Jurnal
Teknologi

Full Paper

APPLICATION OF SPECIAL LIQUID FERTILIZER FROM ORGANIC WASTES TO PROMOTE GROWTH AND PRODUCTIVITY OF RED CHILLI PLANTS (*CAPSICUM ANNUUM L.*)

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Article history
Received
18 September 2023
Received in revised form
14 November 2023
Accepted
17 January 2024
Published Online
20 April 2024

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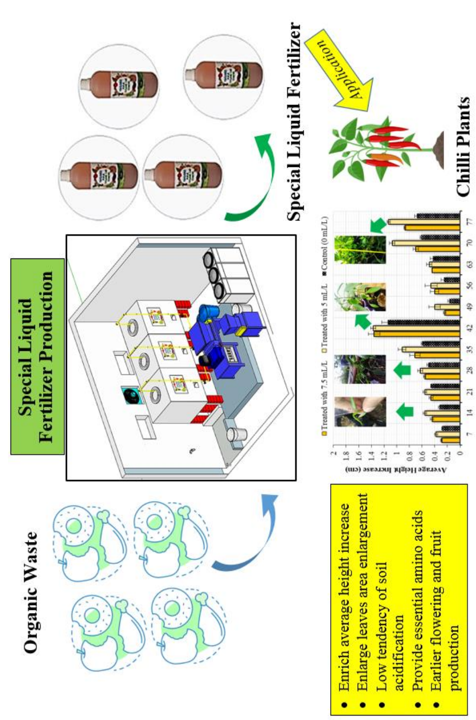
Graphical abstract



Abstract

Zero waste management program (Masaro) offers a solution to process fruit, vegetable, and food waste. They were fermented at 32°C using two types of opaque plastic bioreactors with volumes of 60 L (first 14 days of fermentation) and 120 L (next 14 days of fermentation), respectively. The product of fermentation is a special liquid fertilizer. In this study, the fertilizer is applied to promote the growth and productivity of red chilli plants (*Capsicum annuum L.*) for 77 days. The macro and micronutrients in the fertilizer were analyzed using atomic absorption spectroscopy. The microorganisms and the amino acids therein were also characterized. The results inform that 5 mL/L of special liquid fertilizer signifies the average height increase and leaves area enlargement of the chilli plants. The presence of rhizobacteria in the fertilizer is responsible for promoting plant growth and enhancing plant productivity. In addition, this concentration of the fertilizer provides one week earlier of flowering and fruit production, with the highest number of chilli flowers and fruits reaching 28 and 19. Conclusively, the special liquid fertilizer has shown positive impacts on crop production and quality, with lower production costs. It is also effective, sustainable, eco-friendly, and can be applied in various agricultural sectors.

Keywords: Agricultural, Fertilizer, Nutrients, Productivity, Rhizobacteria, Sustainable

1.0 INTRODUCTION

Red chilli (*Capsicum annuum L.*) is considered one of the major agricultural commodities in Indonesia because of its high market demand and prices. It can be immediately cultivated after the harvest season and also during the dry season due to its ability to grow in dry conditions [1,2]. However, the growth of red chilli plant has significant constraints caused by pests and diseases that hamper its production [3].

The presence of macro and micronutrients in the soil is a crucial parameter to obtain high crop productivity with excellent quality. The macronutrients include nitrogen, potassium, phosphorous, calcium, magnesium, and sulfur, while the micronutrients comprise zinc, iron, manganese, copper, boron, and sodium [4]. Each nutrient has specific roles in plants, and the deficiency or excess of these nutrients may hinder plant growth and decrease crop production [5]. Therefore, the application of cultivation techniques that can efficiently supply essential nutrients required by chilli plants is necessary to enhance their annual production.

Synthetic fertilizers have been widely implemented to improve the yield and quality of red chilli. The supplementation results in a sharp rise in the number of leaves, number of branches, plant height, and productivity of chilli plants [6]. Unfortunately, the use of synthetic fertilizers can alter chemical and microbiological properties in natural soil ecosystems [7].

The long-term damages comprise soil acidification, fungal diversity drops, and bacterial community structure changes [8]. Synthetic fertilizers are also known to be pricy compared with organic fertilizers which can lessen the profits obtained by the farmers [9]. These issues prompt researchers to look for organic fertilizers that are more sustainable and environmentally friendly, with less negative impacts on the environment.

Organic fertilizers are produced from the decomposition of food waste, animal manure, marine-based waste, or agricultural waste [10]. They can be found in solid or liquid forms that can significantly improve the nutrient uptake of crops as well as upgrade the chemical, physical, and biological properties of soil [11, 12]. Roy et al. introduced an organic fertilizer from rural slaughterhouse waste to cultivate chilli. The results indicate an earlier fruiting period and higher yield [13].

According to the study on soil supplementation using weed-based organic compost, the fertilizer positively affects the growth and yield of chilli plants because of the nutrients in the soil. This treatment also results in improved microbial activity in the soil [14]. Anggraheni et al. found that chilli plants treated with compost show the highest growth and yield compared with the plants treated with manure fertilizer [15]. This is due to ameliorated soil texture and enriched nutrient contents upon the addition of organic fertilizers.

Recently, a waste management program (Masaro) to transform waste into value-added chemicals has been introduced [16,17]. At first, the waste is classified into slow-decaying and fast-decaying wastes. The slow-decaying waste is transformed into compost in bio-composter, whereas the fast-decaying waste is converted into special liquid fertilizer, concentrate, and solid animal feed in bioreactors.

Preliminary studies on special liquid fertilizers have shown positive impacts on crop production, quality, and production rate, with relatively lower production costs [18]. This technique is considered sustainable and eco-friendly approach to converting organic waste into value-added products as well as motivating the usage of organic fertilizer rather than synthetic fertilizer.

To the best of our knowledge, this study is the first to report soil fertilization using special liquid fertilizer to escalate the growth and yield of red chilli plants that can simultaneously suppress environmental issues. In this study, the effect of the addition of special liquid fertilizer obtained from the organic waste processed in the Masaro bioreactors was examined on red chilli plants.

The feed for special liquid fertilizer production was organic waste. The growth, flowering, and fruit production of the red chilli plants upon supplementation with the special liquid fertilizer were monitored. Subsequently, the macro and micronutrient contents in the special liquid fertilizer were measured. Afterwards, pH, carbon content, microorganisms and amino acid contents in the special liquid fertilizer were determined.

2.0 MATERIALS AND METHODS

2.1 Raw Materials

Red chilli (*Capsicum annuum L.*) seeds and goat manure were obtained from local markets in Lampung, Indonesia. Organic wastes in the form of fruit, vegetable, and food wastes were collected from Institut Teknologi Sumatera (ITERA). Rice husk was procured from local rice milling in Lampung, Indonesia.

On the other hand, soil, as planting media, was obtained from ITERA Botanical Gardens. The soil was then mixed with food wastes as well as goat manure and rice husk with a weight ratio of soil: food waste:goat manure:rice husk 4:3:2:1.

The addition of food waste and goat manure is believed to boost the providence of organic macronutrient contents since it contains nitrate, ammonia, and phosphate [19]. Besides, rice husk is added to provide carbon source [20–22] as well as essential minerals such as silica, sodium, potassium, calcium, magnesium, aluminium and phosphor for soil ameliorant [22–25].

2.2 Production of Special Liquid Fertilizer

Special liquid fertilizer was produced in the system as depicted in Figure 1. It utilized two types of opaque plastic bioreactors that were made from High-Density Polyethylene (HDPE). The first bioreactor (max. volume of 60 L) fermented organic waste from the solid phase into slurry. This stage depolymerized glucose and protein complex molecules from the substrate.

