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Note

Growth performance of water spinach *Ipomoea aquatica* and freshwater prawn *Macrobrachium rosenbergii* grown in aquaponic and hydroponic units

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ABSTRACT

In the present study, attempts were made to optimise water spinach (*Ipomoea aquatica*) in combination with freshwater prawns (*Macrobrachium rosenbergii*) to be grown under aquaponics culture conditions, especially as an indoor set-up suitable for urban dwellings. A comparison of the morphometric parameters such as linear growth and number of leaves of plants and the survival rate under the soil, aquaponics, aquarium and hydroponics units simultaneously per cycle was done to establish the stability of the system. The water spinach grown under the aquaponics set-up showed significant growth compared to the hydroponics set-up but was less than that of the soil units. Significantly higher growth of freshwater prawns was also recorded in the aquaponics unit compared to the aquarium unit. Though further investigations are still needed to find factors that can give optimum produce, the researchers propose that standardised aquaponic units for water spinach and freshwater prawns can be a safe option for urban households as a sustainable farming practice.

Keywords: Food security, Hydroculture, Symbiotic growth, Urban farming

The Philippines has been experiencing a decline in crop production due to natural calamities, haphazard urbanisation projects and increasing populations, which has further been accelerated due to the COVID-19 pandemic (ADB., 2020). The circumstances of the COVID-19 pandemic have produced a lack of access to fresh farm produce due to major supply chain disruptions that caused heavy losses to the farmers and problems for urban dwellers. This chain of events has made evident the need for a major thrust towards adopting more sustainable food production methods and faster alternatives to existing “farm-to-table” systems, especially in the Philippines. Hence, the exploration and adoption of modern agricultural techniques and methods that can help to increase crop production will prove highly beneficial to the country. Among the array of such available agricultural techniques, hydroponics and aquaponics have emerged as promising methods as sustainable means of increasing global agricultural production (Knaus and Palm, 2017).

Hydroponics uses a system where the plants are directly immersed in a soilless medium or nutrient solution containing nitrogen, phosphorus and potassium (Teellez and Merino, 2012). Aquaponics is a production system that involves growing plants and aquatic organisms symbiotically, where the majority (>50%) of nutrients sustaining the optimal plant growth are derived from wastes originating from feeding the aquatic organisms (Palm *et al*., 2018). Interestingly, compared to hydroponics, aquaponics is not very well known to common people, including farmer communities globally (Milicic *et al*., 2017). The aquaponics set-up is more challenging as the growth of aquatic organisms such as fishes, depends on the nutrition from the fish feed, whereas the plants growing in the same system have different nutrient requirements. Therefore, it remains a challenge to find the conditions that can support the optimal and efficient growth rates of both plants and fishes (Rakocy *et al*., 2006). In line with this, optimising aquaponics systems for various edible plants and aquatic species is considered critical knowledge, especially as this technology could be commercially successful and financially profitable for farmers. With the uncertainty of the containment of the pandemic, especially in the Philippines, along with the prediction of possible future pandemic outbreaks, these models of urban agri-farming can be used to answer the demand for immediate fresh food availability in an urban setup, as well as serve as an alternate means of livelihood for farmers.

In most of the studies on aquaponics, fishes such as tilapia (*Oreochromis niloticus*), catfish (Siluriformes), rainbow trout (*Oncorhynchus mykiss*) and common carp (*Cyprinus carpio*) are common species of interest, besides those of ornamental fishes (Love *et al.,* 2014). Standardising the conditions to grow tilapia fish using a floating raft aquaponic system has been attempted by several workers (Rakocy *et al*., 2004; Akter *et al*., 2018). Decoupled aquaponics designs, where the water with the fish waste is not directly circulated for plant culture, were used to obtain optimal growth of fish and plants (Karimanzira *et al*., 2017). It is also notable that the shrimp aquaculture industry in the Philippines has been growing and developing and contributing towards a better economy by providing jobs and establishing food security for the citizens (Vergel, 2017).

