APPLIED BIO-SYSTEMS TECHNOLOGY

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Efficacy of Liquid Organic Fertilizers Derived from *Eichhornia crassipes*, *Tithonia diversifolia* and *Gliricidia sepium* on the Growth of *Ipomoea aquatica* under Hydroponic Conditions

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Abstract

Background: The current study was conducted to evaluate the efficacy of liquid organic fertilizers produced from the extracts of three plant species, namely, *Eichhornia crassipes*, *Tithonia diversifolia* and *Gliricidia sepium* on the growth of *Ipomoea aquatica* under hydroponic conditions.

Methods: Six liquid organic fertilizer treatments were prepared form the aforementioned plant extracts and were used to cultivate *Ipomoea aquatica*, under hydroponic settings. Each treatment consisted of ten plants and the control system contained Albert solution. The prepared hydroponic systems were arranged in a Completely Randomized Design inside a semi protected plant house and the growth parameters of the plants were recorded up to 60 days. The General Linear Model (GLM) was used for the statistical comparisons.

Results: All the parameters denoted significant differences among the treatments ($P<0.05$), except for dry root weight, plant height and chlorophyll content. The Treatment 2 denoted the highest mean values for the vegetative parameters including, root length (18.2 ± 2.4), fresh root weight (0.44 ± 0.02), dry root weight 0.05 ± 0.01), dry shoot weight (0.21 ± 0.01), number of leaves (8.7 ± 0.6) and plant height (39.5 ± 3.3), while reporting the second highest values for fresh shoot weight (1.57 ± 0.1) and leaf area (48.1 ± 9.8).

Conclusions: Based on the findings, T2 treatment (*Eichhornia crassipes* 50% + Water 50%) can be recommended as the best performing liquid organic fertilizer medium, to be used in hydroponic cultivation systems.

Keywords: *Eichhornia crassipes, Gliricidia sepiumv,* Hydroponic Systems, Organic Fertilizers, *Tithonia diversifolia*

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INTRODUCTION

With the increasing population growth and climate change, ensuring the food security has become a serious concern at both national and global scales. Hence the need for higher productivity with the efficient use of inputs has become a constantly increasing challenge in modern agriculture [1]. Meanwhile, development of the agricultural sector has increased the detrimental impacts on natural ecosystems due to bio-accumulation and bio-magnification of agrochemicals, especially due to the intensive use of synthetic pesticides and fertilizers. Regardless of the efficacy attained from intensive crop production systems, accumulation of chemical residues, leading to different health impairments has become a serious concern [2]. With respect to fertilizers, one of the highest direct form of expenses in farming, the over usage of synthetic chemical pesticides has been a serious issue, which has caused severe negative impacts on the environment and human health. In addition, excessive use of inorganic fertilizers has also created a number of environmental problems, with the most serious one being the built up of phosphate and nitrogen compounds in water and the atmosphere [3].

Therefore, fertilizer application must be practiced in an appropriate manner to maintain the sustainability of the ecosystems, while balancing the cost effectiveness and convenience. However, with the realization of the adverse impacts of prolong and excessive use of agro-chemicals, the demand for adopting eco-friendly agricultural practices for sustainable food production has increased [4]. This has emphasized the necessity of searching for novel fertilizer, herbicide, pesticide and weedicide formulations, which are efficient, effective and environmentally friendly [5, 6].

Organic fertilizers are considered as an effective mode of promoting environmental sustainability, while sustaining the soil fertility and plant growth in the long run [7, 8]. Among different organic fertilizers, application of liquid organic fertilizers is a widely adopted strategy in modern crop management, due to the high nutrient-use efficiency. The source and the physical nature of the fertilizer is having a significant effect on the performance of plants. In this context, liquid fertilizers are convenient and effective method to enhance the nutrient availability, due to the presence of water that ensures uniformness in nutrient mixing [9]. Liquid organic fertilizers consist of essential plant nutrients and beneficial micro-organisms, which are recycled organic matter, formulated from natural materials of either plant or animal origin [10, 11]. Compost extracts, aerated compost teas, herbal extracts, vermicompost extracts and food stillages are few widely utilized organic liquid fertilizers [12-14].