After the solids were separated, the slurry was fed to the second bioreactor (max. volume of 120 L) where fermentation involved the entire liquid phase. Fermentation at this stage produced liquid product that contained amino acids and organic acids

Initially, 8 kg of organic waste (fruit, vegetable, and food waste) was chopped until it had a fine particle size of 4-5 mm. It was then poured into the first bioreactor. Dilute water and proprietary catalyst M1 were then in the mixture until a final volume of 20 L. The fermentation in the first bioreactor was performed at 32°C for 14 days.

Afterwards, the slurry from the first bioreactor was transferred into the second bioreactor. Dilute water and proprietary catalyst M2 were subsequently added until reached 100 L. The fermentation in the second bioreactor was carried out at 32°C for another 14 days until liquid fertilizer was obtained as the final product.

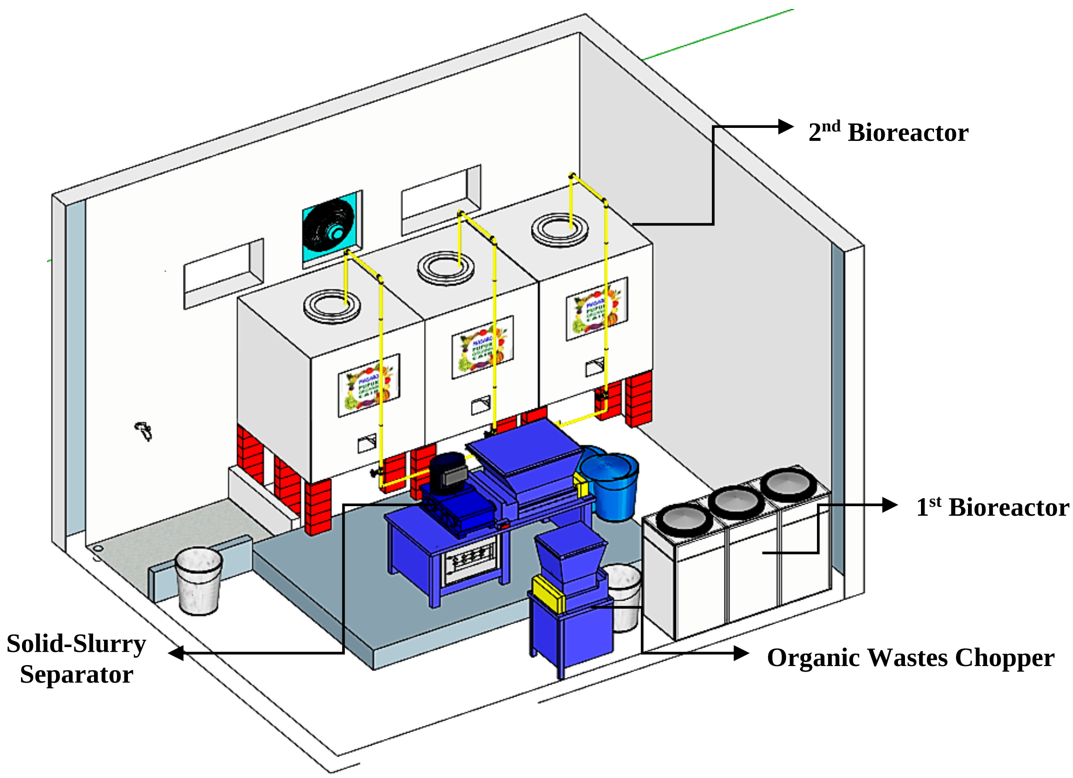


Figure 1 Special liquid fertilizer production system

2.3 Chemical and Biological Analysis of Special Liquid Fertilizer

The special liquid fertilizer was analyzed using atomic absorption spectroscopy (AAS) technique for assaying its carbon, macronutrient, and micronutrient contents. The instrument used a Double Beam High Performance Flame AAS ELICO SL-194 which was manufactured in India.

Other than that, pH of the fertilizer was recorded using a pH meter. The viability of microorganisms (bacteria and fungi) in the fertilizer was investigated using manual plating method. Sample was evenly spread onto the rich-agarous medium in the 85 mm Petri dish. After incubation for 2 days, isolated microorganisms on the plate formed visible colonies and was then counted as colony forming unit per gram (cfu/g).

Subsequently, the amino acids in the special liquid fertilizer sample were characterized using high-performance liquid chromatography with UV detection (HPLC-UV). The instrument was Thermo Scientific Vanquish Core HPLC which was manufactured in United States. It employed a nonpolar column. As much as 2.5 mL of sample was flowed to the column, filtered, and finally injected into the instrument.

2.4 Applications of Special Liquid Fertilizer on Red Chilli Plants

The experiment was carried out for 77 days from March 2023 to May 2023 in ITERA Botanical Gardens, Way Huwi, Jati Agung, South Lampung. The red chilli seeds were planted in the soil and placed in a cylindrical polybag pot with a diameter of 45 cm and height of 45 cm. Three pots planted with red chilli plants were prepared to study the effect of the addition of special liquid fertilizer on the growth of the plants. The special liquid fertilizer obtained from the bioreactors was initially diluted using potable water to produce a concentration of 5.0 mL/L and 7.5 mL/L. Each concentration had a fertilizer spray dose of 0.8 mL.

The red chilli plants grown in the first pot, as a control, were not added to the special liquid fertilizer. Meanwhile, the red chilli plants cultivated in the second and third pots were sprayed with 5.0 mL/L and 7.5 mL/L of special liquid fertilizer, respectively. The fertilizer was sprayed on the surface of the red chilli leaves and in the planting media once a week at 10:00 AM.

The parameters monitored during the investigation were height increase of red chilli plants and leaves area enlargement as vegetative parameters as well as number of red chilli flowers and fruits as generative parameters. All of the vegetative and generative parameters were measured in triplicate and analysis of variance (ANOVA) with two-factor replication was performed to assay its significance.

Apart from that, day and night temperatures at the chilli planting area were also monitored with a GL-89 digital corona hygro-thermometer. Day temperature recordings were carried out at 10:00 AM and 14:00 PM whereas night temperature recordings were performed at 20:00 PM and 00:00 AM. All recordings were carried out regularly until the 77th day.

3.0 RESULTS AND DISCUSSION

3.1 Chemical and Biological Analysis of Special Liquid Fertilizer

The special liquid fertilizer was produced in the bioreactors using organic wastes as the feedstock. The characterization results by means of macro and micronutrient contents are outlined in Table 1. The macronutrients include organic nitrogen and NPK (NO_3, P_2O_5, and K_2O) while micronutrients are in the form of Fe, Mn, Cu, Zn, B, and Mo.

The results present that nutrient contents in the special liquid fertilizer met the minimum amount of nutrient requirement in organic fertilizer [26]. Moreover, the pH of the special liquid fertilizer was close to neutral conditions, which has extremely low possibilities of soil acidification and environmental damage.

In fertilizer, nitrogen acts as a nutritional factor for plant growth and development [27]. This element is essential for the metabolism in plants due to its main function in protein, nucleic acid, and chlorophyll formation [28]. On the other hand, phosphorus plays a vital role in root development, flower formation, and fruit ripening [29,30].

Furthermore, potassium stimulates stronger stem and root growth as well as augments resistance to environmental stresses. This element is also involved in various physiological and biochemical processes that can improve crop quality and prevent plant diseases [31].