Since most green leafy vegetables have short growth cycles and grow well in nitrogen-rich water with low nutrient requirements, they have been used extensively in aquaponic systems (Bailey and Ferrarezi, 2017). Water spinach (*Ipomoea aquatica*), a leafy vegetable belonging to the family Convolvulaceae, while being vitamin and mineral rich, also abundant in proteins, fibers, carotenoids and flavonoids with numerous health benefits (Nuwansi *et al*., 2015). These factors made the plant a viable choice to use for the aquaponic and hydroponic set-ups. For these reasons, this study aimed to produce and maintain aquaponics and hydroponics systems featuring water spinach (*Ipomoea aquatica*) and freshwater prawns (*Macrobrachium rosenbergii*), as the primary organisms of interest. The trials in the study also aimed to use recyclable materials in set-up construction to reduce costs and promote aquaponics and hydroponics systems as viable urban agri-farming practices in the Philippines.

A comparison between the morphometrics of the water spinach (*I. aquatica*) produced by the conventional soil method, hydroponics and aquaponics were done to determine the effectiveness of each method in producing water spinach. The commercially available AB-branded Plant Food Solution hydroponics nutrient was used for the standard hydroponics system. In another separate hydroponics system, discarded algal medium containing Bradford-Reactive Soil Protein (BSRP), which was previously used to grow freshwater green alga (*Chlorococcum infusionum*), was selected as the nutrient medium. The discarded algal medium of known composition was added to explore the possibility of recycling many such nutrient mediums that can be used in the hydroponics/aquaponics cultivation systems. Furthermore, a comparison between the morphometrics of freshwater prawn (*M. rosenbergii*) produced by a traditional aquarium set-up and an aquaponics setup was used to determine which method produces a better quality shrimp in terms of size, which is indicative of the growth rate under both conditions.

All set-ups were subjected to similar and standardised conditions of temperature and light exposure. The initial length of water spinach stem cuttings (7.62 cm) was kept the same for all systems. Both the aquaponics and hydroponics systems had an equal number of plants, along with an equal amount of growing space in between the beds to further strengthen the results of the systems (Wilson *et al*., 2017). Prawns were fed with commercial feed available in pet shops. Water temperature, pH, and conductivity were recorded daily for one growth cycle. Growth cycles were repeated to study the parameters. The results were subjected to t-test to determine any differences between the growth of water spinach grown under different systems (Lennard and Ward, 2019). To promote the adoption of aquaponics and hydroponics as viable and profitable agri-practices, the costs for the production and maintenance of these set-ups were to be kept as low as possible; hence mostly recycled materials were used in the experimental set-ups.

The traditional soil growing unit was set up using regular loamy soil and prepared a week before the experiment. Once the water spinach stem cuttings were planted, the unit was monitored and the cuttings planted were measured once a week. The set-up was kept out in the open and under normal sunlight conditions with regular watering (Fig. 1).

The aquarium set-up utilised a recycled 50 l plastic tub filled with approximately 40-45 l of tap water and was equipped with an integrated filtration and aeration unit that regularly cleaned the system and provided oxygen for the prawns. The set-up housed 10 freshwater prawns. An optimal pH level of 7.4, with a bi-directional tolerance of 0.1, was maintained (USFWS, 2018). The set-up was equipped with a feeding system that supplied prawn feed twice a day. The system also included a hiding space for the prawns for molting and was kept in a shaded area, away from artificial and natural light (Fig. 2).

The hydroponics system utilised a 50 l recycled plastic tub with 10 plastic cups housing water spinach stem cuttings of around 7.62 cm that were each secured in place using cotton. The tub was filled with approximately 40-45 l of tap water and was mixed with commercially available A&B Plant Food branded NPK hydroponics

Fig. 1. Water spinach grown in the traditional soil setup

Fig. 2. Aquarium set-up for freshwater prawns

nutrient solution. Holes were punctured in the plastic cups to allow the flow of nutrients. The system was maintained under indoor laboratory conditions with LED lights placed above the tub to provide light. The system was also equipped with an aerator to allow circulation of the solution and prevent it from settling at the bottom of the tub. The pH level was maintained initially in the optimal range for water spinach (5.5-6.5) and at 6.0 (with a bi-directional tolerance of 0.05) for three weeks, followed by the pH fluctuation up to 7.35 in the weeks closer to the completion of the growth cycle of water spinach (Fig. 3) (Wang *et al*., 2017).

