The Journal of Agricultural Sciences - Sri Lanka
Vol. 18, No 1, January 2023. Pp 01-13
http://doi.org/10.4038/jas.v18i1.10095

Organic Nutrient Solutions for Hydrophonic Spinach (*Basella alba*) Production in Urban Agriculture

B.A. Dhananjani[1] and K. Pakeerathan[2*]

Received:14th July 2021 / Accepted: 17th October 2022

ABSTRACT

Purpose: *Macro and micronutrients rich vegetable and fish wastes are generated hugely in Sri Lanka, but not recycled properly into valuable byproducts. It is a serious problem and needs to be managed to make environment free from pollution. Extraction of nutrients from organic wastes can be used as liquid fertilizers for hydroponic crop production even in congested urban cities.*

Research Method: *Organic hydroponic medium using vegetable waste extracts (M2), fish emulsion (M3), vermi tea (M4), the mixture of M2+M3+M4, and Albert's solution (M1-control) were prepared and tested on Spinach. The experimental setup was arranged in a CRD with four replicates. The nutritional qualities of formulated liquid fertilizers (N, P, K, Ca, Na), pH, EC, spinach growth parameters such as plant height, number of leaves per plant, leaf area, root length, weight (Fresh /Dry) were measured eight weeks after planting and subjected to ANOVA using SAS 9.1. Tukey's HSD multiple comparison test to identify the best treatment combination at P <0.05.*

Findings: *The results revealed that the amount of each N, P, K, Na, and Ca was significantly different between treatments (P <0.05). The highest quantity of each N (11.1mg/L), P (37.99mg/L), and K (145,5 mmol/L) was detected in M2. Whereas, Na and Ca quantities were highly significant in M4 with the values of 208.7 and 96.2 mmol/L, respectively. Plant height and root length in M1, M2 and M3 were significantly higher than those of other treatments. Fresh and dry weights were also significantly higher in M3, M1 and M2 treatments when compared with other treatments. The highest leaf number and leaf area were also recorded in M3 treatment after 8 weeks of planting.*

Originality/ Value: *This study shows that fish emulsion solution is found to be more promising and both fish emulsion and vegetable waste hydrophonics medium can be used as alternatives to Albert's solution.*

Keywords: *Basella alba, Fish emulsion, Hydroponics, Liquid organic fertilizer, Vegetable waste*

INTRODUCTION

The severe shortage of food production in the early 19th century has led to modernization in agriculture sector through the green revolution. Green revolution invented high yielding varieties are more chemical responsive, therefore, the world demand for synthetic fertilizer is estimated to increase N, P_2O_5, and K_2O by 1.5, 2.2, and 2.4 percent, respectively, from 2015 to 2020 (FAO, 2017). Overuse of agrochemicals are posing huge risks to human health and the natural environment (Mirlean and Roisenberg, 2006). considering facts, many country's agricultural policies are being transformed in a mean to promte organic agriculture. As we know food productivity is less

[1] *Department of Biosystem Technology, Faculty of Technology, University of Jaffna, Ariviyal Nagar, 44000, Kilinochchi, Sri Lanka.*

[2*] *Department of Agricultural Biology, Faculty of Agriculture, University of Jaffna, Ariviyal Nagar, 44000, Kilinochchi, Sri Lanka.*

pakeerathank@univ.jfn.ac.lk

https://orcid.org/0000-0001-7373-3481

through organic agriculture, we need more land. Agriculture has already encroached one-third of the total land area of the earth. Hence, it is not advisable to extend agriculture in new lands. Home gardening and urban agriculture would be the suitable approaches to produce vegetables for their own needs, but many cities are more congested due to the migration of rural people to city areas for jobs, high-level education, and enjoying other advanced facilities. Finding at least small land for cultivation in cities are costly and would be a difficult task in highly congested cities. City people are solely dependent on rural agriculture, but, COVID-19 pandemic travel restriction delayed supply of vegetables on time and posed a shortage of vegetables, fruits, and other necessary food items for more than 821 million people around the world (FAO, IFAD, UNICEF, WFP, and WHO, 2019). Simplified hydroponic technology offers the potential of reducing hunger and helps enhance food production per unit area of acreage. Hydroponic cultivation would also be a better solution to mitigate malnutrition, drastic climate change and meet the growing demand for food to feed the rapidly increasing population (Stewart *et al.*, 2005).

Hydroponics is a soil-less culturing system which has been popularised worldwide. Hydroponics involved in the commercial agriculture system reduces land requirements for crops by 75%. Hydroponics technique is practiced for efficient and effective management of water (90% less water) and nutrients available in the system with the proper control of climate (Libia and Fernando, 2012). Hydroponics expresses more advantages of cultivating plants under soilless culture compared to soil-based agriculture because this technology minimizes environmental pollution by zero use of herbicide and minimum use of pesticides (Bradley and Marulanda, 2000; Radhakrishnan *et al.*, 2018). Hydroponics is not only utilizing the minimum resources very efficiently but also highly profitable on small scale without applying high technology. However, the problem is the availability of nutrient-rich hydroponic solutions at cheaper prices.

For commercial hydroponic cultivation of Spinach , the nutrient solution is the major factor to determine the quality and quantity of the product. Usually, Albert's solution is a commercially popular nutrient solution for crop cultivation in hydroponics systems, but, a variety of hydroponic nutrient solutions is available in the market (Iqram and Seran, 2016). All the commercially available hydroponic solutions are not purely organic. Therefore, a pure organic hydroponic growth media is important to invent to produce pure organic food from a hydroponic system. In the Spinach cultivation, to achieve clean and high-quality leave production, nutrition, oxygen concentration, pH and EC play major role with daily light integral (DLI) and light spectrum in a hydroponic system (Gao *et al.*, 2020).