Table 1 Macro and micronutrient contents in special liquid fertilizer

Parameter	Unit	Measured Value	Standard Value [26]
C-organic	%w/v	14.25	> 10
pH	-	6.93	4-9
Macronutrients:			
NPK (NO_3 + P_2O_5 + K_2O)	%w/v	2.77	2-6
N-organic	%w/v	9.53	> 0.5
Micronutrients:			
Fe	ppm	120.25	90-900
Mn	ppm	28.9	25-500
Cu	ppm	30.25	25-500
Zn	ppm	28.5	25-500
B	ppm	20.1	12-250
Mo	ppm	4.1	2-10

The microorganisms content in the special liquid fertilizer is tabulated in Table 2. The results reveal that this fertilizer contains plant growth-promoting rhizobacteria (*Azotobacter sp., Pseudomonas sp., Bacillus sp., and Lactobacillus sp.*) which is responsible for supplying essential macro and micronutrients to plants. The number of these bacteria is higher than the minimum requirement number of bacteria in organic fertilizer, which implies good properties of the fertilizer [26].

Azotobacter sp. has vital roles as plant growth promoter that can produce minerals and organic compounds available for plants from unavailable minerals and organic sources. This species tends to intensify plant growth and productivity, and its population is greatly affected by the presence of other microorganisms [32].

Pseudomonas sp. is responsible for plant growth and disease resistance. These bacteria can also perform nitrogen fixation, phosphate solubilization, siderophore formation, and antibiotic production [6]. *Bacillus sp.* works as an effective biocontrol agent due to its ability to suppress phytopathogenic fungi [33]. Other than that, *Lactobacillus sp.* promotes seed germination and elongates the plumule [34].

Beyond Rhizobacteria, the presence of nitrogen-fixing bacteria is important to augment plant productivity by converting atmospheric nitrogen into ammonia that plants can absorb [35]. The phosphate-solubilizing bacteria also contribute to solubilizing phosphorus and potassium, suppressing pathogen levels, and intensifying plant productivity via the formation of plant growth regulators [36].

In this fertilizer, fungi are detected in the form of *Trichoderma sp.* which act as biocontrol agents because of their ability to combat pathogens [37]. The levels of pathogens in the special liquid fertilizer were significantly lower than the maximum allowable value of pathogen levels in organic fertilizer, which were not likely to cause any adverse effects on soil and plants [26].

Table 2 Microorganisms in special liquid fertilizer

Microorganisms	Measured Value (cfu/g)	Standard Value (cfu/g) [26]
Rhizobacteria:		
Azotobacter sp.	1.06×10^7	$\geq 1\times10^5$
Pseudomonas sp.	7.38×10^7	
Bacillus sp.	6.75×10^7	
Lactobacillus sp.	4.68×10^7	
Nitrogen-Fixing Bacteria	6.22×10^6	$\geq 1\times10^5$
Phosphate-Solubilizing Bacteria	7.01×10^3	$\geq 1\times10^5$
Cellulolytic Bacteria	3.77×10^5	$\geq 1\times10^5$
Chitinolytic Bacteria	1.63×10^5	$\geq 1\times10^5$
Fungi:		
Trichoderma sp.	2.54×10^6	$\geq 1\times10^5$
Pathogen:		
Escherichia coli	1.10×10^2	$< 1\times10^3$
Salmonella sp.	3.00×10^1	

The amino acid contents in the special liquid fertilizer are summarized in Table 3. Amino acids have positive effects on plants that can upgrade plant yield and crop quality. When the amino acids are sprayed at different stages of plant growth, they alleviate environmental stress by altering the osmotic potential of plant tissue which can accelerate biochemical and physiological processes in the formation of biomolecules [38]. These compounds are also responsible for the plant signalling process and stress response [39].

In detail, different types of amino acids have different roles in plant growth and development. Chlorophyll synthesis involves alanine, lysine, and serine. Phenylalanine and tyrosine help to stimulate root growth. Aspartic acid, lysine, methionine, and threonine stimulate plant germination [40]. In the meantime, proline, hydroxyproline, and lysine regulate water balance in plants, act as anti-stress agents, and signify pollen fertility [41].

Serine, tryptophan, and valine are related to the synthesis of auxin. Alanine and arginine work as virus and cold-weather-resistant compounds [42]. Glutamic acid is useful as a growth stimulator as well as provider of organic nitrogen and protein synthesis. Glycine is involved in cell division [43]. Cysteine and histidine keep a micronutrient from undesirable reactions in soil [44].

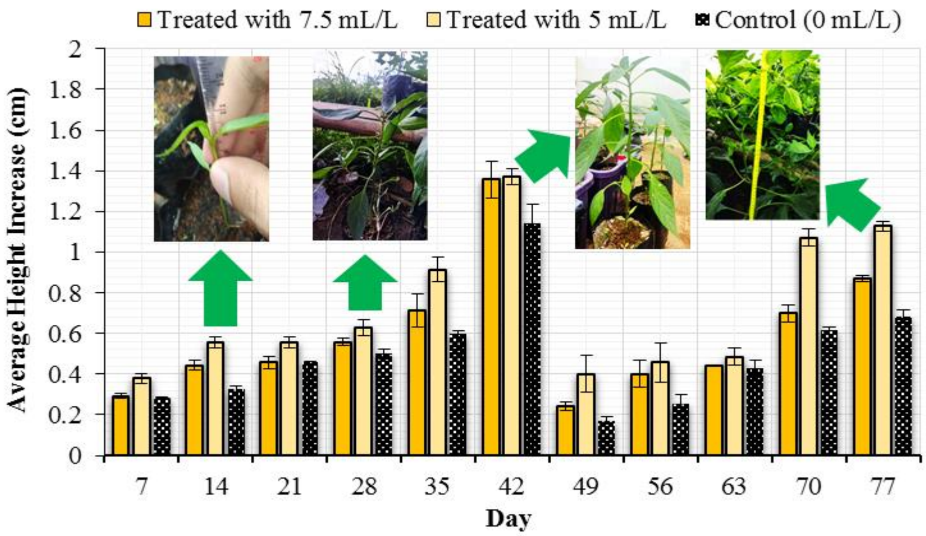
Table 3 Amino acid contents in special liquid fertilizer

Amino Acid	Content (ppm)	Amino Acid	Content (ppm)	Amino Acid	Content (ppm)
Glycine	402	Histidine	136.06	Serine	830.17
Alanine	338.66	Isoleucine	37.82	Cystine	48.42
Arginine	428.38	Leucine	67.81	Threonine	257.31
Aspartic acid	399.37	Lysine	156.34	Tyrosine	698.74
Glutamic acid	394.11	Methionine	732.20	Tryptophan	16.86
Phenylalanine	614.07	Proline	1071.84	Valine	236.32

3.2 Vegetative Parameter Results

3.2.1 Height Increase of Red Chilli Plants

The red chilli plants were grown in the planting media with different treatments. The average height increase of the red chilli plants was monitored for 77 days, and the results are plotted in Figure 2. It can be seen that there is a significant difference in the average height increase of the red chilli plants treated with special liquid fertilizer and control as strengthened by ANOVA results since the $P_{value} < 0.05$. This is caused by the K element which can accelerate the height growth of chillies. This is also supported by research on the effect of K fertilization on lowland rice growth which tends to induce plant heights. It shows that the addition of K augments grain weight which is reflected by large grain volumes and higher height of rice plants [45].