To explore the possibility of using recycled medium of known compositions that could still be rich in nutrients for hydroponics systems, a hydroponics system with recycled Bradford-Reactive Soil Protein (BRSP) medium, which was used to grow freshwater green alga (*Chlorococcum infusionum*), was set up (Table 1). The BRSP medium is generally discarded after the growth of green algae (*Chlorococcum infusionum*). This medium was collected from the algal culture laboratory of De La Salle University and a second hydroponic system, similar to the first one, was set up using a 50 l recycled plastic tub containing 10 suspended and half-submerged plastic cups with water spinach stem cuttings of roughly 7.62 cm in length, each secured by cotton. Holes were also punctured in the plastic cups to allow the medium to circulate through the stem cuttings. This medium had a relatively high pH level of 7.0 (with a bi-directional tolerance of 0.1), as compared to the optimal pH levels for growing water spinach (5.5-6.5) (Wang *et al*., 2017). The same process used in the construction and maintenance of the nutrient-based hydroponics system was used to keep similar conditions (Fig. 4).

Table 1. Bradford-Reactive Soil Protein (BRSP) media components in the algal medium

	Standard solution	Utilisation
Component	(g l^{-1}) (per 1000 ml stock Soln)	(ml l^{-1})
$CaNO_3$	125.8	1
$MgCl_2$ (or $MgCl_2.6H_2O$)	65.4 (139.7)	1
$MgSO_4$ (or $MgSO_4.7H_2O$)	45.0 (92.17)	1
KCl	19.1	1
NaCl	81.2	1
$NaSiO_3$	186.1	1
$NaNO_3$	257.3	1
Na_2HPO_4	22.9	1
$FeCl_2$	0.3	1
Trace elements	mg l^{-1} (per 100 ml stock solution)	
H_3BO_3	200	1
$MnCl_2{\cdot}H_2O$ (or $MnCl_2.4H_2O$)	150 (206)	1
$ZnSO4{\cdot}7H_2O$ (or $ZnSO_4$)	20 (0.011)	1
$CaCl_2H_2O$	10	1
Na_2MoO_4	1	1

The experimental aquaponics system was set up and operated under laboratory conditions with a 50 l plastic tub for aquaculture connected to two separate rectangular plant boxes for the hydroculture unit. The water spinach stem cuttings with a length of approximately 7.62 cm were placed in cups with punctured holes at the bottom and suspended on the plant box, half-submerged overflowing

Fig. 3. Hydroponics unit with dissolved commercial nutrients and water spinach

Fig. 4. Algal hydroponic medium with water spinach growth

water. A total of 5 plant stalks were placed per plant box. The plant boxes also contained porous, aquarium-treated rocks to serve as growing spots for *Nitrobacter* bacteria. The growth of these bacterial colonies in the system is essential for converting ammonic prawn waste into nitrate, which is essential for plant development (Rashmi *et al*., 2013). The aquaculture portion of the system featured aquarium bedding to help in water filtration. The aquaculture system was positioned one meter below the hydroculture unit to minimise light interference that may disturb prawns. The aquaculture part of the set-up was made to house 10 prawns, with a sheltered spot for shrimp molting (Fig. 5). The pH levels in the set-up were maintained at 7.23-6.26 for the hydroponics part and at 7.3, with a bi-directional tolerance of 0.09, for the aquaculture portion.

The starting samples of water spinach stem cuttings measured at 7.62 cm each with branching nodes not longer than 1 cm on either end. The upper branching node was the growth point for the leaves and the lower one was submerged or planted and was observed to be the growth point of the roots. The stem cuttings were then half-submerged for seven days, allowing for the basic development of leaves and roots. Afterwards, the cuttings were transferred into the different growth system setups. Weekly measurements of the length of the plants and the number of fully functional leaves were taken and the total number of plants alive at the end of the growth cycle was noted. The leaf number counts included only the connected fully extended leaves and the small, underdeveloped, folded leaves were not included in the data collection.

Fig. 5. Aquaponics system with water spinach in the plant boxes with water recycled from the tank at the bottom with freshwater prawns

The initial lengths and weights of the prawns were recorded before their acclimation and transferred into the respective tank set-ups. All the shrimp specimens were hand-picked to be of relatively similar weight and length to allow for accuracy and consistency throughout the study. Weekly sampling were done for morphometrics measurements. The sampled prawns were carefully extracted, held and measured from the tip of the rostrum to the end of the telson. The weight of each prawn was measured using the water displacement method. The prawns were then returned to the set-ups, observing utmost care throughout the process.

