenous particles and used for the preparation of liquid organic fertilizer (OLF), as mentioned below. In addition to prepared compost, banana peels, wild sunflower leaves, and goat manure were used at the rates of 80:50:80:80 (w/w) respectively, and brown sugar (25g/l of water) was added to OLF preparing air tight plastic container. Subsequently, these materials were fermented at ambient temperature for 30 days in cleaned 15-liter air tight plastic containers. One third of containers were left without media. The mixture was stirred using a wooden pole 3 times per day during the fermentation process to make a homogenous mixture. The OLF subsamples were filtered twice by using a 0.45-micron filter at 15 and 30 days after fermentation (DAF) in order to obtain the best organic liquid fertilizer. Then samples were subjected to nutrient analysis such as total nitrogen, total phosphorus, and total potassium by employing the Kjeldahal methods, wet digestion spectrophotometer employing flame photometer methods, respectively (Thanaporn and Nuntavun, 2019).

Setting up of portable hydroponic system

A hybrid variety cv. Platina, a determinate growth habit and drought tolerant tomato variety was used in this experiment as research area comes under Dry zone of Sri Lanka. Seedlings were established in plant propagators supplemented with compost, sterilized coir dust and river sand (1:1:1) and maintained for one-month.

The hydroponic system was established in plant net house facilities (50% shade) using the following technique. One month tomato seedlings were established with four plants in a Polystyrene container (15 liters). The experimental design was a completely randomized block with six treatments and four replications. The following six treatments were arranged (Table 1). Here, T1-T5 received prepared OLF, while positive control (T6) comprised with Albert solution (Unipower, USA) supplied at the rates of 1.5 g/L. At the onset of the experiment, each Polystyrene containers (15 litters) were supplemented with 1.2 L OLF per 15 Liter of water. Then the OLF was added at the rates of 0.39 Liter per hydroponic tank once in every two weeks. The pH was maintained according to the treatments (T1–T6) and based on a previous study (Dyśko et al., 2009), while pH was adjusted by adding the required volume of 0.01M HCl or 0.01M NaOH solutions and mixing the hydroponic liquid in order to maintain a homogenous pH within the container. According to the treatments, additional nutrients were supplemented through the seaweed extracts (Maxi crop Inc. USA) at rate of 10 mL/L (for T3 and T4) or Murate of potash for rates of 1 g/L for T5 (Chapagain et al., 2003) at the intervals of once every two weeks. The Electric Conductivity (EC) was maintained as 1.5 – 2.5 ds/M in all treatments.

Table 1. Details of treatments for conducting tomato trials using organic liquid fertilizer

Treatments	Details of treatments	Volume of added OLF/ Biweekly (Liter)
T1	1.2 Liter OLF, pH-5.5-6.5	0.39
T2	1.2 Liter OLF, pH-6.5-7.5	0.39
T3	1.2 Liter OLF, pH-5.5-6.5, SWE	0.39
T4	1.2 Liter OLF, pH-6.5-7.5, SWE	0.39
T5	1.2 Liter OLF, pH-5.5-6.5, MOP	0.39
T6 (control)	1000 ppm Albert solution ,pH-5.5-6.5	0.39

T1-T6- treatments, OLF-organic liquid fertilizer, SWE- Sea weeds extract (10ml/L), MOP-Muriate of potash (1g/L),

Data collection

Data collection was performed at vegetative characteristics (2 to 9 weeks after planting, WAP) and reproductive (9-16 WAP) stages, while the photosynthetic parameters were measured at 9 WAP from randomly selected four- plants of each treatment.

Measurement of vegetative characters

The leaf area, leaf length, and width were measured using a portable leaf area meter (LI-3100C, Nebraska, and USA). The total number of leaves produced per plant was counted. Plant height and root length were measured using 1mm least count measuring tape. The stem diameter at the base of stem, and the longest root length and width were measured by employing a 0.15mm least count and 0.1mm resolution digital caliper (NEIKO 01407A, China).