ANOVA: Two-Factor With Replication

Source of Variation	*Sum of Square*	*Degree of Freedom*	*Mean Square*	*F-value*	*P-value*	*F critical*
Sample	7.199	10	0.720	181.331	5.789E-44	1.977
Columns	0.198	2	0.099	24.910	8.711E-09	3.136
Interaction	1.273	20	0.064	16.034	4.018E-18	1.732
Within	0.262	66	0.004			
Total	8.932	98				

Figure 2 Average height increase of red chilli plants monitored for 77 days of planting time equipped with ANOVA results [*Inserted figure: Chilli plant at day 14, day 28, day 42, and day 77*]

The addition of 5 mL/L of fertilizer gives more superior performance than 7.5 mL/L because there is an excess dose of N and P in the soil which impacts an imbalance of nutrients and growth inhibition. Similar results were reported by Medeiros et al. on a morphophysiological study of eggplants flooded with doses of N and P [46]. Likewise, it is also found that the interaction between doses of N and P affects the growth and physiological characteristics of eggplants in the form of nutrient imbalance.

Nevertheless, in the 7th week (days 43 to 48), the average height increase in chilli plants reduces drastically. It happens because of the parasitic exposure in chilli plants caused by peach aphids (*Myzus persicae*) and cotton aphids (*Aphis gossypii*) on the underside of leaves and on the top of chilli plants.

Aphids attack chilli plants by sucking the fluid from the leaves and shoots. Long-term effects cause the leaves to wrinkle, turn yellowish, twist, and stunt plant growth [47]. After the pest attack was taken over, the height increase of the chilli plants slowly escalated again and even increased with the exponential pattern.

3.2.2 Leaves Area Enlargement

Leaves area enlargement is calculated from the increase in leaf length and leaf width. These two parameters are then multiplied and the result is multiplied again by a factor of 0.73 [48]. This procedure leads to the production of leaf area enlargement as presented in Figure 3. The ANOVA results of leaf area enlargement have P_{value} of below 0.05 which reflects that the application of fertilizer produces a meaningful discrepancy compared to those without the use of fertilizer.

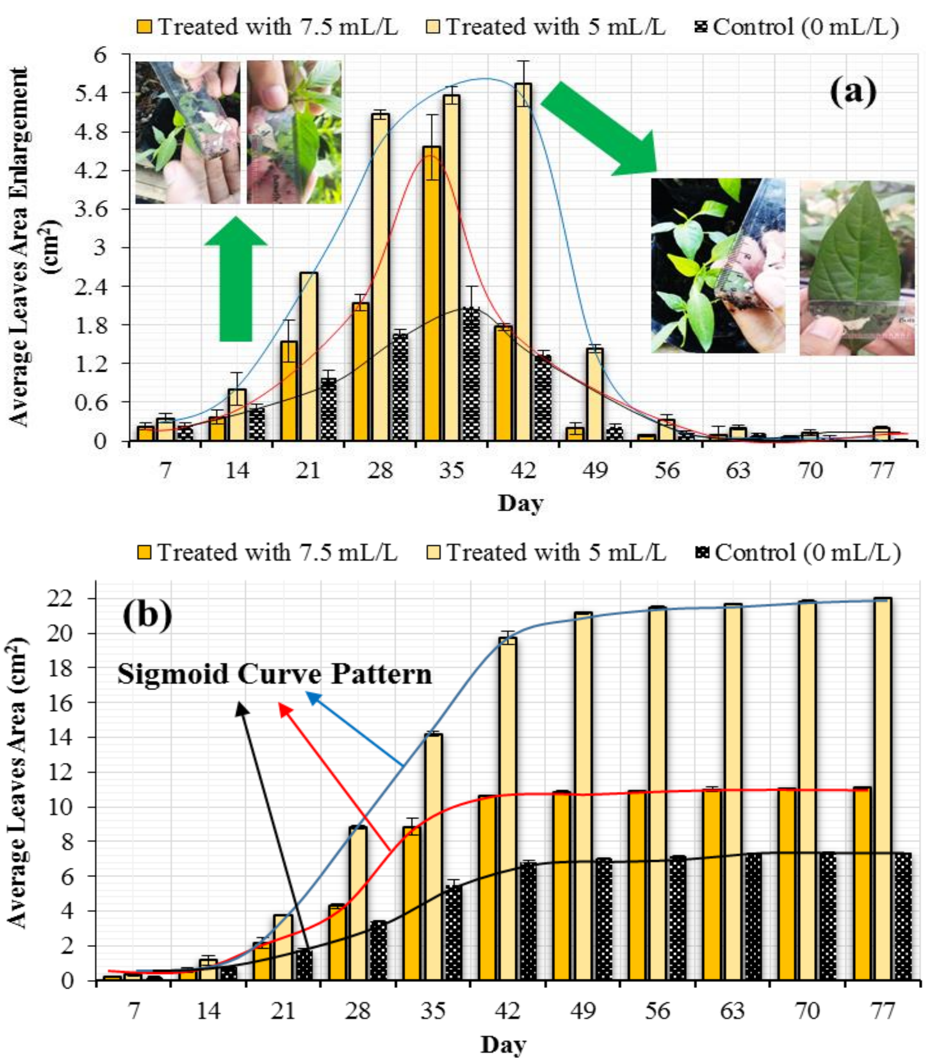
A fertilizer concentration of 5 mL/L gives the greatest value, the same as found in the height increase of chilli plant. This is logical because these two vegetative parameters have similar characteristics. The optimal amount of nutrients in fertilizer (in this case = 5 mL/L) induces the metabolism to produce its own cells. Cell growth from the vegetative point of view is indicated by height increase as well as leaves area enlargement.

Interestingly, the pattern of leaves area enlargement is different from the height increase pattern. The height increase pattern is exponential, whereas the pattern for leaves area enlargement forms a normal distribution curve for all treatment variations (see blue, red, and black curves in Figure 3a).

It should be remembered that aphid attacks only occur between days 43 to 48. This pest attack causes the plant height increase to slow down as Figure 2 conveys. It should also be noted that pest attacks do not reduce the plant height, but reduce the plant height increase. Once resolved, the rest days follow the normal growth pattern where the plant height increase follows exponential again.

This condition is similar to the pattern of leaves area enlargement. Pest attacks cause leaves to shrink and wrinkle because the nutrient fluid is absorbed by the pest [47]. However, from our monitoring in this study, the pest has not yet caused leaves shrinkage because the leaves area enlargement remains positive. If the leaves area shrinks or wrinkles, the enlargement value will definitely be negative.

Although each plant has a different leaves form and vegetative growth pattern, cumulative leaves expansion under sunlight actually generally meets a sigmoidal curve [49]. The results of this study are in line because the leaves area from day to day (cumulative mode) follows a sigmoidal curve as in Figure 3b. In other words, the leaves area enlargement (non-cumulative mode) pattern certainly follows a normal distribution (Figure 3a).



ANOVA: Two-Factor With Replication

Source of Variation	*Sum of Square*	*Degree of Freedom*	*Mean Square*	*F-value*	*P-value*	*F critical*
Sample	46.998	10	4.700	82.430	2.514E-33	1.977
Columns	1.343	2	0.672	11.782	4.214E-05	3.136
Interaction	12.293	20	0.615	10.780	7.053E-14	1.732
Within	3.763	66	0.057			
Total	64.398	98				

Figure 3 Average leaves area enlargement (a) and average leaves area (b) monitored for 77 days of planting time equipped with ANOVA results [*Inserted figure (a): Leaves length at day 14 and day 42; Leaves width at day 14 and day 42*]