Data were analysed by comparison of the growth rate and the number of leaves of the plants, along with the increase in the growth of freshwater shrimps. A t-test assuming equal variance ($\alpha=0.05$) was performed for each parameter (number of leaves, stem height and shrimp length) to determine significant differences between each treatment (Wilson *et al*., 2017).

In all treatments (the soil, hydroponics and aquaponics systems), the water spinach plants showed consistent growth over time (Fig. 6). A statistically significant difference ($p<0.05$) in the average growth of water spinach was observed when the traditional soil growth was compared against the growth in the hydroponics and aquaponics conditions, with more growth observed in the soil treatment (Fig. 6, Table 2). There was a significant difference in the average growth of water spinach under treatment of traditional soil and hydroponics treatment ($p<0.05$), with higher growth in the traditional soil treatment compared to hydroponics (Table 2). It was also observed that there was no significant difference between the plant's growth under hydroponics and aquaponics treatments (Fig. 6, Table 2). Furthermore, there was a significant difference between the plant growth in the soil and the algal medium treatments ($p<0.05$, Table 2). However, there was no difference in the growth of water spinach under hydroponics and aquaponic treatments *versus* the growth in the hydroponics system with the algal medium ($p>0.05$, Table 2).

The aquaponics, hydroponics and algal medium units depicted lower performance in terms of number of leaves generated from the stems than the soil unit (Fig. 7a). Significant differences were observed between the number of leaves in the plants grown in soil, hydroponics and aquaponics set-ups ($p<0.05$, Table 2). No significant difference was observed in leaf number recorded in the hydroponics and aquaponics units. Furthermore, the leaf number in the algal medium did not exhibit significant difference from either the hydroponics or aquaponics units (Table 2). The hydroponics unit with the commercially available nutrient solution sustained the growth of the

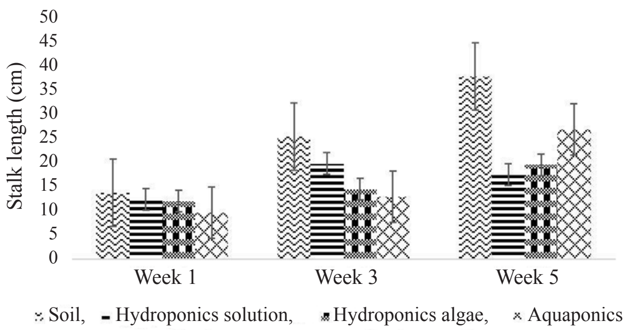

Fig. 6. Growth comparison of water spinach by length under the four experimental set-ups

Table 2. Comparison of different morphometric parameters under different treatments in 5 weeks

Treatment	p value
Growth of plants	
Soil *vs* Hydroponics	0.003507
Soil *vs* Aquaponics	0.062645
Hydroponics *vs* Aquaponics	0.019344
Soil *vs* Algal medium	0.007079
Hydroponics *vs* Algal medium	0.286264
Aquaponics *vs* Algal medium	0.052914
Number of leaves	
Soil *vs* Hydroponics	0.000695
Soil *vs* Aquaponics	0.015735
Hydroponics *vs* Aquaponics	0.000416
Soil *vs* Algal medium	0.004018
Hydroponics *vs* Algal medium	0.072017
Aquaponics *vs* Algal medium	0.051129
Growth of shrimps	
Aquarium *vs* Aquaponics	0.1768838

plants only until the third observation week (Fig. 7b). The water spinach was then observed to wither and rot, beyond third week. Fluctuation in the pH level from 6.1 to 7.35 was noticed following the third week.

It was also observed that the plants grown under LED lights developed vine-like tendencies towards the end of the trial. Common characteristics in the plants within the indoor set-ups included large inter-nodal spaces and long, slender, twirled climbing stems. These characteristics are not normally observed in the wild-type water spinach.

During the first to the third week of the experiment, prawns raised in the aquarium set-up exhibited better growth than the prawns in the aquaponics set-up. However, during the fourth and fifth weeks, prawns in the aquaponics unit exhibited higher rate of increase in length, as compared to the aquarium unit (Fig. 8). However, no statistically significant difference was observed between the growth of prawns grown in aquarium and aquaponic set-ups ($p>0.05$, Table 2). The aquarium and the aquaponics units had similar shrimp survival rate (Fig. 9).