Measurement of photosynthetic parameters

Photosynthesis rates (*Pn*), stomatal conductance (*Gs)*, transpiration rate (*Tr)* and intercellular CO_2 (*Ci*) parameters were measured using an infrared gas analyzer (L1-6800-Portable Photosynthesis System, Nebraska, USA). The measurements were taken from the first three leaves of the plant. The chlorophyll content in the leaves was measured by a portable chlorophyll meter (SPAD 502 plus Minolta; Spectrum Technologies Inc., Aurora, IL, USA). The optical density difference measurement method was employed for the wavelengths of 650 nm and 940 nm. Randomly selected, the first three leaves from each plant were measured.

Measurement of reproductive characteristics

The number of inflorescence/plant, number of flowers per cluster, and number of set fruits per plant were manually counted at 10WAP. Similarly, individual tomato fruit length and width were recorded by employing a 0.15mm least count and 0.1mm resolution digital caliper (NEIKO 01407A, China).

Statistical method

An analysis of variance (ANOVA) was performed using Minitab 18 (Minitab HK Limited, Hong Kong) to analyze the data. The significance of means was analyzed with the least significant differences (LSD) between treatments means, and a Tukey post-hoc test was performed to find out the significance between the treatments at $p<0.05$.

Results and Discussion

Changes of total nitrogen content

During OLF preparation, a significant ($p<0.05$) variation in total nitrogen concentration was observed with time interval. At 15 DAF, increased total nitrogen (513.4mg/L) was recorded than at 30 DAF (329.1 mg/L) (Table 2). According to Nur et al. (2016) proved that increased nitrogen content was recorded at 17 days after fermentation during OLF preparation. As such, these findings are in line with the present findings as the maximum nitrogen content was found 15 DAF. According to Tantrip and Supadma, (2016), total nitrogen availability in OLF is influenced by the amount of organic carbon material as carbon composition promotes the nitrifying bacteria (*Rhizobium mayense*) on the organic material hence increase the nitrogen content.

Changes of total phosphorous content

Total available phosphorous in OLF significantly decreased with the fermentation time interval. Peak amount was achieved at 15 DAF (588.19±0.6 mg/L) while a significantly reduced amount of phosphors was recorded at 30 DAF (64.53±0.53 mg/L). In a previous study, the dissolution of phosphate bacteria is reported to be higher due to the availability of carbon in OLF (Sureshkumar et al., 2013). Hence, due to the peak breakdown of organic carbon material, more phosphorous was produced at 15 DAF. The possible reason behind the reduction of nutrients was, at 30 days of fermentation, bacteria tend to reduce their activities due to the organic carbon matter (Surtinah, 2013).

Changes of total available potassium content

Unlike total nitrogen and phosphorous, the total potassium was significantly increased at 30 DAF (6.42±0.02mg/L) than at 15 DAF (4.24±0.04 mg/L). This may be due to increasing of potassium dissolving microbes (mucilaginous) present under organic carbon (Achmad and Mansyur, 2021). As such the potassium production in OLF enhances the metabolism of the microbes, leading to further increases in the amount of potassium in OLF. Therefore, according to the findings of the present study, OLF at 15 days after fermentation provides highest amount of nitrogen and phosphorous for the cultivation of tomato.

Table 2. Time course changes of total nitrogen, phosphorous and potassium contents in the organic liquid fertilizer

Volume of Liquid fertilizer (Litre)	Total Nitrogen (mg/L)		Total phosphorous (mg/L)		Total potassium (mg/L)	
	15DAF	30DAF	15DAF	30DAF	15DAF	30DAF
1 L	513.4± 0.74^{b}	329.1± 1.81^{a}	588.19± 0.6^{b}	64.53± 0.53^{b}	4.24± 0.04^{b}	6.42± 0.02^{b}
Adding 1.2 L /hydroponic tank	616.3± 0.47^{a}	394.9± 0.09^{a}	705.8± 0.05^{a}	77.44± 0.09^{a}	5.08± 0.01^{a}	7.70± 0.01^{a}
Adding 0.39L/week	102.2± 0.29^{c}	128.34± 0.12^{b}	229.43± 0.25^{c}	25.16± 0.07^{c}	1.65± 0.02^{c}	2.5± 0.008^{c}