3.3 Generative Parameter Results

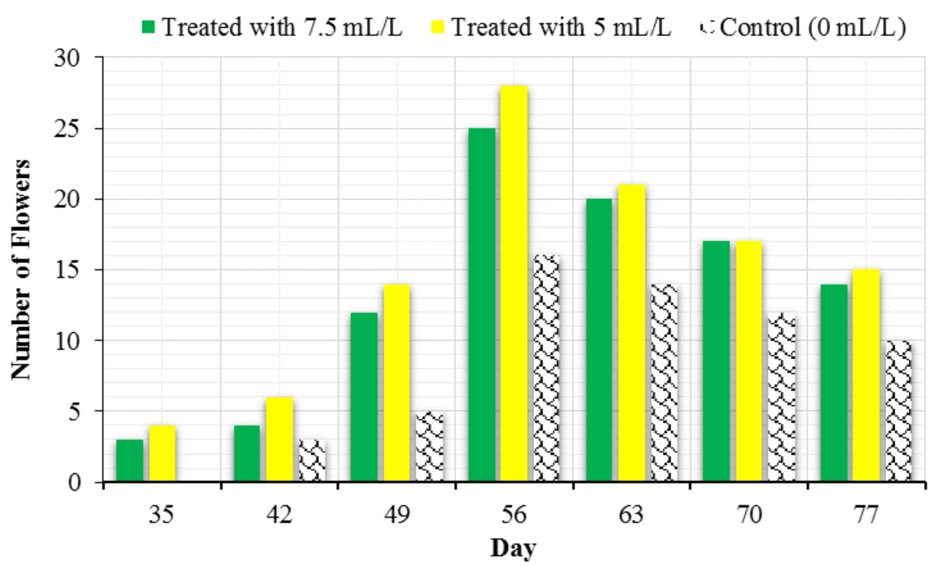
3.3.1 Number of Red Chilli Flowers

The number of chilli flowers for 77 days was observed. The results reflect that the plants treated with the special liquid fertilizer have a one-week-earlier flowering period than control as served in Figure 4. This phenomenon occurs due to the attendance of macro and micronutrients in the soil upon fertilization that accelerate chilli flowering. The nutrients absorbed by the plants are not only used for plant growth but also for plant flowering, as proven by the higher number of flowers monitored. The liquid fertilizer is proven to provide additional NPK to the plants which is responsible for accelerated plant flowering [50] and enhanced fruit production [51].

Kumari et al. studied the effect on growth, yield, and quality of tomato plants and concluded that liquid fertilizer from 10% aqueous seaweed extract promotes earlier flowering periods than control (without fertilizer). This is due to a diverse range of bioactive compounds in their fertilizer (e.g., vitamins, growth regulators, K mineral, P mineral, organic nitrogen), which assist in preserving the nutrients and moisture in the soil [52].

In the study carried out by Aluko et al. on NPK fertilizer implementation on muskmelon (*Cucumis melo L.*), the fertilized plants provided an earlier flowering period than the plants without fertilization. The number of flowers observed increased with all treatments and reached a maximum value due to the contribution of N, P, and K elements in their fertilizer [53].

From Figure 4, the treatment using fertilizer provides a meaningful impact on flower number as evidenced by $P_{value} < 0.05$. Nevertheless, the alteration of the fertilizer concentration from 5 mL/L to 7.5 mL/L slightly reduced the number of flowers (from 28 to 25 on the 56th day). This is in line with the phenomenon reported by Ye et al. where too much N content in fertilizer can inhibit flowering. Although P and K elements also increase at higher concentrations and doses of liquid fertilizer, the effect of these two elements is weaker than the influence of N [54].



ANOVA: Two-Factor With Replication

Source of Variation	Sum of Square	Degree of Freedom	Mean Square	F-value	P-value	F critical
Sample	21.201	10	43.042	46.337	1.263E-11	1.977
Columns	4.303	2	0.143	35.566	4.221E-04	3.136
Interaction	4.536	20	0.073	11.750	2.556E-05	1.732
Within	2.333	66	0.047			
Total	32.374	98				

Figure 4 The number of flowers in the red chilli plants monitored for 77 days of planting time

In this study, the first time the plant flowers is at the 5th week of observation (or on the 35th day). The number of flowers reaches maximum on the 56th day of observation. During this period, the planting location experiences a rainy season and the average temperature is (25.9±1.0)°C during the day and (19.5±1.4)°C at night.

Afterwards, the number of flowers dropped from days 56 to 77 because of dry season in May 2023 which led to higher day temperatures at (29.3±1.4)°C and night temperatures at (25.0±0.7)°C as seen in Figure 5.

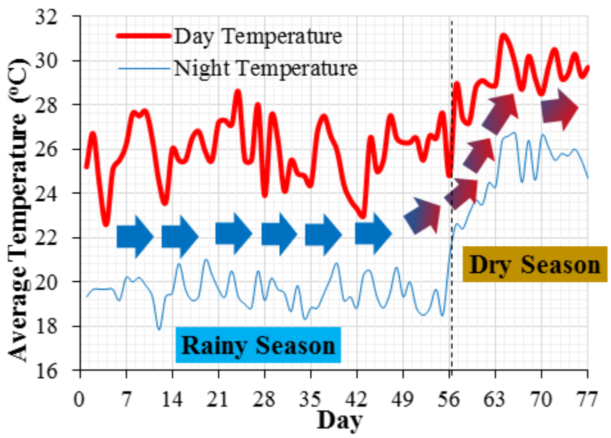


Figure 5 Average day and night temperatures monitored for 77 days of planting time [The arrow indicates increasing temperature conditions ahead of the dry season, indicated by the change in color from blue (low temperature) to red (high temperature) as well as the direction of the arrow increasing]

High temperature is the main environmental stress that sharply upgrades flowering duration and lessens the number of flowers and pods generated compared with ambient temperature [55]. Polowick and Shawney reported that day temperatures of 18-23°C and night temperatures of 15-18°C resulted in greater flower numbers of chilli plants (*Capsicum annuum L.*) [56]. From another study, temperature ranges of 18-20°C are necessary to optimize chilli plant flowering [57].

3.3.2 Number of Red Chilli Fruits

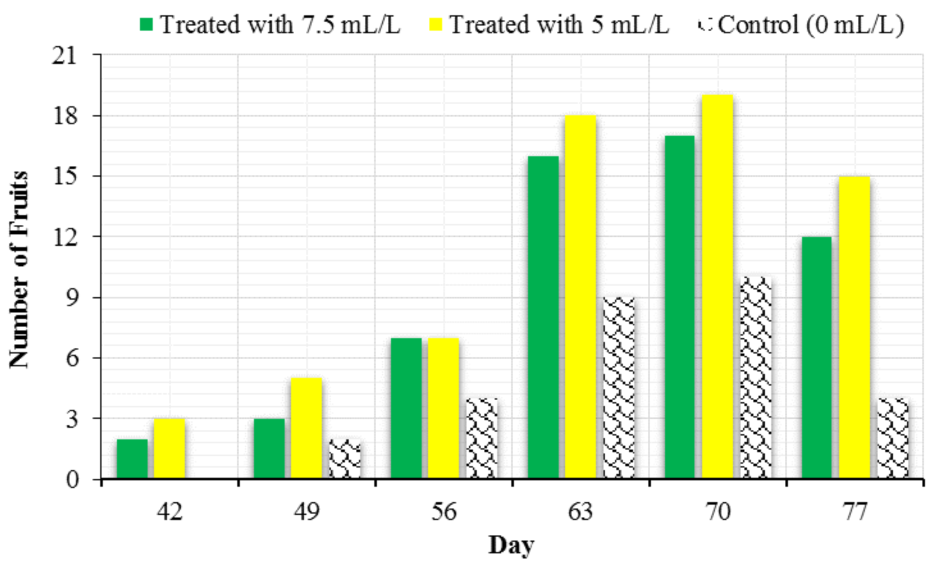
The number of chilli fruits produced during 77 days of planting time is shown in Figure 6. The moment when this plant first bears fruit is 1 week after this plant's first flowers, namely on the 42nd day or 6th week of observation. The results also indicate that the plants treated with the special liquid fertilizer exhibited earlier fruit production than control. The chilli fruits start to form one week after the formation of flowers.