In the past, research in the field of aquaponics has employed the use of mathematical models and *in silico* simulations for the construction and optimisation of systems suitable for commercial use (Yep and Zheng, 2019). The aquaponic culture practices involving Nile tilapia (*O. niloticus*) and other varieties of fish, in combination with common herbs, had been the subjects in studies for system optimisation, with their commercial profitability and viability also being considered (Love *et al*., 2014). However, studies on the use of aquaponics systems containing other edible aquatic organisms, such as prawns are limited. Results of the present study indicated that it is possible to grow freshwater prawns, along with

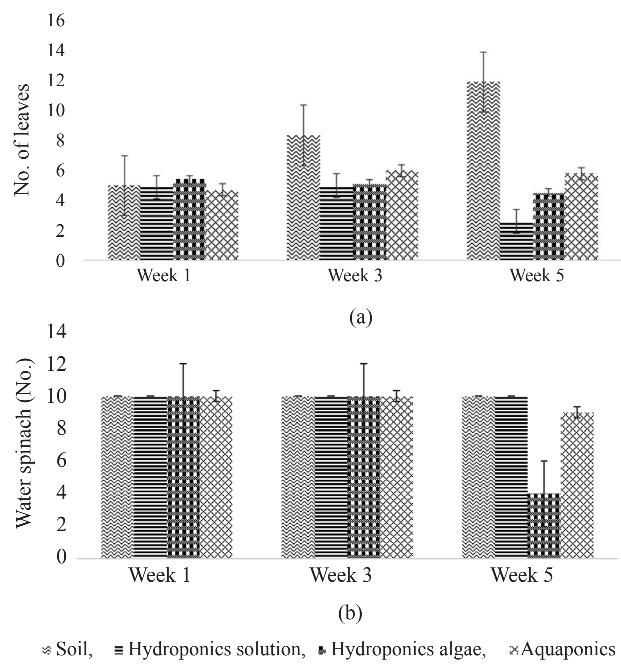

Fig. 7. Comparison of growth of water spinach in terms of (a) No. of leaves and (b) Survival of plants under the four experimental set-ups

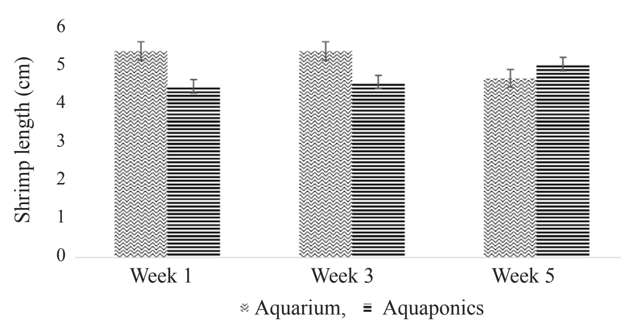

Fig. 8. Comparison of growth of prawns under aquarium and aquaponic set-ups

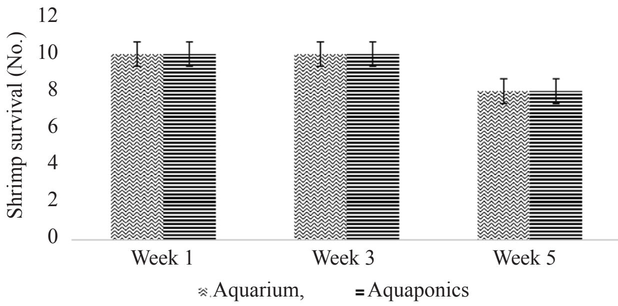

Fig. 9. Comparison of the survival rate of prawns under aquarium and aquaponics

water spinach, under an aquaponics set-up. The study may also open up a discourse on further optimisation studies for commercial viability.