Hydroponics or soil-less culture is a technology for growing plants in mineral nutrient solutions, where nutrients are fed directly to the roots, along with elements needed for optimum plant growth with or without the use of an inert medium such as gravel, rock wool, peat moss, saw dust, coir dust or coconut fiber [15, 16]. This method is a sustainable alternative to constraining factors in conventional agriculture, offering better nutrient control, less labour, relatively less cost and time requirements for land preparation, while being free from soil borne pathogens. The plant density per unit area of hydroponic systems can be doubled, so that it enhances the productivity, while providing with quality products. According to literature, hydroponic technology can reduce land requirements for crops by 75% or more, and water use by 90%. Further this enables continuous cultivation cycles, regardless of certain serious limitations in soil and environmental concerns [17].

Apart from using this technology in commercial scale cultivation projects, hydroponic cultivation system is a better counterpart in urban agriculture, which enables urban crowd in obtaining their own harvest of crops within the limited land availability. Hence, this can improve the living spaces physically and psychologically, while ensuring ecological sustainability of urban landscapes [18].

Even though, hydroponics is an excellent technique for the cultivation of vegetable crops and other plants, it often utilizes inorganic fertilizers [4]. In recent years, peoples' consciousness on food-safety and environment has increased, which have lifted the interest in organic farming techniques. Hence, hydroponic producers are facing a challenge of adopting in to "organic hydroponic systems", by developing a satisfactory organic nutrient medium. However, a limited number of studies have focused on development of an organic fertilizer medium to be used in hydroponic systems, while ensuring a satisfactory productivity. Therefore, this study attempted to develop an organic nutrient medium produced from the extracts of three plant species, namely *Eichhornia crassipes* (EC), *Tithonia diversifolia* (TD) and *Gliricidia sepium* (GS).

METHODOLOGY

Experiment Site

The study was conducted at the Faculty of Agriculture and Plantation Management Wayamba University of Sri Lanka, Makandura located in the low country intermediate zone (IL1a).

Preparation of Extracts

Three plant species, namely Water Hyacinth (*Eichhornia crassipes*), Wild/Mexican Sunflower (*Tithonia diversifolia*) and Gliricidia (*Gliricidia sepium*) were considered for the development of an organic liquid fertilizer, as shown in Figure 1. *Eichhornia crassipes* (Water Hyacinth) is a floating aquatic plant that belongs to the family Pontederiaceae (Figure 1). It is native to South America, and the rapid growth and reproduction of water hyacinth has made it to be distributed throughout the world. This plant is considered as an invasive plant, which adversely affects the quality and functionality of freshwater bodies in Sri Lanka [19]. *Tithonia diversifolia*, (Mexican Sunflower) belongs to the family Asteraceae and it is widely distributed throughout the South America, Asia and Africa. Mexican sunflower is used for a variety of purposes including, ornamental, as a fuel, for compost preparation, land demarcation, soil erosion control, soil remediation, as building materials and shelter for poultry etc. This plant is having a high potential as a green manure. The green biomass of *Tithonia diversifolia* is an important resource of nutrients, which contains notable amounts of Nitrogen (3.5%), Phosphorous (0.37%) and Potassium (4.1%) [20].

Gliricidia sepium, (Gliricidia) is a leguminous tree belonging to the family Fabaceae (Figure 1). It has spread from its native range throughout the tropics due to its diversified uses in crop management aspects. It serves as shade tree in plantation crops, while being used for green manure, fodder, live fencing, intercropping etc. The high initial Nitrogen, low Carbon Nitrogen ratio (C: N; lignin+ polyphenol), generally favour high rates of decomposition of fresh leguminous leaves, making Gliricidia a good candidate for development of a nutrient medium [21].