Moreover, the addition of special liquid fertilizer provides a greater number of fruits compared with no fertilizer treatment. It is strengthened by the statistical analysis that P_{value} is below 0.05. The concentration of 5 mL/L of fertilizer gives the highest flower number, i.e. 19 on the 70th day.

This condition is reinforced to become an optimum concentration of fertilizer for balancing N, P, and K nutrients [54]. Higher nitrogen concentration in organic manure liquid fertilizer tends to cause an imbalance of secondary and micronutrients in the soil, resulting in low yields [58]. Excessive nitrate in liquid NPK fertilizer also leads to poor efficiency of nutrient usage and lower photosynthetic rate which not only reduces plant growth but distracts the flower and fruit development [59]. Besides, sustainable nutrient management schemes are of great importance for achieving environmental and ecological sustainability [60].

The number of fruits from the chilli plants also remains stagnant after the 63rd day and drops after the 77th day because the plants enter the vegetative stage. This condition happens because of higher temperatures during day and night due to dry season at that moment (Figure 5), similar to the cause of the flower drop.

It is in line with the fact that the growth of chilli plants is strongly related to pollen which is susceptible to slight temperature changes during reproductive development [61]. Temperatures that are too high or too low cause pollen infertility which further leads to sterility of chilli plants [56,62].



ANOVA: Two-Factor With Replication

Source of Variation	*Sum of Square*	*Degree of Freedom*	*Mean Square*	*F-value*	*P-value*	*F critical*
Sample	7.364	10	7.337	59.389	1.51E-11	1.977
Columns	4.288	2	0.756	21.348	2.52E-04	3.136
Interaction	0.207	20	0.069	20.073	1.77E-05	1.732
Within	0.931	66	0.103			
Total	12.789	98				

Figure 6 The number of chilli fruits produced in the red chilli plants monitored for 77 days of planting time

4.0 CONCLUSION

In summary, special liquid fertilizer was produced by Masaro bioreactors using fruit, vegetable, and food wastes as feed. It has been successfully applied to stimulate the growth and productivity of red chilli plants for 77 days. From the results, the addition of special liquid fertilizer enriches the average height increase and leaves area enlargement of the red chilli plants. Under the same spray dose of 0.8 mL of special liquid fertilizer, the treatment with a concentration of 5 mL/L gives the maximum productivity of red chilli plants because of balanced N, P, and K contents. The rectified productivity is also reinforced by the presence of plant growth-promoting rhizobacteria, such as *Azotobacter sp.*, *Pseudomonas sp.*, *Bacillus sp.*, and *Lactobacillus sp.* that provide essential macro and micronutrients for the red chilli plants. In addition, the special liquid fertilizer also comprised essential amino acids that are vital for red chilli plants. Furthermore, the plants treated with the fertilizer reveal earlier flowering and fruit production. In contrast, the phenomena of flower drop and fruit loss are observed due to dry season which reflects higher temperatures at day and night. Notwithstanding, fertilization using special liquid fertilizer is overall promising and can be applied in agricultural sectors to enrich crop productivity that is sustainable and eco-friendly.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Acknowledgement

The authors thank Institut Teknologi Sumatera (ITERA) for financial support through ITERA Research Grant.

References

[1] Widuri, L. I., Lakitan, B., Sakagami, J., Yabuta, S., Kartika, K., Siaga, E. 2020. Short-term Drought Exposure Decelerated Growth and Photosynthetic Activities in Chili Pepper (Capsicum annuum L.). *Ann Agric Sci.* 65: 149-58. https://doi.org/10.1016/j.aoas.2020.09.002.

[2] Susilowati, D. N., Karomah, D., Dasumiati. 2020.

Application of Plant Growth Hormone from Bacillus vallismortis to Improve the Growth and Production of Chili Plants. *AIP Conf. Proc*. 030024. https://doi.org/10.1063/5.0015959.

[3] García-Gaytán, V., Gómez-Merino, F. C., Trejo-Téllez, L. I., Baca-Castillo, G. A., García-Morales, S. 2017. The Chilhuacle Chili (Capsicum annuum L.) in Mexico: Description of the Variety, Its Cultivation, and Uses. *Int J Agron*. 2017: 1-13. https://doi.org/10.1155/2017/5641680.

[4] Pandey, P., Ge, Y., Stoerger, V., Schnable, J. C. 2017. High Throughput In vivo Analysis of Plant Leaf Chemical Properties Using Hyperspectral Imaging. *Front Plant Sci*. 8: 01348. https://doi.org/10.3389/fpls.2017.01348.

[5] Kathpalia, R., Bhatla, S. C. 2018. Plant Mineral Nutrition. *Plant Physiol. Dev. Metab.* 37-81. https://doi.org/10.1007/978-981-13-2023-1_2.

[6] Fidiyawati, E., Setyorini, D., Sa'adah, S. Z., Prayitno, A., Istiqomah, N. 2021. The Effect of the Consentration of Macro-nutrient-liquid-foliar- NPK and Dosage of NPK 15-5-15 Fertilizer to Improve the Quality of Red Chilies (Capsicum annum L.). *IOP Conf Ser: Earth Environ Sci*. 759: 012039. https://doi.org/10.1088/1755-1315/759/1/012039.

[7] Qiao, C., Xu, B., Han, Y., Wang, J., Wang, X., Liu, L., *et al*. 2018. Synthetic Nitrogen Fertilizers Alter the Soil Chemistry, Production and Quality of Tea. A Meta-analysis. *Agron Sustain Dev*. 38: 10. https://doi.org/10.1007/s13593-017-0485-z.

[8] Bai, Y-C., Chang, Y-Y., Hussain, M., Lu, B., Zhang, J-P., Song, X-B., *et al*. 2020. Soil Chemical and Microbiological Properties are Changed by Long-term Chemical Fertilizers that Limit Ecosystem Functioning. Microorganisms. 8: 694. https://doi.org/10.3390/microorganisms8050694.

[9] Sunarpi, H., Pebriani, S. A., Ambana, Y., Putri, F. E., Nikmatullah, A., Ghazali, M., *et al*. 2019. Effect of Inorganic Fertilizer and Brown Alga Solid Ectract on Growth and Yield of Rice Plants. *AIP Conf. Proc*. 070006. https://doi.org/10.1063/1.5141320.

[10] Noh, N. M., Azhari, N. A., Mohamad, S. N. M. Rosa. 2015. Bitamina (organic fertilizer) Effects in Enhancing Rosa Centifolia Resistancy and Flowering Process. *Procedia - Soc Behav Sci.* 195: 1715-8. https://doi.org/10.1016/j.sbspro.2015.06.282.

[11] Suri, A. M., Yudono, P. 2020. Effects of Chromolaena Odorata Compost on Soil and Nutrient Uptake of Lettuce (Lactuca sativa). *Planta Trop J Agro Sci.* 8. https://doi.org/10.18196/pt.2020.111.33-38.

[12] Badar, R., Khan, M., Batool, B., Shabbir, S. 2015. Effects of Organic Amendments in Comparison with Chemical Fertilizer on Cowpea Growth. *Int J Appl Res.* 1: 66-71.

[13] Roy, M., Karmakar, S., Debsarcar, A., Sen, P. K., Mukherjee, J. 2013. Application of Rural Slaughterhouse Waste as an Organic Fertilizer for Pot Cultivation of Solanaceous Vegetables in India. *Int J Recycl Org Waste Agric*. 2: 1-11. https://doi.org/10.1186/2251-7715-2-6.