The trial results concerning plant survival suggest that the soil and hydroponics units depict higher stability in maintenance of the water spinach stem cuttings throughout the study, as compared to the aquaponics system (Fig. 7b). One factor heavily suspected causing withering of the plants is the varied pH levels. Although water spinach can tolerate a wide range of pH levels, its optimal range is from pH 5.5 to an upper limit of pH 7.0 (Wang *et al*., 2015). The aquaponics and algal systems required higher pH levels. The freshwater prawns in the aquaponics set-up require a pH level of approximately 7.5, as lower pH levels may affect their growth and survival (Kawamura *et al*., 2015). Similarly, the hydroponics algal solution required maintenance of a pH range between 8.0 and 9.0 (Beltran *et al*., 2018). Similar literature also states that algal growth is known to cause marked changes in the pH of culture media (Dubinsky and Rotem, 1974).

Maintenance of pH levels between 5.8-6.2 for plant roots and a range of 6.5-9.0 for most aquatic organisms in aquaponic set-ups has been reported as the standard in many studies (Timmons and Ebling, 2010; Rakocy, 2012). Several of these studies have labeled the differences between pH requirements of the plants in the horticulture component and the aquaculture component in aquaponics systems as one of the major water quality compromises leading to either the failure of the aquaponics culture systems or sub-optimum yields from both plant and animal components (Resh, 2012; Goddek *et al*., 2015; Suhl *et al*., 2016). Presently, the varying requirements of the different components of the system have led to a compromise of the small operating pH range for the systems to work successfully in terms of the overall sustainability of the whole aquaponics set-up. However, further research is required to determine an exact pH value or range, possible transitions and other requirements for the growth optimisation of water spinach and freshwater prawns in aquaponics.

In order to tackle the issue of finding an optimum pH balance using minimum resource inputs that can be advantageous for both plants and fishes in an aquaponic set-up, simulator-based mathematical models are being used to explore the efficiency of decoupled multi-loop aquaponics systems (Goddek and Korner, 2019) as compared to more common, coupled aquaponics system (CAS) (Ru *et al*., 2017; Gullian-Klanian *et al*., 2018). The decoupled multiloop systems separate the recirculated aquaculture system (RAS) and hydroponic (HP) units from each other and mimic the detached ecosystems. Most of the studies proposing decoupled multiloop systems are based on simulations using mathematical modeling using Nile tilapia (*O. niloticus*) and tomato (*Solanum lycopersicum*) (Reyes-Lastiri *et al*., 2016). The decoupled aquaponics design does have the advantage of easy manipulation of the nutrient mixtures and alteration of the water chemistry specific to the plant and the aquatic organism, thereby achieving optimum conditions for growth under an aquaponics setup (Kloas *et al*., 2015; Goddek and Keesman, 2018). Though decoupled multiloop designs seem to be more suitable for large-scale aquaponic systems operating in advanced countries, it could be an option for the farmers in the Philippines also,who grow freshwater prawns in open ponds. The coupled aquaponics system seems to be relatively easy to use for small Filipino farmers with limited agri-space who are likely to adopt aquaponics more as an additional source of income. Using a decoupled aquaponic system, one can manipulate the fish feed and other plant nutrients to achieve the optimal growth of plants and aquatic organisms and hence optimisation of the decoupled aquaponic system for water spinach and freshwater prawns should be undertaken as well (Suhl *et al*., 2016).

It has been observed that light exposure affects the growth of the plant in terms of length. Plants grown in soil were placed outdoors, thus being more exposed to sunlight than the other systems. The hydroponics and the aquaponics systems were placed indoors and were only provided with a white LED light. Studies have shown that using blue and red combination LED lights are effective in growing plants as they allow a higher photosynthetic activity than monochromatic ones (Darko *et al*., 2014). By using only monochromatic LED lights and failing to mimic natural light, the growth rate of plants will be slowed and inhibited (Hemming, 2011).

The results also showed that light exposure can be attributed to the lowered leaf production of plants grown indoors and under LED lights. The standard hydroponics, aquaponics and algal medium units utilised white LED light as an alternative to natural light, the preferable light source for water spinach. A better alternative would be to use blue LED lights as it was proven to promote an increase in the leaf area of water spinach plants. The limited light spectrum and lowered lumen intensities provided by the monochromatic LEDs may have pushed the plants to decrease the biomass used for leaf production and enlargement and instead relocate it toward the stems to allow the plants to close the distance toward the LED light source. This reallocation of biomass towards stem growth may also explain the shift of the water spinach towards more vine-like behaviour, as climbing stems would allow the plants to latch onto the structure of the set-up and decrease the distance between the plant and the light source. As aquaponic systems are promoted for use in an urban set-up, such as apartments or flats with limited sunlight access, the information about the most appropriate artificial source of light for optimal plant growth remains crucial to the creation of these systems (Khwankaew *et al*., 2018) and therefore, must be studied further.