The plant materials were collected from the Kurunegala District. The collected plant materials were dried in room temperature for 4-5 days to precondition the extraction. The plant extractions were carried out according to the standard procedures recommended by Andika *et al*. [22] and Kolhe and Singh [23]. At the end of digestion period, the individual extracts were obtained, separately. The extracts were subsequently mixed in different ratios to prepare six treatments, as shown in Table 1. A recommended dosage of Albert solution was used as the control.

Experimental Design

The efficacy of the prepared plant extract formulations was evaluated using *Ipomoea aquatica* (Kangkung), a popular leafy vegetable crop in Sri Lanka. The crop was established under non circulating hydroponic settings (trough culture) using commercially available seeds. A total of ten *Ipomoea aquatica* plants were introduced to each fertilizer treatment, which were arranged in a Completely Randomized Design (CRD) with three replicates for each, inside a semi protected plant house. The plants were maintained for five weeks, since transplanting.

(A)

(B)

(C)

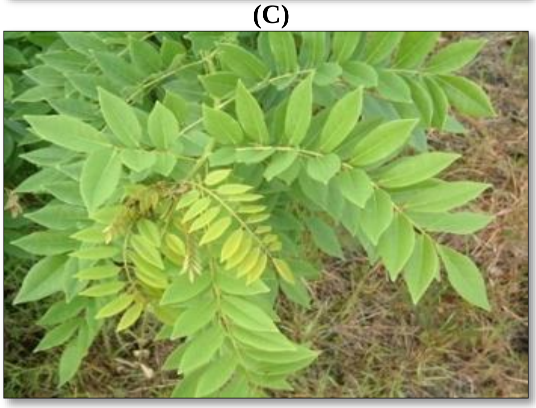

Figure 1: (A): Water Hyacinth; (B): Wild/Mexican Sunflower and (C): Gliricidia plants

Table 1: Treatments used in the Study

Code	Treatment
T1	Albert solution (recommended dosage) (control)
T2	EC 50% + Water 50%
T3	EC 25% + Water 75%
T4	EC 25% + (TD + GS Mixture)25% + Water 50%
T5	EC 25% + (TD + GS Mixture)50% + Water 25%
T6	TD + GS Mixture)50% + Water 50%
T7	TD + GS Mixture)75% + Water 25%

Note: EC: *Eichhornia crassipes;* TD: *Tithonia diversifolia;* GS: *Gliricidia sepium*

Data Recording and Analysis

Selected vegetative parameters were recorded from all plants in each treatment. Plant height (cm) were measured from the base of the plants, along with the number of leaves per plant. Further, the Chlorophyll contents were recorded using a SPAD Meter (S 502 plus) at weekly intervals starting from the first week. In addition, the total leaf areas (cm^2) of the plants were measured using a bench top leaf area meter (Li-3100C) at weekly intervals.

The root length (cm) and fresh weight of above ground biomass (g) were measured after five weeks, since transplanting. The oven drying method at 80 °C for 48 h was used to determine the dry weight of the above ground biomass (g). Further pH and Electrical Conductivity (EC) levels of every treatment were monitored weekly using a pH meter and an Electrical conductivity meter. The nutrient analysis was done to identify the Nitrogen, (Kjeldahl method), Phosphorus (Olsen method) and Potassium (Flame Photometer), composition of each plant extract. The recorded data was analyzed using the General Linear Model (GLM) followed by the Tukey's pair-wise comparison for mean separation. All statistical analysis were performed in SPSS (version 23).

RESULTS AND DISCUSSION

Nutrient Analysis

According to the initial nutrient analysis of the stock solutions, the highest N level (0.075 %) was found in gliricidia extract, while the highest P (70.43 ppm) and K values (1076.0 ppm) were recorded by the extract of giant Mexican sunflower (Table 2).

Variations in Vegetative Parameters

Nutrient element combinations, concentration and adequate supply heavily influence the plant growth and development. Hence, plant growth parameters can be directly influenced by the fertilizers. The studied morphological and physiological parameters of the *Ipomoea aquatica* plants revealed different responses to varying treatments of fertilizers.