[14] Setyowati, N., Muktamar, Z., Suriyanti, B., Simarmata, M. 2014. Growth and Yield of Chili Pepper as Affected by Weed Based Organic Compost and Nitrogen Fertilizer. *Int J Adv Sci Eng Inf Technol.* 4: 84-7. https://doi.org/10.18517/ijaseit.4.2.382.

[15] Anggraheni, Y. G. D., Nuro, F., Paradisa, Y. B. 2019. Effect of Organic Fertilizer on Growth and Yield of Chili Pepper. *Proc 3rd SATREPS Conf*. 2: 30-7.

[16] Abidin, A. Z., Choliq, N. S., Yemensia, E. V., Hastuti, R. 2020. Study on Environmental Health Aspect of Plastic Refinery in MASARO Cirebon Unit in Indonesia. *2020 4th Int. Conf. Green Energy Appl. IEEE*. 116-20. https://doi.org/10.1109/ICGEA49367.2020.239716.

[17] Abidin, A. Z., Yemensia, E. V., Wijaya, K. W., Rahardjo, A. P. 2021. Circular Economy on Non-Biodegradable Waste Management with MASARO Technology. *IOP Conf Ser: Mater Sci Eng.* 1143: 012052. https://doi.org/10.1088/1757-899X/1143/1/012052.

[18] Abidin, A. Z., Bramantyo, H., Baroroh, M. K., Egiyawati, C. 2021. Circular Economy on Organic Waste Management with MASARO Technology. *IOP Conf Ser: Mater Sci Eng*. 1143: 012051. https://doi.org/10.1088/1757-899X/1143/1/012051.

[19] Kurniawati, A., Windriyati, R. D. H., Wulansari, N. K., Toth, G., Toth, Z. 2021. Alternatives for Circular Bioeconomy in Organic Farming under Excessive Nutrients (Goat manure and Arbuscular Mycorrhizal Fungi): A Case Study in Indonesia. *Sustainability*. 13: 12333. https://doi.org/10.3390/su132212333.

[20] Steven, S., Restiawaty, E., Pasymi, P., Bindar, Y. 2021. Influences of Pretreatment, Extraction Variables, and Post Treatment on Bench-scale Rice Husk Black Ash (RHBA) Processing to Bio-silica. *Asia-Pac J Chem Eng.* 16: e2694. https://doi.org/10.1002/apj.2694.

[21] Steven, S., Restiawaty, E., Bindar, Y. 2022. Operating Variables on Production of High Purity Bio-silica from Rice Hull Ash by Extraction Process. *J Eng Technol Sci.* 304. https://doi.org/10.5614/j.eng.technol.sci.2022.54.3.4.

[22] Steven, S., Pasymi, P., Hernowo, P., Restiawaty, E., Bindar, Y. 2023. Investigation of Rice Husk Semi-continuous Combustion in Suspension Furnace to Produce Amorphous Silica in Ash. *Biomass Conv Bioref.* https://doi.org/10.1007/s13399-023-04777-7.

[23] Bindar, Y., Steven, S., Kresno, S. W., Hernowo, P., Restiawaty, E., Purwadi, R., *et al*. 2022. Large-scale Pyrolysis of Oil Palm Frond using Two-box Chamber Pyrolyzer for Cleaner Biochar Production. *Biomass Conv Bioref.* https://doi.org/10.1007/s13399-022-02842-1.

[24] Steven, S., Hernowo, P., Restiawaty, E., Irawan, A., Rasrendra, C. B., Riza, A., *et al*. 2022. Thermodynamics Simulation Performance of Rice Husk Combustion with a Realistic Decomposition Approach on the Devolatilization Stage. *Waste Biomass Valor.* 13: 2735-47. https://doi.org/10.1007/s12649-021-01657-x.

[25] Shen, Y. 2017. Rice Husk Silica Derived Nanomaterials for Sustainable Applications. *Renew Sustain Energy Rev*. 80: 453-66. https://doi.org/10.1016/j.rser.2017.05.115.

[26] Minister of Agriculture of the Republic of Indonesia. 2019. Decree of the Minister of Agriculture of the Republic of Indonesia No. 261/KPTS/SR.310/M/4/2019 on the Minimum Technical Requirements for Organic Fertilizer, Biological Fertilizer, and Soil Supplement.

[27] Santos, M. L. dos, Berlitz, D. L., Wiest, S. L. F., Schünemann, R., Knaak, N., Fiuza, L. M. 2018. Benefits Associated with the Interaction of Endophytic Bacteria and Plants. *Brazilian Arch Biol Technol.* 61: 1-11. https://doi.org/10.1590/1678-4324-2018160431.

[28] Jilani, M. S., Afzal, M. F., Waseem, K. 2008. Effect of Different Nitrogen Levels on Growth and Yield of Brinjal (Solanum melongena L.). *J Agric Res.* 46: 245-51.

[29] Bora, R., Yadav, S. K., Chilwal, A., Chauhan, V., Bhandari, S. 2018. Effect of Long Term Balance Fertilizer Application on Growth Parameters of Rice (Oryza sativa L.). *Pharma Innov J.* 7: 596-8.

[30] Wezi, G. M., Sieglinde, S., Y. K-P. 2017. Biological Nitrogen Fixation and Yield of Pigeonpea and Groundnut: Quantifying Response on Smallholder Farms in Northern Malawi. African J Agric Res. 12: 1385-94. https://doi.org/10.5897/AJAR2017.12232.

[31] Cakmak, I. 2005. The Role of Potassium in Alleviating Detrimental Effects of Abiotic Stresses in Plants. *J Plant Nutr Soil Sci.* 168: 521-30. https://doi.org/10.1002/jpln.200420485.

[32] Amira, S. S., Ebtsam, M. M., Osama, N. M. 2015. Tolerance of Bio-fertilized Delonix Regia Seedlings to Irrigation Intervals. *J Hortic For.* 7: 73-83. https://doi.org/10.5897/JHF2014.0380.

[33] Ait-Kaki, A., Kacem-Chaouche, N., Ongena, M., Kara-Ali, M., Dehimat, L., Kahlat, K., *et al*. 2014. In Vitro and In Vivo

Characterization of Plant Growth Promoting Bacillus Strains Isolated from Extreme Environments of Eastern Algeria. *Appl Biochem Biotechnol*. 172: 1735-46. https://doi.org/10.1007/s12010-013-0617-0.

[34] Hussein, K. A., Joo, J. H. 2018. Plant Growth-promoting Rhizobacteria Improved Salinity Tolerance of Lactuca sativa and Raphanus sativus. *J Microbiol Biotechnol*. 28: 938-45. https://doi.org/10.4014/jmb.1712.12027.

[35] Chapin, F. S. 1980. The Mineral Nutrition of Wild Plants. *Annu Rev Ecol Syst*. 11: 233-60. https://doi.org/10.1146/annurev.es.11.110180.001313.

[36] Sturz, A. V., Christie, B. R. 2003. Beneficial Microbial Allelopathies in the Root Zone: The Management of Soil Quality and Plant Disease with Rhizobacteria. *Soil Tillage Res.* 72: 1073-23. https://doi.org/10.1016/S0167-1987(03)00082-5.

[37] Sharma, P., Vignesh, K. P., Ramesh, R., Saravanan, K., Deep, S., Sharma, M., *et al*. 2011. Biocontrol Genes from Trichoderma Species: A Review. *African J Biotechnol.* 10: 1-10. https://doi.org/10.5897/AJBX11.041.

[38] Baqir, H. A., Zeboon, N. H., Al-behadili, A. A. J. 2019. The Role and Importance of Amino Acids within Plants: A Review. *Plant Arch*. 19: 1402-10.