Liquid organic fertilizers are by-products of everyday life. Organic fertilizer contains high levels of nutrients, e.g., N and P, and high amounts of organic matter and slowly release the nutrients that retain within the soil long time without leaching (Kochakinezhad *et al.*, 2012). Under organic fertilization, soil pH, plant-available nutrient concentrations may be higher, and the total microbial population of soil increases (Dinesh *et al.*, 2010). Liquid organic fertilizer solution can be prepared from plant and animal wastes.

Vegetable waste is a biodegradable material generated in massive quantities; most vegetable wastages are dumped openly, and create a big nuisance by emitting an unpleasant odor and attracts birds, rats, and pigs, vectors of varied diseases. Globally, a considerable portion of vegetables are lost as a wastage throughout the supply chain of vegetables. Most probably, it may be in the post-harvest stage and processing stage. In Sri Lanka, it has been estimated that 30% of vegetables being wasted in Dumbulla economic centre (Weerasinghe and Priyadharsan, 2017). Vegetable and fish wastes are generated hugely in Sri Lanka too, but not recycled properly into valuable byproducts. It is a serious problem and needs to be managed to make the environment free from pollution. By producing fertilizer from vegetable wastages, it is focused on successful plant fertilization to take advantage of waste vegetables. Fish emulsion and vermitea were also used as nutrient solutions. Fish emulsions are fermented liquid by-products of fish waste. Fish emulsion has been recognized as a useful nutrient source for vegetable fertilization (Aung *et al.*, 1984). According to Aslam and Ahmad (2020), the vermi-tea treatment showed maximum morphological and physiological performance of tomatoes. For sustainable agriculture, these liquid fertilizers can be used as a hydroponic medium successfully. Spinach (*Basella alba*) is an edible flowering plant in the family of Basellacea. Spinach plants have medicinal properties. Spinach is a medically recommended green leafy vegetable to hop up with Iron deficiency. It also contains high antioxidants, different carotenoids, high concentration of vitamins and minerals (Kavitha and Saradha, 2013).

The current investigations attempt to make a nutrient-rich hydroponic medium using biowastes and evaluate their efficacy to produce nutrient-rich green leafy vegetable Spinach (*B. alba*) as an alternative to the costly Albert's (M1) solution.

MATERIALS AND METHODS

Experimental Location

This field investigation was conducted at the organic home garden training unit at the Department of Agricultural Biology, Faculty of Agriculture, University of Jaffna, Sri Lanka (Longitude : 80.4, Latitude : 9.32, Altitude : 46m), belongs to the dry zone. The mean annual rainfall is around 1125mm and the mean annual temperature is around 25-35 ^{o}C (Department of Meteorology, 2021).

Preparation of Vegetable Waste Liquid Fertilizer

Vegetable wastes were collected from the canteens in the Kilinochchi premises of the University of Jaffna. The pumpkin and potato were selected as the main component of the vegetable waste because these two were identified major vegetables thrown away as waste in large quantities in Sri Lanka. The waste materials were weighed and chopped into small pieces. To prepare vegetable base liquid fertilizer, 700g of potato, 1.5kg of pumpkin, and 1.7kg of mixer of organic vegetables [brinjal, Indian pennywort, carrot, leeks, sessile joy weed (Mukkunuwenna)] were transferred to a 50L plastic barrel with the addition of additional ingredients such as 500g of cow dung, 500g of Gliricidia leaves, 100g brown sugar, and 10L of water. Then the barrel was closed tightly, kept in a dark place at room temperature, and allowed fermentation for two weeks with alternate days agitation. The fermented vegetable waste liquid fertilizer was filtered using a 0.5mm sieve and stored in a dry and dark place for the experiment.

Preparation of Fish Emulsion

Fish waste (fish offal parts, fins, and fish heads) was collected from the fish market in the Kilinochchi district. The 1kg fish wastages were collected and sterilized with hot water. Sterilized fish wastage was mixed with 1kg of Sawdust, and 50g of brown sugar in a 25L barrel and water was added until solid materials were fully immersed. Fish emulsion units were tightly closed and it was allowed to a fermentation process for 2 weeks and it was agitated each day. After the fermentation process of fish emulsion, it was filtered by using a sieve and muslin cloth. The prepared fish emulsion was stored in a dry and dark place.

Preparation of Vermi-tea

Vermi tea was prepared from the vermiculture training unit, Department of Agriculture Biology, Faculty of Agriculture, University of Jaffna. Vermiwash was collected from the passage of water through the earthworm (*Eisenia foetida*) processed organic substrate prepared by mixing of plant wastes (Teak+Jack leaves): cowdung at the ratio of 1:1 containing 50 L plastic container fixed with the tap at the bottom. A coarse sand layer of 15cm thick was filled into the container and overlayered by preprepared 10kg of moist organic substrate (plant wastes: cow dung (1:1)) and nearly 1000 earthworms were released into the container. This setup was gently moistened by one liter of water and the excess water drained off through the tap was collected and this process was repeated once in three days for three weeks. The added water slowly percolated through the compost and rhizospheres, carrying with it nutrients from freshly formed castings, worm body secretions as well as washing from drilospheres through filter unit, and the resultant solution is called “Vermi-tea”.

Chemical Analysis of Liquid Fertilizers

The nutrient content of each liquid fertilizer prepared was analyzed. Nitrogen was analyzed by semi-micro Kjeldahl method), Phosphorous percentage was measured by vanado-molybdate yellow spectrophotometric method at the wavelength of 450 nm (Jackson, 2005), Potassium percentage, Sodium percentage, and Calcium percentage were measured by flame photometer [JENWAY- PFP7] (Jackson, 2005). pH value and EC value of the organic liquid fertilizers were measured using pH meter [DKK-TOA(HM-30P)] and Electrical Conductivity meter [DKK-TOA(CM-42X)], respectively.