Mean values ± SD are shown. Mean values followed by the same letter were not significantly different at (p<0.05) Probability level based on one-way ANOVAs followed by Tukey post-hoc test within the same column, (n=4). DAF-Days after fermentation

Changes of vegetative characters of tomato

Tables 3 and 4 show the dynamic changes in leaf and root, plant height, and stem thickness of tomato. Greater performances on plant height (166.5±0.5), root length (108.67), root width, and stem thickness (19.35±1) (Table 3) were recorded in T6 treatment (1000 ppm Albert solution, pH-5.5-6.5). In response to organic liquid fertilizers, plants treated with T3 treatment produced the second significant increased plant height (151.3±0.3), root length (79.63±0.7), root width (6.6±0.3) and stem diameter (16.74±0.5) at 9 week after planting. This result implies that the significant effects of the T3 treatment supplemented with seaweed extract (SWE) with the pH (5.5-6.5), this could have positively influenced the vegetative parameters. Furthermore, Layek et al. (2018) and Sharma et al. (2017) stated that the application of SWE led to increases in tomato plant growth and yield. In addition, Singh et al. (2019) reported that the optimal pH in the root zone of most hydroponically grown crops ranges from 5.5 to 6.5.

Table 3. Effects of organic liquid fertilizer on the vegetative characters of tomato plants

Treatment	Plant height (cm)			Root length (cm)			Root diameter (cm)			Stem diameter (mm)		
	2WAP	6WAP	9WAP	2WAP	6WAP	9WAP	2WAP	6WAP	9WAP	2WAP	6WAP	9WAP
T1	36.3± 0.5^{d}	99.3± 0.5^{c}	135.6± 0.8^{c}	12.23± 0.15^{e}	33.9± 4.2^{d}	46.13± 0.3^{b}	2.07± 0.08^{c}	3.2± 0.13^{c}	5.27± 0.4^{c}	4.05± 0.45d^{e}	9.87± 0.4^{c}	13.92± 0.4^{c}

T2	27.1± 20.3[e]	70.5± 0.5[e]	97.6± 1.1[e]	9.2± 0.16[f]	20.6± 2.3[e]	29.8± 1.1[f]	1.53± 0.15[e]	2.2± 0.04[e]	3.73± 0.7[e]	3.9± 0.08[e]	6.57± 0.3[d]	10.47± 0.2[f]
T3	42.1± 0.2[b]	109.2± 0.2[b]	151.3± 0.3[b]	26.13± 0.13[b]	53.5± 1.7[b]	79.63± 0.7[b]	3± 0.07[b]	3.6± 0.2[b]	6.6± 0.3[b]	5.22± 0.11[b]	11.52± 0.7[b]	16.74± 0.5[b]
T4	36.5± 0.4[d]	65.2± 0.3[f]	101.7± 0.4[d]	21.07± 0.08[c]	43.3± 1.8[c]	64.37± 0.6[c]	1.79± 0.06[d]	2.3± 0.1[e]	4.09± 0.1[d]	4.25± 0.18[d]	6.98± 1.1[d]	11.23± 0.9[e]
T5	40.4± 0.5[c]	83.02± 0.1[d]	123.4± 1.2[c]	19.2± 0.11[d]	40.92± 1	60.07± 0.6[d]	2.07± 0.5[c]	2.7± 0.08[d]	4.77± 0.2[c]	4.77± 0.08[c]	6.98± 1.4d	11.75± 0.4[d]
T6 (Control)	51.3± 1.3[a]	115.2± 0.3[a]	166.5± 0.5[a]	35.22± 0.18[a]	73.5± 1.5[a]	108.67±[a]	4.02± 0.11[a]	5.45± 0.2[a]	9.47± 0.8[a]	6.75± 0.15[a]	12.6± 1.6[a]	19.35± 1.2[a]

Mean values ± SD are shown. Mean values followed by the same letter were not significantly different at (*p*<0.05). Probability level based on one-way ANOVAs followed by Tukey post-hoc test within the same column. WAP-week after planting (n=4).