Shrimp mortality could be due to the high volumetric spatial requirements of the shrimps. The suspected insufficiency of the aquaculture space within the recycled plastic tubs may have instigated competition and stress for the shrimps. Both setups may have been subject to similar stressors due to the pattern of the systems constructed. Hence, it is recommended that density per unit of space in aquaponics set-ups should be reviewed and met to ensure optimal growth and survival of the shrimps. Tanks with larger volumes featuring more swim space and additional hideouts and crevices are recommended, especially for shrimps, due to their increased vulnerability during molting periods.

The results of the study also suggested that recycled algal media, generally discarded after the culturing process, can be successfully used as a hydroponics medium to supplement some of the nutrients required for plant growth. The trial's findings align with other studies, where rainwater or reverse osmosis-treated water was found to be suitable for aquaponics (Lennard, 2017). The use of recycled algal medium as nutrient medium for horticulture, hydroponics and aquaponics may be viewed as a promising field of study for researchers.

It is also suggested that the composition of the following materials be put under academic scrutiny, as further studies are needed to investigate their compositions: the shrimp feed used, the store-bought nutrient supplements for the plants, and the efficient buffering systems used to keep the pH levels for optimum growth of both plants and shrimps under aquaponics culture. It is suggested that future research needs to optimise their effectivity-to-financial cost ratios.

The critical importance of the maintenance of stability within the chemo-physical parameters in aquaponics systems, as compared to hydroponics systems, was made evident in the higher growth rates achieved in similar studies employing different sample organisms such as basil (*Ocimum basilicum*), tomatoes (*Lycopersicon esculentum*), white shrimps (*Litopenaeus vanna*mei) (Mariscal-Lagarda *et al*., 2012), freshwater prawn (*Macrobrachium rosenbergii*) (Ronzon-Ortega *et al*., 2012) and Nile tilapia (*O. niloticus*) (Sace and Fitzsimmons, 2013).

Since nutrient recycling is dependent on the water flow rate, as reported in studies involving water spinach (*Ipomoea aquatica*) and koi carp (*Cyprinus carpio* var *koi*) (Nuwansi *et al*., 2015), *Beta vulgaris* and goldfish (*Carassius auratus*) (Hussain *et al*., 2015), further investigations are needed to find the most suitable water flow rate for prawns and water spinach growth under aquaponics set-up. The use of standard, aquarium-grade water cycles may not provide enough water circulation due to differences in water viscosity and density, density and nutrient solute content. However, optimisation of circulation systems must also consider additional energy costs, as this may nullify the very purpose of producing urban agri-farming systems.

As several plant growth-promoting microorganisms (PGMA) such as *Pseudomonas*, *Bacillus*, *Enterobacter* and *Streptomyces* are known to increase nutrient availability and have been reported to be suitable for use in aquaponics (Bartelme *et al*., 2018), future research may also further investigate the appropriate PGMA strains suitable for optimal growth of water spinach and freshwater prawns in aquaponics.

The results of the present study have shown the growth and survival rates of water spinach and freshwater prawns under hydroponics and aquaponics set-ups. Water spinach grown in the aquaponics unit exhibited the highest growth in terms of length and more leaves among the indoor units, supporting its proposed use in aquaponics systems. The plants grown under hydroponics set-ups had lower survival rates and lower leaf productivity, which implies that growing water spinach hydroponically with the commercially available nutrient solution is not an effective alternative to current outdoor planting practices. The freshwater prawns exhibited similar growth rates in the aquaponics unit and aquarium unit, thereby confirming that they can be grown under an aquaponics set-up with minimal to no compromise in growth rate. Since water spinach cultivated in soil and in aquaponics did not exhibit differences in growth, the standardised aquaponics units can be used as an alternative for urban farming, providing both fresh vegetables and aquatic protein. Further studies are recommended to focus on the optimisation of the systems studied and the scrutiny of the different components included in the systems.

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