[39] Hildebrandt, T. M., Nunes Nesi, A., Araújo, W. L., Braun, H-P. 2015. Amino Acid Catabolism in Plants. *Mol Plant.* 8: 1563-79. https://doi.org/10.1016/j.molp.2015.09.005.

[40] Salvador, V. H., Lima, R. B., dos Santos, W. D., Soares, A. R., Böhm, P. A. F., Marchiosi, R., *et al*. 2013. Cinnamic Acid Increases Lignin Production and Inhibits Soybean Root Growth. *PLoS ONE*. 8: e69105. https://doi.org/10.1371/journal.pone.0069105.

[41] Trovato, M., Funck, D., Forlani, G., Okumoto, S., Amir, R. 2021. Editorial: Amino Acids in Plants: Regulation and Functions in Development and Stress Defense. *Front Plant Sci.* 12. https://doi.org/10.3389/fpls.2021.772810.

[42] Popko, M., Michalak, I., Wilk, R., Gramza, M., Chojnacka, K., Górecki, H. 2018. Effect of the New Plant Growth Biostimulants Based on Amino Acids on Yield and Grain Quality of Winter Wheat. *Molecules* 23: 470. https://doi.org/10.3390/molecules23020470.

[43] Sowmya, R. S., Warke, V. G., Mahajan, G. B., Annapure, U. S. 2023. Effect of Amino Acids on Growth, Elemental Content, Functional Groups, and Essential Oils Composition on Hydroponically Cultivated Coriander under Different Conditions. *Ind Crops Prod*. 197: 116577. https://doi.org/10.1016/j.indcrop.2023.116577.

[44] Liu, G., Hanlon, Ez., Li, Y. 2022. Understanding and Applying Chelated Fertilizers Effectively based on Soil pH. University of Florida.

[45] Islam, A., Chandrabiswas, J., Sirajul, Karim, A. J. M., Salmapervin, M. S. T., Saleque, M. D. 2015. Effects of Potassium Fertilization on Growth and Yield of Wetland Rice in Grey Terrace Soils of Bangladesh. *Res Crop Ecophysiol.* 10: 64-82.

[46] Medeiros, A. de S, Nobre, R. G., de Queiroz, M. M. Fz., Pereira, M. de O, dos Santos, T. C., Gonzaga, G. B. M., *et al*. 2019. Morphophysiology of Eggplant Irrigated With Wastewater and Nitrogen and Phosphorus Doses in the Semi-arid Region of Brazil. *J Agric Sci.* 11: 470. https://doi.org/10.5539/jas.v11n5p470.

[47] Wulandari, P., Sulistyaningsih, E., Handayani, S., Purwanto, B. H. 2019. Growth and Yield Response of Maize (Zea mays L.) on Acid Soil to Different Rates of Humic Acid and NPK Fertilizer. *Ilmu Pertan Agricultural Sci.* 4: 76. https://doi.org/10.22146/ipas.36680.

[48] Rawson, H. M., Constable, G. A. 1980. Carbon Production of Sunflower Cultivars in Field and Controlled Environments. I. Photosynthesis and Transpiration of Leaves, Stems and Heads. *Funct Plant Biol.* 7: 555. https://doi.org/10.1071/PP9800555.

[49] Kriedemann, P. E., Virgona, J. M., Atkin, O. K. 2017. Growth Analysis: A Quantitative Approach. Price C, Munns R, editors. Plants Action, 2nd Ed., Australian Society of Plant Scientists. 1-40.

[50] Maluki, M., Ogweno, J., Gesimba, R. 2016. Evaluation of Nitrogen Effects on Yield and Quality of Watermelon {Citrullus lanatus (Thunb.) Matsumara & Nakai} Grown in the Coastal Regions of Kenya. *Int J Plant Soil Sci*. 9: 1-8. https://doi.org/10.9734/IJPSS/2016/18821.

[51] Kurniastuti, T. 2018. Effects of Rice Husk Ash and Eggshell on the Growth and Yield of Red Chili (Capsicum annuum L.). *J Acad Res Sci.* 3: 9-15. https://doi.org/10.30957/jares.v3i1.437.

[52] Kumari, R., Kaur, I., Bhatnagar, A. K. 2011. Effect of Aqueous Extract of Sargassum johnstonii Setchell & Gardner on Growth, Yield and Quality of Lycopersicon Esculentum Mill. *J Appl Phycol.* 23: 623-33. https://doi.org/10.1007/s10811-011-9651-x.

[53] Aluko, M. 2020. Sowing Dates and Fertilizer Application on Growth and Yield of Muskmelon (Cucumis melo L.) at Ado-Ekiti. *Asian J Agric Hortic Res*. 11-21. https://doi.org/10.9734/ajahr/2020/v5i330052.

[54] Ye, T., Li, Y., Zhang, J., Hou, W., Zhou, W., Lu, J., *et al*. 2019. Nitrogen, Phosphorus, and Potassium Fertilization Affects the Flowering Time of rice (Oryza sativa L.). *Glob Ecol Conserv*. 20: e00753. https://doi.org/10.1016/j.gecco.2019.e00753.

[55] Jumrani, K., Bhatia, V. S., Pandey, G. P. 2018. Screening soybean Genotypes for High Temperature Tolerance by in Vitro Pollen Germination, Pollen Tube Length, Reproductive Efficiency and Seed Yield. *Indian J Plant Physiol.* 23: 77-90. https://doi.org/10.1007/s40502-018-0360-1.

[56] Polowick, P. L., Sawhney, V. K. 1985. Temperature Effects on Male Fertility and Flower and Fruit Development in Capsicum annuum L. Sci Hortic (Amsterdam). 25: 117-27. https://doi.org/10.1016/0304-4238(85)90083-4.

[57] Kaimuddin, Ulfa F., Stoeber, S., Ramba, T., Iswoyo, H., Dermawan, R., *et al*. 2021. Growth and Production of Indigenous Katokkon Chilies of Toraja (Capsicum chinense jacq) in Various Organic Tithonia Compost Compositions. *IOP Conf Ser: Earth Environ Sci.* 870: 012045. https://doi.org/10.1088/1755-1315/870/1/012045.

[58] Bhatt, M. K., Labanya, R., Joshi, H. C. 2019. Influence of Long-term Chemical Fertilizers and Organic Manures on Soil Fertility - A Review. *Univers J Agric Res*. 7: 177-88. https://doi.org/10.13189/ujar.2019.070502.

[59] Albornoz, F., Heinrich, Lieth, J. 2015. Over Fertilization Limits Lettuce Productivity because of Osmotic Stress. *Chil J Agric Res.* 75: 284-90. https://doi.org/10.4067/S0718-58392015000400003.

[60] Ihtisham, M., Liu, S., Shahid, M. O., Khan, N., Lv. B., Sarraf, M., *et al*. 2020. The Optimized N, P, and K Fertilization for Bermudagrass Integrated Turf Performance during the Establishment and Its Importance for the Sustainable Management of Urban Green Spaces. *Sustainability.* 12: 10294. https://doi.org/10.3390/su122410294.

[61] Ozga, J. A., Kaur, H., Savada, R. P., Reinecke, D.M. 2016. Hormonal Regulation of Reproductive Growth under Normal and Heat-stress Conditions in Legume and Other Model Crop Species. *J Exp Bot.* 68: 1885-94. https://doi.org/10.1093/jxb/erw464.

[62] Najeeb, U., Sarwar, M., Atwell, B. J., Bange, M. P., Tan, D. K. Y. 2017. Endogenous Ethylene Concentration is Not a Major Determinant of Fruit Abscission in Heat-stressed Cotton (Gossypium hirsutum L.). *Front Plant Sci.* 8: 01615. https://doi.org/10.3389/fpls.2017.01615.