The production of leaves and increasing leaf-area is for the increment of photosynthesis and dry matter production. According to our observations, all treatments significantly increased the number of leaves in all treatments at 2, 6, and 9 WAP respectively (Table 4). However, at 9WAP, the control treatment T6 (1000 ppm Albert solution, pH-5.5-6.5) produced the highest number of leaves (41.1±1.5) followed by T3 (30.6±0.5 and T1 (26.3±0.7). Likewise, T6 (Control) showed the highest leaf width (24±1.3), leaf length (37.7±0.4) and cumulative leaf area (372.3±3.5). Conversely, a second highest vegetative performance was recorded in T3 on leave width (20.6±1.1)), leaf length (30.7±0.2) and cumulative leaf area (334.9±2.5).

Table 4. Effects of organic liquid fertilizer on the leaf characteristics of tomato plants

Treatment	Cumulative number of leaves			Leaf width (cm)			Leaf length (cm)			Cumulative Leaf area (cm^2)		
	2WA	6WAP	9WAP	2WAP	6WAP	9WAP	2WAP	6WAP	9WAP	2WAP	6WAP	9WAP
T1	7.0± 0.8[e]	19.3± 1.9[b]	26.3± 0.7[c]	5.2± 0.2[b]	11.8± 0.3[c]	17.0± 0.6[c]	8.3± 0.9[e]	14.7± 0.5[c]	23.0± 0.4[c]	43.23± 1.8[d]	163.6± 1.3.[c]	206.9± 1.9[c]
T2	6.3± 0.4[f]	11.8± 1.3[d]	18.0± 0.5[f]	4.7± 0.1[cd]	9.4± 1.1[d]	14.1± 0.5[d]	7.1± 0.2[f]	12± 1.1[d]	19.1± 0.5[e]	33.4± 1.23[e]	110.9± 2.5[d]	144.3± 0.9[e]
T3	10.8± 0.9[b]	19.8± 0.4[b]	30.6± 0.5[b]	5.3± 0.04[b]	15.3± 0.5[b]	20.6± 1.1[b]	13.4± 0.2[b]	17.3± 0.7[b]	30.7± 0.2[b]	70.8± 1.53[b]	264.1± 1.8[b]	334.9± 2.5[b]
T4	9.3± 0.44[c]	15.3± 1.1[c]	24.6± 0.8[e]	4.4± 0.9[d]	12.1± 0.7[c]	16.5± 0.4[c]	9.9± 0.04[d]	14.2± 0.6[c]	24.03± 0.2[d]	43.4± 0.94[d]	171.6± 1.2[c]	215± 5.9[d]
T5	7.8± 0.44[d]	14.5± 0.6[c]	22.3± 0.5[d]	5.0± 0.1b[c]	12.0± 1.1[c]	17.0± 2.7[c]	11.3± 0.19[c]	14.4± 1.5[c]	25.7± 0.6[d]	56.4± 0.47[c]	172.9± 2.7[c]	229.3± 5.8[d]
T6 (control)	14.8± 0.9[a]	26.3± 0.4[a]	41.1± 1.5[a]	7.5± 0.8[a]	16.5± 1.1[a]	24.0± 1.3[a]	16.5± 0.3[a]	21.2± 0.2[a]	37.7± 0.4[d]	24.4± 16.05[a]	347.9± 2.3[a]	372.3± 3.51[a]

Mean values ± SD are shown. Mean values followed by the same letters were not significantly different at the (P<0.05) probability level based on one –way ANOVAs followed by Turkey post-hock test within the same column.WAP-Week after planting. (n=4)