Processing of Liquid Fertilizers and Establishment of the Hydroponic Unit

To know the best hydroponic medium, different liquid fertilizers with different concentrations (Table1) were prepared as treatment and each treatment was replicated four times. pH, Electic conductivity (EC), and Dissolved Oxygen (DO) values were adjusted to suitable growing conditions to Spinach as per the proposal of Sharma *et al.* (2018). The diluted liquid fertilizer’s pH range was 5.6-7.0, EC was 1.8–2.4 dS m-1, and dissolved oxygen was maintained at 6-8 ppm by aeration.

Plastic bottles 5L capacity were used to plant the spinach in the hydroponics system. In a net house (50% Shade), top and bottom removed perforated pots were filled with coir-pith. Twenty metal trays (cake trays) were taken and coir pith-filled pots were placed at the middle of the trays. Half of every five trays were filled with the same hydroponic solution. The next day, all the pots were planted with five seeds per pot and covered with topsoil. The entire setup was randomly arranged and hydroponic solutions were aerated using a small air pump and hydroponic solutions were replenished from time to time when required.

Table 01: Prepared hydroponic nutrient solutions and its concentration

Medium	Constituents	Dilution ration of Liquid fertilizer with pure water
M1	Albert’s solution	1g:450 mL
M2	Pure water + Liquid waste vegetable fertilizer	1:6
M3	Pure water + Fish emulsion	1:13
M4	Pure water + Vermi tea	1:10
M5	Pure water + Liquid waste vegetable fertilizer + Fish emulsion + Vermi tea	1:5:2:3

Data Collection and Statistical Analysis

Data on Nitrogen, Phosphorous, Potassium percentage, Sodium and Calcium content, pH, EC, and OD value of the liquid fertilizers were measured. The experimental period was three months. The data on plant height, leaf length, leaf width, leaf area [ADC BioScientific Ltd.- AM350], root length, plant weight (Fresh /Dry), number of leaves per plant were measured once a week from two weeks after planting (WAP). At the time of harvesting (8 WAP) Chlorophyll content [Konica Minolta Inc.- SPAD-502Plus], of the plants was measured.

The collected data were subjected to Analysis of Variance (ANOVA) using SAS 9.4 and mean separation was performed using Tukey's HSD multiple comparison test option available in the same software to identify the best treatment combination at $P<0.05$.

RESULTS AND DISCUSSION

Nutrition Composition of Liquid Fertilizers

The results of nutrient analysis of the five nutrient solutions showed that the macronutrients N, P, K, and other essential elements Na and Ca were significantly different among them at $P<0.05$ (Figure 1-6). Plants can grow well in liquid or solid media if all the macro and micro mineral elements that are essential for plant physiology are supplied properly. There are 16 elements for the completion of a productive life cycle in plants (Pandey, 2018). These elements should be able to supply either by inorganic or organic fertilizer media.

The available Nitrogen (N): The N content of vegetable waste solution (M2) (11.1 mg/L) was significantly the highest among the other treatments, except for liquid nutrient solution mix (M5) containing 10.8 mg/L N which was identical ($P<0.05$). The lowest amount of 6.6 mg/L N was recorded in Vermi tea (Figure 01).

The available Phosphorus (P): The highest P content of 37.99 mg/L was recorded with vegetable waste solution (M2) and the lowest P content of 15.87 mg/L was recorded with Vermi tea (M4) which was not significantly different when compared with that of fish emulsion (M3) (17.02 mg/L) ($P<0.05$) (Figure 02).

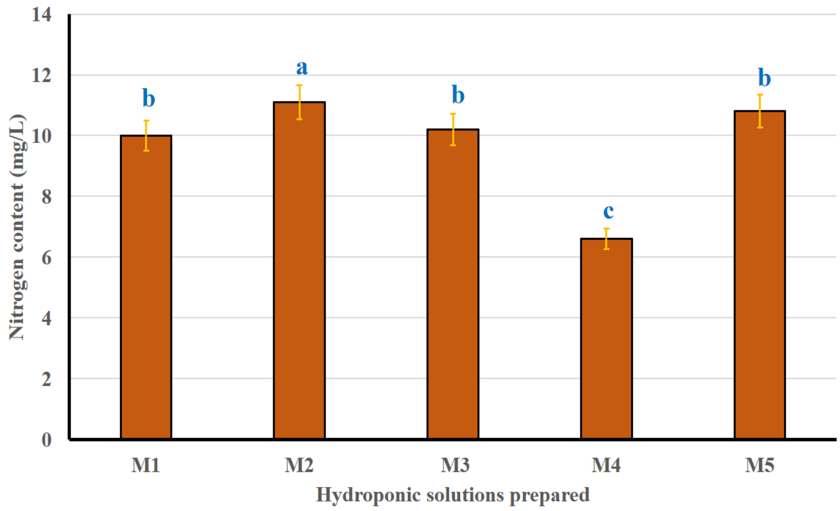

Figure 01: Nitrogen content of the different hydroponic solutions

M1: Albert's Solution; M2: Pure water + Liquid waste vegetable fertilizer (1:6); M3: Pure water + Fish emulsion (1:13); M4: Pure water + Vermi tea (1:10); M5: Pure water + Liquid waste vegetable fertilizer + Fish emulsion + Vermi tea (1:5:2:3)

Error bars mean values with the same alphabets are not significantly different according to the Tukey's HSD at 95% confidence interval