Plant Height

Plant height is an important morphological phenotype, which is a direct identifier of the overall plant growth. In this study, plant height did not indicate any significant variations among the treatments (P>0.05 at 95 % level of confidence), as shown in Table 3. However, the highest mean value for plant height was observed under T2 (39.5 ± 3.3 cm), while the lowest value was observed from T3 treatment (27.0 ± 1.8 cm). A similar study by Andika *et al.* [22], which has been conducted to evaluate the effect of a water hyacinth liquid fertilizer on *Crotalaria ochroleuca*, has denoted a significant proliferation of plant height over the inorganic liquid fertilizers. Further Abu, [24] has reported that an organic fertilizer developed with water hyacinth, has resulted a significant effect on the plant height of *Colocasia esculenta*. Additionally, organic fertilizer extracts from Tithonia and Gliricidia and cocao skin, have also shown promising results on plant growth, indicating a significant increase in plant height of water spinach, lettuce and cauliflower like crops [6, 25].

Number of Leaves and Total Leaf Area

Number of leaves and leaf area determines the light interception capacity of a crop and is often used as a key plant growth parameter, which will influence the photosynthetic rate and carbon partitioning [26]. As per the results of the current study, the leaf counts denoted significant variations among different treatments (P<0.05 at 95% level of confidence). The highest mean value for number of leaves was observed in T2 as 8.7 ± 0.6 leaves, followed by T7 (6 ± 1.6 leaves), while T3 reported the lowest value as 4.0 ± 0.4 leaves, as shown in Table 3.

Similarly, the total leaf area also denoted significant variations among the treatments (P<0.05). According to the results, the highest mean value for total leaf area was observed under T1 (48.4 ± 6.1 cm^2), while the lowest value was observed from T3 treatment (14.0 ± 2.0 cm^2). A similar trend was observed during a previous study by Talkah [27], while using organic fertilizer extracts for plant taro (*Colocasia esculenta* L.).

Further, several other experiments on organic hydroponic cultivation of crops have also denoted higher leaf numbers and leaf area with the treatments of plant extracts compared to the inorganic control treatments [25, 28-29].

Table 2: Nutrient Composition of the Pure Extracts

Plant Material	Nitrogen (N) %	Phosphorous (P) ppm	Potassium (K) ppm	pH value	EC Value (mS/cm)
Water Hyacinth	0.075	14.75	902.20	7.2	4.38
Giant Mexican Sunflower	0.016	70.43	1076.00	6.9	7.74
Gliricidia	0.109	63.75	712.0	5.6	7.57

Chlorophyll Content
Chlorophyll is an essential element for photosynthesis, where high chlorophyll content enables efficient gain of energy and production of foods [30]. Hence, chlorophyll content acts as an important indicator of plant health. Despite being non-significant, the highest mean value for chlorophyll content was observed in T1 as (36.22 ± 1.3 SPAD Units [SU]), followed by T4 (34.63 ± 2.6 SU), while T3 reported the lowest value (28.87 ± 3.2 SU), as shown in Figure 2. As previously stated, no significant variation in chlorophyll content was observed among these seven treatments. ($P>0.05$ at 95 % level of confidence). Organic fertilizers are good sources of nitrogen, which favour chlorophyll production. This scenario has been further emphasized by the previous studies conducted with different plant extracts [8, 31].

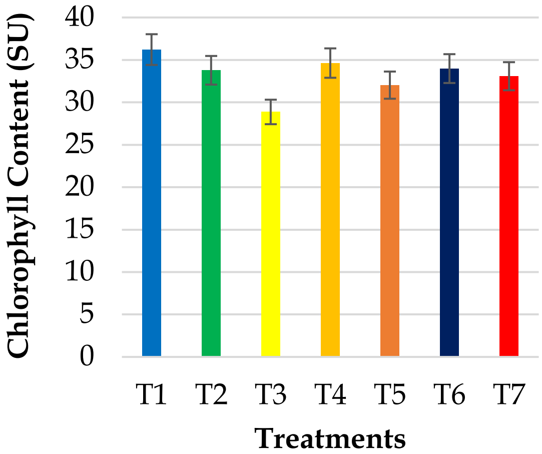

Figure 2: Chlorophyll Contents of *Ipomoea aquatica* Plants Grown under Different Treatments