The effects of organic liquid fertilizer on Chlorophyll content (SPAD) of tomato

The degree of photosynthesis could be indicated by the soil plant analysis development (SPAD) and it could further have an impact on plant growth (Lu et al., 2022). Ulissi et al., (2011) also reported that the amount of nutrient in plants correlated with the chlorophyll concentration in the leaves. According to our results, significant variations were observed between the treatments. Higher SPAD readings were recorded in T6 (1000 ppm Albert solution, pH-5.5-6.5) (58±0.6), followed by T3 (53.8±1.4) (Table 5). This may due to the supplement of balanced nutrients by the Albert's solution T6 outperform the OLF treatments. Among the OLF, T3 had a higher significant SPAD reading. This implied that SWE, with a favorable pH range (5.5-6.5) and OLF had the potential to improve the chlorophyll content in T3 than the other OLF. According to Doganlar et al. (2000), SWE could significantly increase chlorophyll content in tomato plants. This may due to an increase supplement of nitrogen to crops as the N% which is varied from 0.1% to 7.2% (Ertani et al., 2018).in sea weeds extract derived from brown algae (*Ascophyllum nodosum* L.).

Table 5. Effects of organic liquid fertilizer on the photosynthetic attributes of the tomato plants

Treatment	*(Pn)* (μmol·m⁻²·s⁻¹)	*(Gs)* (mol·m⁻²·s⁻¹)	*(Ci)* (μmol·mmol⁻¹)	*(Tr*10⁻⁴)* (mmol m⁻²·s⁻¹)	SPAD
T1	16.4±1.8[ab]	0.14±0.06[bc]	246.4±25.9[ab]	2.7±0.9[bc]	52.2±0.8[c]
T2	14.5±2.9[b]	0.03±0.007[c]	217.5±40.2[b]	7 ±0.9[c]	44.3±0.8[e]
T3	17.5±0.9[ab]	0.21±0.03[b]	262.42±13.73[ab]	4.2 ±0.5[b]	53.8±1.4[b]
T4	14.38±1.6[b]	0.054±0.00b[c]	215.6±23.6[b]	1.1 ±0.9 [c]	47.2±2[d]
T5	16.38±0.8[ab]	0.07±0.009[bc]	245.7±12.24[ab]	1.3 ±0.2 [c]	51.9±0.7[c]
T6 (control)	18.9±0.78[a]	0.48±0.18[a]	284.4±11.7[a]	8 ±0.2 [a]	58±0.6[a]

Mean values ± SD are shown. Mean values followed by the same letter were not significantly different at the 0.05 probability level based on one-way ANOVAs followed by Tukey post-hoc test within the same column (n=4), *Pn*- Net photosynthetic rates, *Gs*- Stomatal conductance, *Ci*- Internal CO_2 concentration, *Tr*- Transpiration.

The effect of organic liquid fertilizer on photosynthesis characters of tomato leaves

The net photosynthetic rate (*Pn*), intercellular carbon dioxide concentration (*Ci),* stomatal conductance (*Gs*), and transpiration (*Tr*) of the photosynthesis parameters showed larger, significant variations between the treatments. Significantly higher *Pn* was recorded at T6 (18.9±0.78) followed by T3 (17.5±0.9) while insignificant readings were recorded between T1, T3 and T5 and T2. (Table 5). In addition, like *Pn*, the same trends were observed for *Gs*, *Tr,* and *Ci.* Significantly increased values were recorded in T6, followed by T3 respectively, while other treatments such as T1, T2, T4, and T5 significantly showed lower readings compared to T3 and T6. These results, implied that T6 and T3 had higher values for photosynthesis parameters. Lu et al. (2022) pointed out, that balanced nutritional status with ideal pH are essential to boost the photosynthesis of tomatoes.

Effect of organic liquid fertilizer on tomato flower characters

Out of all treatments, T6 (control) had the significantly (P<0.05) highest number of flower clusters (9.13) per plant, flowers (17.9), number of fruits setting (7) and total number of fruits (13.1) followed by T3, which achieved a second performance among the treatments with increased number of flower/clusters(16.9**)** compared to other OLF. Furthermore, if consider the collective fruit attributes, T6 had the maximum performance, and T3 achieved the best results compared to other OLF treatments. This phenomina is owing to the T3's fertilizer composition (OLF, seaweed extract, and pH 5.5–6.5) or absorption of nutrient performance (Umamaheswari et al. (2016) reported that the pH value between 5.5 - 6.5 could ensure the optimum plant nutrition uptake of the plant.