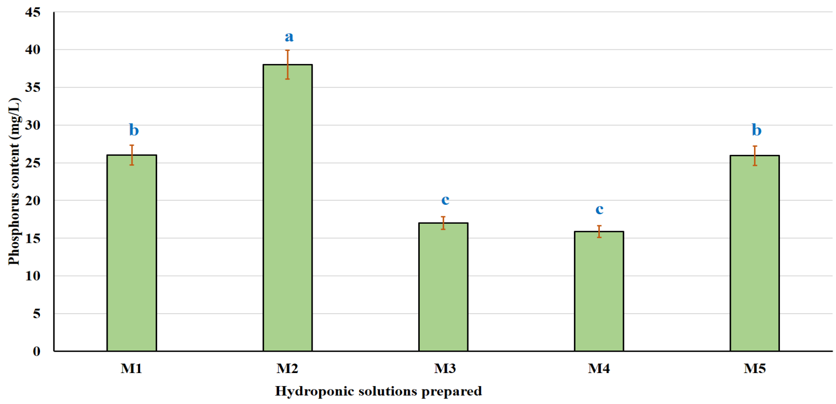

Figure 02: Phosphorus content of the different hydroponic solutions

M1: Albert's Solution; M2: Pure water + Liquid waste vegetable fertilizer (1:6); M3: Pure water + Fish emulsion (1:13); M4: Pure water + Vermi tea (1:10); M5: Pure water + Liquid waste vegetable fertilizer + Fish emulsion + Vermi tea (1:5:2:3)

Error bars mean values with the same alphabets are not significantly different according to the Tukey's HSD at 95% confidence interval

The available Potassium (K): The amount of K present in different liquid nutrient media was significantly varied (Figure 03), and vegetable waste solution (M2) consisted the highest K of 145.5 mmol/L whilst the lowest was present in fish emulsion (M3) (40.5 mmol/L). The amounts of K present in the Vermi tea (M4), mixed nutrient solution (M5), and Albert solution (M1) were 124.2 mmol/L, 100.0 mmol/L, and 94.5 mmol/L, respectively. Levine and Mattson (2021) reported that less K concentration in the hydroponic solution affected the yield, morphology, and tissue mineral content of leaf Spinach (*Spinacia oleracea* L.) as well as prone to pests and diseases.

The available Sodium (Na): The highest Na content of 208.7 mmol/L was recorded with Vermi tea, whereas the lowest (48.6 mmol/L) was recorded with Albert's solution. Na content of vegetable waste solution and mixed nutrient solution were equal (141.2 mmol/L) (Figure 04). The higher Na content in the nutrient solution reduces the K^+ uptake due to the physicochemical similarities between these two ions and leading to disorders in the metabolicactivity of the plants (Sperling *et al.*, 2014; Cova *et al.*, 2017).

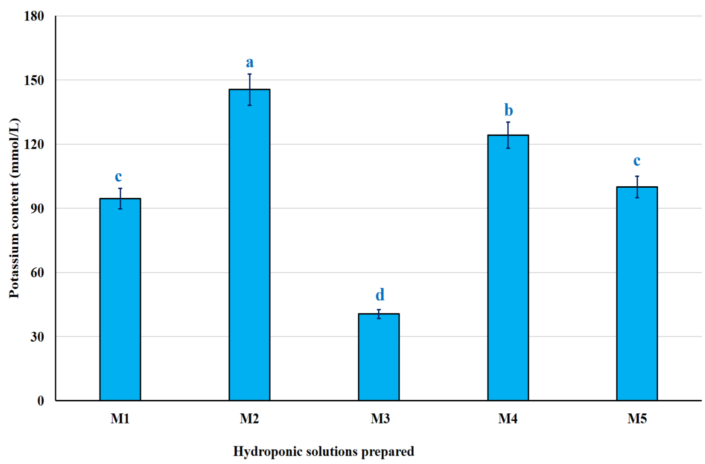

Figure 03: Potassium content of the different hydroponic solutions

M1: Albert's Solution; M2: Pure water + Liquid waste vegetable fertilizer (1:6); M3: Pure water + Fish emulsion (1:13); M4: Pure water + Vermi tea (1:10); M5: Pure water + Liquid waste vegetable fertilizer + Fish emulsion + Vermi tea (1:5:2:3)

Error bars mean values with the same alphabets are not significantly different according to the Tukey's HSD at 95% confidence interval

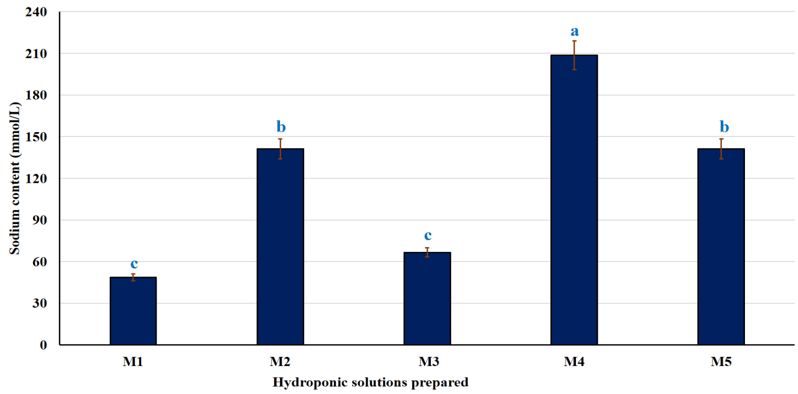

Figure 04: Sodium content of the different hydroponic solutions

M1: Albert's Solution; M2: Pure water + Liquid waste vegetable fertilizer (1:6); M3: Pure water + Fish emulsion (1:13); M4: Pure water + Vermi tea (1:10); M5: Pure water + Liquid waste vegetable fertilizer + Fish emulsion + Vermi tea (1:5:2:3)

Error bars mean values with the same alphabets are not significantly different according to the Tukey's HSD at 95% confidence interval

The available Calcium (Ca): The amount of Ca present in the vermi tea (M4) (96.2 mmol/L) was significantly higher when compared to all other treatments (P <0.01). The lowest was recorded with fish emulsion (27.8 mmol/L). The amounts of Ca present in the mixed nutrient solution, vegetable waste solution, and Albert solution were 69.4 mmol/L, 66.5 mmol/L, and 45.8 mmol/L, respectively (Figure 05). Neeser *et al.* (2007) reported that 300ppm application of Ca increases the leaf Ca content of the Lettuce to 179 mg/100 g to 229 mg/100 g, therefore, increasing the calcium content in leafy vegetables could further improve their nutritional benefits.