Root Length
Root development is an important parameter of plant development. The root systems of plants perform important roles in plant growth by actively mediating the acquisition of nutrients and water to plants, while facilitating other functions such as anchorage, synthesis of plant hormones etc. [32]. The root development of a plant is profoundly regulated by genetic aspects, as well as external environmental factors such as nutrient levels [33].

According to the results of the current study, the root length denoted a significant variation among the treatments ($P<0.05$ at 95% level of confidence) as shown in Table 3. The highest mean value for root length was reported under T2 (18.2 ± 2.4 cm), while the lowest value was reported from T3 treatment (7.2 ± 0.9 cm). A study conducted by Ji *et al.* [8], has reported an effective root development in chrysanthemum with the liquid organic fertilizer treatments that they have tested, while Andrian *et al.* [28] and Phibunwatthanawong and Riddech [11] have further experienced similar observations in root length with the organic fertilizer treatments in hydroponically grown water spinach and lettuce, respectively.

Fresh Weight and Dry Weight
Different sources of nutrient (organic or mineral) possess a significant effect on total plant biomass. When the fresh weight is considered, it can be separately measured as fresh shoot weight and fresh root weight. Both of these parameters were indicating significant variations among the treatments ($P<0.05$ at 95% level of confidence), as shown in Table 3. The highest mean value for fresh shoot weight was reported under T5 (1.59 ± 0.2 g), while the lowest value was reported from T3 treatment (0.75 ± 0.1 g). In case of fresh root weight, the highest mean value was observed under T2 (0.44 ± 0.02 g), while the lowest value was observed from T7 treatment (0.12 ± 0.1 g).

Same as fresh weight, dry weight was also measured separately as the dry shoot weight and dry root weight. Dry shoot weight denoted significant variations among treatments ($P<0.05$ at 95% level of confidence). In here, the highest mean value was observed under T2 (0.21 ± 0.01 g), while the lowest value was observed from T3 and T4 treatments (0.10 ±0.01 g). Meanwhile, the dry root weight did not indicate any significant variations among treatments ($P<0.05$ at 95% level of confidence). However, the highest mean value for dry root weight was observed under T2 (0.05 ± 0.01 g).

Table 3: Summarized Mean Values for Morphological Parameters of *Ipomoea aquatica* Treated under Different Fertilizer Combinations

Trt.	Plant Height (cm)	Number of Leaves	Root Length (cm)	Leaf Area (cm²)	Fresh Root Weight (g)	Fresh Shoot Weight (g)	Dry Root Weight (g)	Dry Shoot Weight (g)
T1	30.8 ± 1.1^{a}	5.2 ± 0.9^{ab}	7.8 ± 0.7 ^{a}	48.4 ± 6.1^{c}	0.22 ± 0.03^{a}	1.30 ± 0.1^{b}	0.03 ± 0.005^{a}	0.11 ± 0.01^{a}
T2	39.5 ± 3.3^{a}	8.7 ± 0.6^{b}	18.2 ± 2.4^{b}	48.1 ± 9.8^{c}	0.44 ± 0.02^{b}	1.57 ± 0.1^{b}	0.05 ± 0.01^{a}	0.21 ± 0.01^{b}
T3	27.0 ± 1.8^{a}	4.0 ± 0.4^{a}	7.2 ± 0.9^{a}	14.0 ± 2.0^{a}	0.25 ± 0.05^{a}	0.75 ± 0.1^{a}	0.04 ± 0.02^{a}	0.10 ±0.01^{a}
T4	33.1 ± 2.5^{a}	5.7 ± 0.4^{ab}	9.4 ± 2.2^{ab}	26.9 ± 5.2^{b}	0.17 ± 0.04^{a}	0.88 ± 0.2^{a}	0.02 ± 0.01^{a}	0.10 ±0.01^{a}
T5	38.5 ± 2.02^{a}	5.0 ± 0.5^{a}	11.9 ± 1.5^{b}	28.6 ± 5.8^{b}	0.29 ± 0.1^{b}	1.59 ± 0.2^{b}	0.05 ± 0.01^{a}	0.15 ± 0.01^{b}
T6	30.4 ± 4.1^{a}	5.0± 0.7^{a}	9.0 ± 2.3^{a}	30.7 ± 7.2^{b}	0.14 ± 0.03^{a}	1.16 ± 0.4^{a}	0.02 ± 0.004^{a}	0.10 ± 0.03^{a}
T7	35.1 ± 4.9^{a}	6.0 ± 1.6^{ab}	8.0 ± 3.8^{a}	26.0 ± 6.4^{b}	0.12 ± 0.1^{a}	1.19 ± 0.3^{ab}	0.05 ± 0.03^{a}	0.11 ± 0.01^{a}