Table 6. Impact of organic liquid fertilizer on the flower characteristics of tomato plants

Treatment	Number of flower cluster/plant	Number of flowers /cluster	Number of fruit setting/cluster	Total number of fruits /cluster
T1	5.5±0.8[c]	13.8±0.7[b]	9±0.54[b]	8.7±1.18[b]
T2	3.13±0.35[d]	6.7±1.6[d]	5.4±1.3[c]	4.9±1.13[d]
T3	7.62±7.62[b]	16.9±1.13[a]	13±1.19[a]	12.5±0.54[a]
T4	3.4±3.38[d]	8.8±1.17[c]	7±1.06[c]	5.7±1.4[cd]
T5	5.4±5.38[c]	10±1.7[c]	7.4±1.5[bc]	7±1.06[c]
T6 (Control)	9.13±9.13[a]	17.9±0.83[a]	13±1.19[a]	13.1±1.36[a]

Mean values ± SD are shown. Mean values followed by the same letter were not significantly different at the 0.05 probability level based on one-way ANOVAs followed by Tukey post-hoc test within the same column (n=8).

The effect of organic liquids fertilizer on tomato fruit yield parameters

Table 7 shows the changes in reproductive attributes of the tomato fruit yield. The OLF treatments significantly impacted on fruit yield parameters. The highest total fruit yield/plant was recorded in T6 (701.3±0.41 g), followed by T3 (557.6±5.46 g). In addition, the highest mean individual fruit weight was achieved by T6 (43.04±0.6 g) followed by T3 (41.6±0.56). Moreover, Franzoni et al. (2022) reported SWE increase the photosynthetic and fruit yield. These results summarize that other than the control treatment (T6), and T3 showed the maximum yield parameters compared to other OLF treatment strategies, demonstrating SWE in OLF under a favourable pH range (5.5–6.5) had a significantly impacted on tomato yield parameters.

Table 7. Fruit characteristics of tomato plants grown under organic liquid fertilizer

Treatments	Tomato fruit yield parameters			
	Fruit length (mm)	Fruit diameter (mm)	Individual fruit weight (g)	Total Fruit yield/(g/plant)
T1	30.05±0.35^{c}	32.71±0.3^{c}	37.1±1^{d}	445±3.6^{c}
T2	19.56±0.14^{e}	21.25±0.17^{f}	32.6±1.3^{e}	178.9±5.55^{f}
T3	33.26±0.28^{b}	35.99±0.4^{b}	41.6±0.56^{b}	557.6±5.46^{b}
T4	22.21±0.4^{d}	24.61±0.59^{e}	27.6±0.57^{f}	220.6±1.76^{e}
T5	22.38±0.4^{d}	25.57±0.4^{d}	39.2±0.33^{c}	321.4±3.8^{d}
T6 (Control)	36.48±0.56^{a}	40.46±0.53^{a}	43.04±0.6^{a}	701.3±0.41^{a}

Mean values ± SD are shown. Mean values followed by the same letter were not significantly different at the 0.05 probability level based on one-way ANOVAs followed by Turkey post-hock test within the same column (n=8)

Conclusion

Organic liquid fertilizers have greater demand among tomato growers. We developed a simple and cost effective organic hydroponic solution which can be prepared in 15 days after fermentation with the materials available in home gardens. Furthermore, the control treatment supplemented with Albert solution- a commercial popular fertilize, showed the best vegetative, physiological, and yield traits compared to other OLF treatments, as this is capable of supplying of balanced macro and micro nutrients throughout the tomato cultivation. However, organic liquid fertilizers supplemented with sea weed extracts (T3) could be a good alternative hydroponic solution for organic tomato growers.

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Conflicts of Interest

The authors declare no conflict of interest.

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