Aung *et al.* (1984) reported that the fish emulsion is as a useful plant nutrient source for crop fertilization. Fish emulsions contain inorganic and organic substances which induce the plant growth but those nutrients concentrations were in unbalanced form especially with micronutrients. In the present investigation, fish emulsion contained N, P and K in balanced and available form, therefore, the plant height, number of leaves per plant, root length, leaf area were significantly increased.

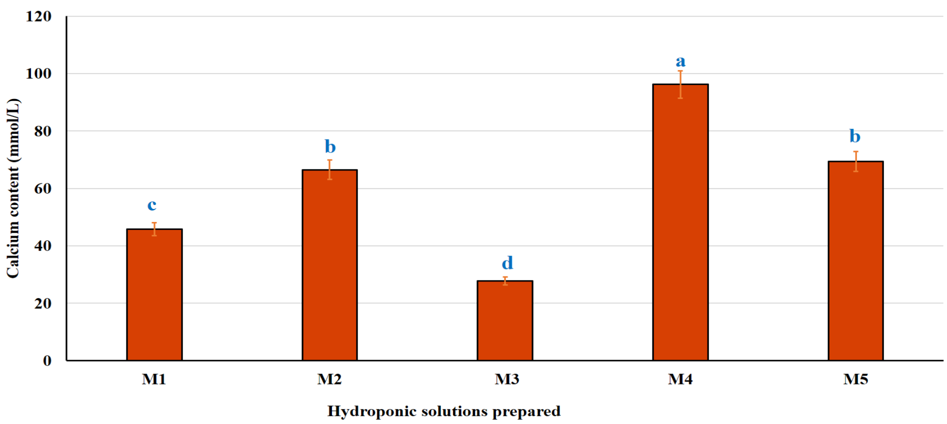

Figure 05: Calcium content of the different hydroponic solutions

M1: Albert's Solution; M2: Pure water + Liquid waste vegetable fertilizer (1:6); M3: Pure water + Fish emulsion (1:13); M4: Pure water + Vermi tea (1:10); M5: Pure water + Liquid waste vegetable fertilizer + Fish emulsion + Vermi tea (1:5:2:3)

Error bars mean values with the same alphabets are not significantly different according to the Tukey's HSD at 95% confidence interval

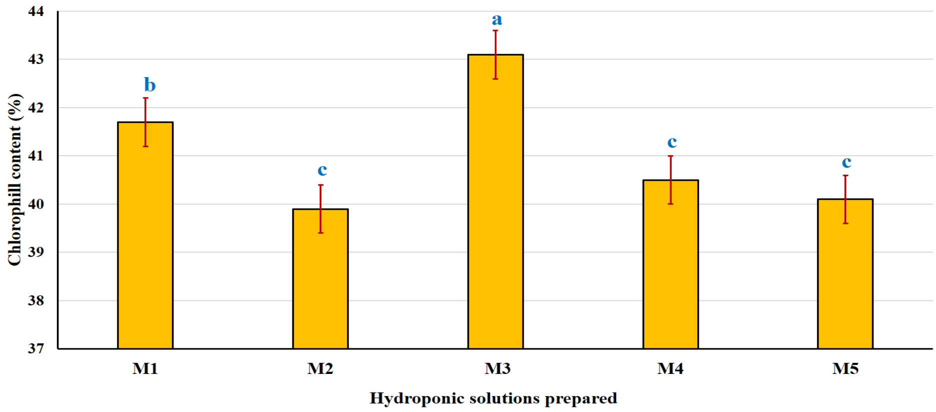

Figure 06: Chlorophill content of the plants grown in different hydroponic solutions

M1: Albert's Solution; M2: Pure water + Liquid waste vegetable fertilizer (1:6); M3: Pure water + Fish emulsion (1:13); M4: Pure water + Vermi tea (1:10); M5: Pure water + Liquid waste vegetable fertilizer + Fish emulsion + Vermi tea (1:5:2:3)

Error bars mean values with the same alphabets are not significantly different according to the Tukey's HSD at 95% confidence interval

Chlorophill content: The chlorophyll content of the leaves 8 WAP was the highest with fish emulsion (M3) (43.1%) whilst the lowest of 39.9% was recorded with vegetable waste solution (M2). However, this was not significantly different from other treatments. (39.9% to -41.7 %) (M1, M4, M5) (Figure 06). Several attempts have been made to grow plants in different nutrient solutions made using plant and animal wastes, but yield and other growth and reproductive paramentes of the crops have been varied (Atkin and Nichols, 2004; Bertoldi *et al.*, 2006; Wortman *et al.*, 2016). Moreover, spinach plants grown in fish emulsion based hydroponic media produced dark green fleshy shiney leaves due to the high chlorophyll content.

Plant Growth Parameters

Plant growth parameters such as plant height, number of leaves per plant, leaf area, root length, fresh weighand dry weight of Spinach (*B. alba*) were recorded under different nutrient solutions for an 8 weeks period and the mean values of the parameters recorded 7 and 8 WAP are summarized in table 02.