Note: *Trt.: Treatment*

Meanwhile the lowest value was observed from T4 treatment (0.02 ± 0.01 g). Similar to inorganic fertilizers, organic fertilizers can also improve the plant biomass [34-35]. Biomass stimulation is a consequence of the hormone like effect of humic acids present in organic fertilizers [36]. Several previous studies conducted by Andrian *et al.* [28] and Setyowati *et al*. [6] have reported similar variations in plant fresh and dry weight. However, in certain cases, organic nitrogen may not significantly influence the biomass production of plants, where Kasim *et al*. [3] and Williams and Nelson [37] have reported relatively lower values of fresh and dry weights of the organically fertilized plants, in comparison with inorganically treated ones.

At present, resource constraints in agricultural production have become sterner than in the past. Hence, hydroponic/soil-less culture has been identified as a good solution, which provides many socio-economic benefits [16]. Furthermore, the soil-less cultivation approaches can ensure continuous supply of fresh and hygienic vegetables in sufficient quantities, especially in urban settings to facilitate urban agriculture under limited space conditions [15]. Application of liquid fertilizers is both effective and convenient in crop management, when compared to use of solid forms. Therefore, the use of organic nutrient solution based hydroponic systems can cater for the increasing demand in food supply, while resulting minimum impacts on the environment [16].

The findings of the current study revealed that liquid organic fertilizers can be successfully used as a substitute for conventional inorganic fertilizers in hydroponic cultivation systems. The most important factor of this study was the utilization of water hyacinth plant as a major component. Being an invasive plant, water hyacinth possesses negative effects on ecosystems and considered to be an irritation in control and management of inland waterbodies in many countries including Sri Lanka [22, 38]. Hence utilization of a such plant in an effective way as a nutrient source, would be immensely helpful in reduction and management of ecological and economic burdens caused by it [38].

CONCLUSIONS

Based on the overall findings, the T2 (*Eichhornia crassipes* 50% + Water 50%) treatment denoted the highest mean values for majority of vegetative parameters, including root length, fresh root weight, dry root weight, dry shoot weight, number of leaves and plant height, while denoting the second highest values for fresh shoot weight and leaf area. Therefore, based on the findings, out of all the tested treatments, T2 can be recommended as a successful organic fertilizer medium to be used in hydroponic cultivation systems. However, more research efforts are required for the optimization of the formulation of the fertilizers, quantifying the optimal fertilizer rate, efficacy against different crops and microbial responses in organic hydroponic systems.

CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest.

AUTHORS' CONTRIBUTIONS

NS: Designed the study, supervised the experimental procedures and wrote the manuscript. MA, TS, AW and KW: Conducted the experiments, collected the data and prepared the first draft of manuscript. LU: Conceptualized the study, supervised the study, conducted the statistical analysis and wrote the manuscript. All authors read and approved the manuscript.

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