Table 02: Mean values of the growth parametes recorded with differnet hydroponic solutions

	Plant Height		Number of leaves/ plant		Leaf area (cM^2)		Root length (cM)		Fresh weight (g)		Dry weight (g)	
Treatment	Week 7	Week 8	Week 7	Week 8	Week 7	Week 8	Week 7	Week 8	Week 7	Week 8	Week 7	Week 8
M1	12.83± 2.03^a	13.33± 2.1^a	6.75± 0.50^{ab}	7.50± 0.58^b	32.75± 8.46^{ab}	40.69± 5.06^b	16.43± 2.13^a	17.78± 1.18^a	8.18± 0.70^{ab}	10.4± 0.68^{ab}	1.22± 0.21^b	2.13± 0.14^{ab}
M2	11.56± 0.79^a	11.8± 0.96^{ab}	6.50± 0.58^{bc}	7.50± 0.58^b	30.08± 4.46^{bc}	39.74± 5.79^b	11.80± 2.53^b	15.7± 1.69^a	7.64± 1.07^{bc}	9.45± 0.86^{ab}	0.97± 0.29^{bc}	1.74± 0.21^b
M3	11.86± 1.36^a	13.2± 0.9^a	7.50± 0.58^a	8.50± 0.58^a	39.44± 3.77^a	51.18± 3.61^a	16.85± 2.33^a	17.73± 2.14^a	9.23± 0.43^a	11.63± 2.09^a	1.65± 0.29^a	2.44± 0.57^a
M4	8.56± 0.97^b	10.2± 0.44^b	5.75± 0.50^c	7.25± 0.50^b	22.10± 5.28^d	38.22± 5.85^b	10.15± 1.79^b	14.58± 0.84^a	5.93± 0.45^d	7.27± 4.07^b	0.77± 0.10^c	1.73± 0.34^b
M5	9.56± 0.76^b	10.3± 0.96^b	6.25± 0.50b^c	7.50± 0.58^b	25.23± 3.51^{cd}	39.69± 4.72 ^{b}	11.20± 1.70^b	15.00± 2.41^a	6.75± 0.57^{cd}	10.3± 1.56^{ab}	0.89± 0.12^{bc}	1.67± 0.44^b

Mean values with the same alphabets are not significantly different according to the Tukey's HSD at 95% confidence interval

Plant height: Significantly the highest plant height of 12.83± 2.03 cM and 13.33± 2.1 cM was recorded with Albert's solution 7 and 8 WAP., respectively. The lowest plant height of 8.56± 0.97 cM and 10.2± 0.44 cM was recorded with Vermi tea, respectively. But the height was not significantly different between Albert's solution and fish emulsion as well as among vegetable waste solution, vermi tea, and mixed nutrient solutions (P <0.05) 8 WAP. Resh (2012) reported that N is the key element of the plants to produce proteins and nuclic acide which promote the plant growth. Maneejantra *et al.* (2016) reported that spinch shoot growth was high when the N, P, K, and Mg concentrations increased in the hydrophhonic solution to a certain extent.

Number of leaves per plant: The number of leaves per plant of 8.50± 0.58 was significantly higher in fish emulsion treatment (M3) compared with all other nutrient solutions (P <0.05) which were comparable 8 WAP. Resh (2012) reported that N is the key element which helps to produce more number of leaves and the leaf area of the plants.

Leaf area: Leaf area of 51.18± 3.61 cM^2 recorded in fish emulsion treatment (M3) was significantly higher than that of all other treatments which were comparables. The lowest of 38.22± 5.85 cM^2 was recorded in Vermi tea followed by Albert solution(40.69± 5.06 cM2) (P <0.05). The current findings tally with the reports of Resh (2012) and Maneejantra *et al.* (2016) who reported that the major plant element's concentration is the deciding factor of the yield of a plant.

Root length: Root length was not significantly affected by any of the treatments 8 WAP. However, the highest of 17.78± 1.18 cM and the lowest of 14.58± 0.84 were recorded in Albert solution and vermitea 8 WAP (P <0.05).

Fresh weight: The highest fresh weight of 11.63± 2.09 g/plant was recorded in fish emulsion treatment (M3) which was significantly greater than the lowest of 7.27± 4.07 g/plant recorded in Vermi tea (M4) treatment. The same of other treatments was comparable 8 WAP.

Dry weight: The dry weight of 2.44± 0.57 g/plant was recorded in fish emulsion treatment and it was in both fish emulsion and Albert solution (2.13± 0.14 g/plant) which was comparable. The lowest dry weight of 1.67± 0.44 g/plant was recorded in the mixed nutrient solution 8 WAP.

Albert solution is commonly used inorganic nutrient rich hydroponic medium, but costly. Present investigation was undertaken using different organic hydroponic media based on plant and fish wastes. Yildirim *et al*. (2016) stated that the application of fish emulsion liquid solution increased plant growth and productivity by triggering the production of plant hormones and the biological activity of the plant, therefore, the micro and macronutrient supply to the leaves would be more adequate to produce more chlorophyll. High chlorophyll content in leaf is an indication that it will be photosynthectically efficient, and it helps to well growth of plants. Moreover, the chlorophyll content is the one parameter to identify the crop nitrogen status in remote sense. It is important for the crop nutrient balance, and crop productivity (Dong *et al*., 2019). The chlorophyll content of plant leaves is related to the condition of the plant, and it can be used to determine when additional fertilizer is necessary. By optimizing nutrient conditions, healthier plants can be grown, resulting in a larger crop yield (Konica, 2009). Atkin and Nichols (2004) reported that the lettuce grown in organic hydroponic media produced a two and four times greater yield than conventional nutrient solution. Gül *et al*. (2007) proved that enrichment of organic nutrient media with dissolved poultry manure limited the yield loss of cucumber by only 11% in comparison to solid media with synthetic fertilizer. But in contrast, Wortman *et al.* (2016) found that strawberry yield was increased 15% more in synthetic nutrient solution than the bio-based, liquid nutrient source and vermicompost mixed with soilless media. Tikasz *et al.* (2019) reported that Lettuce grown in a compost tea extracted from the animal manures produced higher above ground dry mass compared to the commercialy avialble Hoagland solution, but, the success depnds on the careful monitoring of NO3−, NH4+, Ca, Mg, Mn, and

Na. Liquid organic fertilizers produced from waste molasses, distillery slop and sugarcane leaves produced similar growth and yield as synthetic fertilizer solution of Green Cos Lettuce (*Lactuca sativa* var. *longifolia*) in hydroponic medium (Phibunwatthanawong and Riddech, 2019).

CONCLUSION

It was found that among four different organic liquid media, fish emulsion medium was found to be more promising for Spinach cultivation. Fish emulsion and vegetable waste based hydroponic solutions can be used as an alternative to Albert's solution in Spinach cultivation. Repeated experiments with different crops are suggested for the further standerdization of the nutrientcontent of the media.

Conflicts of Interest

The authors declare no conflict of interest.

ACKNOWLEDGMENTS

This research was carried out in JICA research and laboratory complex, Faculty of Agriculture, University of Jaffna. The authors thank the Japanese Government and the people of Japan for providing equipment facilities through the JICA grant.

REFERENCES

Aslam, Z. and Ahmad, A. (2020). Effects of Vermicompost, Vermi-tea and chemical fertilizer on morpho-physiological characteristics of maize (*Zea mays* L.) in Suleymanpasa District, Tekirdag of Turkey. *Journal of Innovative Sciences*. 6(1), 41-46. DOI | http://dx.doi.org/10.17582/journal.jis/2020/6.1.41.46

Atkin, K. & Nichols, M.A. (2004). Organic hydroponics. *Acta Horticulturae*. 648, 121–127. DOI: https://doi.org/10.17660/ActaHortic.2004.648.14

Aung, L.H., Flick, G.J., Buss, G.R., Aycock, H.S., Keefer, R.F., Singh, R., Brandon, D.M., Griffin, J.L., Hovermale, C.H. and Stutte, C.A. (1984). Growth responses of crop plants to fish soluble nutrients fertilization. *Virginia Agricultural Experiment Station Bulletin,* 84(9), 1-80

Bertoldi, F.C., Sant'Anna, E., Villela da Costa Braga, M. and Barcelos Oliveira, J.L. (2006). Lipids, fatty acids composition and carotenoids of *Chlorella vulgaris* cultivated in hydroponic wastewater. *Grasas Y Aceites*. 57(3), 270–274. https://doi.org/10.3989/gya.2006.v57.i3.48

Bradley, P. and Marulanda, C. (2000). Simplified hydroponics to reduce global hunger. *In World Congress on Soilless Culture: Agriculture in the Coming Millennium*. 554, 289-296. DOI: https://doi.org/10.17660/ActaHortic.2001.554.31

Cova, A.M., de Freitas, F.T., Viana, P.C., Rafael, M.R., Azevedo, A.D.D. and Soares, T.M. (2017). Content of inorganic solutes in lettuce grown with brackish water in different hydroponic systems. *Revista Brasileira de Engenharia Agrícola e Ambiental*. 21, 150-155. DOI: https://doi.org/10.1590/1807-1929/agriambi.v21n3p150-155

Department of Meteorology, (2021). http://www.meteo.gov.lk/index.php?lang=en (Accessed on 2021 March 15)

Dinesh, R., Srinivasan, V., Hamza, S. and Manjusha, A. (2010). Short-term incorporation of organic manures and biofertilizers influences biochemical and microbial characteristics of soils under an annual crop [Turmeric (*Curcuma longa* L.)]. *Bioresource technology*. 101(12), 4697-4702. DOI: https://doi.org/10.1016/j.biortech.2010.01.108

Dong ,T., Shang, J., Chen, J.M., Liu, J., Qian, B., Ma, B., Morrison, M.J., Zhang, C., Liu, Y., Shi, Y. and Pan, H. (2019). Assessment of portable chlorophyll meters for measuring crop leaf chlorophyll concentration. *Remote Sensing*. 11(22), 2706. DOI: https://doi.org/10.3390/rs11222706

FAO, IFAD, UNICEF, WFP and WHO. (2019). The State of Food Security and Nutrition in the World 2019. Safeguarding against economic slowdowns and downturns. Rome, FAO. (http://www.fao.org/3/ca5162en/ca5162en.pdf) (Accessed on 2021 March 15)

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS (FAO) (2017). World fertilizer trends and outlook to 2020 (https://www.fao.org/3/i6895e/i6895e.pdf) (Accessed on 2021 March 15)

Gül, A., Kıdoğlu, F. and Anaç, D. (2007). Effect of nutrient sources on cucumber production in different substrates. *Scientia Horticulturae*. 113(2), 216-220. https://doi.org/10.1016/j.scienta.2007.02.005

Gao, W., He, D., Ji, F., Zhang, S. and Zheng, J. (2020). Effects of daily light integral and LED spectrum on growth and nutritional quality of hydroponic spinach. *Agronomy*. 10(8), 1082. DOI: https://doi.org/10.3390/agronomy10081082

Iqram, A.M. and Seran, T.H. (2016). Effect of foliar application of Albert solution on growth and yield of tomato (*Lycopersicon esculentum* mill.). *Journal of Advance Research in Food, Agriculture and Environmental science*. 3(4),17-22

Jackson, M.L. (2005). Soil chemical analysis: advanced course. UW-Madison Libraries Parallel Press.

Kavitha ,V. and Saradha ramdas V. (2013). Nutritional composition of raw fresh and shade dried form of spinach leaf (*Spinach oleracea*). *JPR:BioMedRx: An International Journal*. 1(8), 767–770.

Kochakinezhad, H., Peyvast, G.A., Kashi, A.K., Olfati, J.A. and Asadi, A. (2012). A comparison of organic and chemical fertilizers for tomato production. *Journal of organic systems*. 7(2), 14-25.

Konica Minolta, INC. (2009). Chlorophyll meter spad-502plus a lightweight handheld meter for measuring the chlorophyll content of leaves without causing damage to plants. (https://www.konicaminolta.com/instruments/download/catalog/color/pdf/spad502plus_catalog_eng.pdf) (Accessed on 2021 March 15)

Levine, C.P. and Mattson, N.S. (2021). Potassium-deficient nutrient solution affects the yield, morphology, and tissue mineral elements for hydroponic baby leaf spinach (*Spinacia oleracea* L.). *Horticulturae*. 7(8), 213. DOI: https://doi.org/10.3390/horticulturae7080213

Libia I. and Fernando, C. (2012). Nutrient Solutions for Hydroponic Systems. In (Ed.), Hydroponics - A Standard Methodology for Plant Biological Researches. *IntechOpen*. DOI: https://doi.org/10.5772/37578

Maneejantra, N., Tsukagoshi, S., Lu, N., Supoaibulwatana, K., Takagaki, M. and Yamori, W. (2016). A quantitative analysis of nutrient requirements for hydroponic spinach (*Spinacia oleracea* L.) production under artificial light in a plant factory. *Journal of Fertilizers & Pesticides*. 7(2). DOI: https://doi:10.4172/24712728.1000170

Mirlean, N. and Roisenberg, A. (2006). The effect of emissions of fertilizer production on the environment contamination by cadmium and arsenic in southern Brazil. *Environmental Pollution*. 143(2), 335-340. DOI: https://doi.org/10.1016/j.envpol.2005.11.022

Neeser, C., Savidov, N. and Driedger, D. (2007). Production of hydroponically grown calcium fortified lettuce. *Acta Horticulturae*. 744, 317-322 DOI: https://doi.org/10.17660/ActaHortic.2007.744.33

Pandey, N. (2018). Role of plant nutrients in plant growth and physiology. In: Plant nutrients and abiotic stress tolerance. Springer, Singapore, 51–93 DOI: https://doi.org/10.1007/978-981-10-9044-8_2

Phibunwatthanawong, T. and Riddech, N. (2019). Liquid organic fertilizer production for growing vegetables under hydroponic condition. *International Journal of Recycling of Organic Waste in Agriculture*. 8(4), 369-380. DOI: https://doi.org/10.1007/s40093-019-0257-7

Radhakrishnan, G., Upadhyay, T.K. , Singh, P. and Sharma S.K. (2018). Impact of Hydroponics: Present and Future Perspective for Farmer'S Welfare. *Journal of Chemical Information and Modeling*. 53(9), 1689–1699.

Resh HM (2012) Hydroponic food production. 7th edn. CRC Press, FL, pp: 9-12

Sharma , N., Acharya, S., Kumar, K., Singh, N. and Chaurasia, O.P. (2018). Hydroponics as an advanced technique for vegetable production: An overview. *Journal of Soil and Water Conservation*. 17(4), 364-371. DOI: https://doi.org/10.5958/2455-7145.2018.00056.5

Sperling, O., Lazarovitch, N., Schwartz, A and Shapira, O. (2014). Effects of high salinity irrigation on growth, gas-exchange, and photoprotection in date palms (*Phoenix dactylifera* L., cv. Medjool). *Environmental and Experimental Botany*. 99, 100-109. DOI: https://doi.org/10.1016/j.envexpbot.2013.10.014

Stewart, W.M., Dibb, D.W., Johnston, A.E. and Smyth, T.J. (2005). The contribution of commercial fertilizer nutrients to food production. *Agronomy Journal*. 97(1), 1–6. DOI: https://doi.org/10.2134/agronj2005.0001

Tikasz, P., MacPherson, S., Adamchuk, V. and Lefsrud, M. (2019). Aerated chicken, cow, and turkey manure extracts differentially affect lettuce and kale yield in hydroponics. *International Journal of Recycling of Organic Waste in Agriculture*. 8, 241–252. DOI: https://doi.org/10.1007/s40093-019-0261-y

Weerasinghe, K.P.W.D.R. and Priyadharsan S. (2017). Factors influencing on effective handling of wastage of the vegetable marketing system in dambulla dedicated economic centre. Proceedings of 7th International Symposium, SEUSL, 7th & 8th December 2017. DOI: http://ir.lib.seu.ac.lk/handle/123456789/3057

Wortman, S. E., Douglass, M. S. and Kindhart, J. D. (2016). Cultivar, Growing Media, and Nutrient Source Influence Strawberry Yield in a Vertical, Hydroponic, High Tunnel System. *HortTechnology hortte*. 26(4), 466-473. DOI: https://doi.org/10.21273/HORTTECH.26.4.466

Yildirim, E., Kul, R., Turan, M. and Ekinci, M. (2016). Effect of nitrogen and fish manure fertilization on growth and chemical composition of lettuce. International Conference on Advances in Natural and Applied Sciences (AIP conference Proceedings 1726). 1-5. DOI: https://doi.org/10.1063/1.4945847