Compare the growth and productivity of *I. aquatic* species on hydroponic subsystems within an aquaponic system

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Compare the growth and productivity of *I. aquatic* species on hydroponic subsystems within an aquaponic system

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Abstract. The growth and productivity of two the Water Spinach varieties [Kangkung Unggul Bika^{R} and Kangkung Bangkok LP-1^{R}] had already been an experiment on two different Hydroponic culture subsystems [Floating Raft and Pumice Bed] of an Aquaponic circulatory system, where mineral nutrients of the Water Spinach vegetables were absorbed from biochemical processes occurring in solid wastes of fish and excess feeds. Consequently, this study showed individual functions of these two different Hydroponic culture subsystems from new established dates no significant differences at the 7th test date, until increasingly significant difference for the Hydroponic culture subsystem of Floating Raft is less effective than Hydroponic system of Pumice Bed based on the height of shoot, length of petiole and width of leaf on the 14th test date and the height of shoot, length of petiole, length of leaf, the number of leaf and length of root on the 21st test date. Nonetheless, Hydroponic subsystems did not support the growth and productivity of the Water Spinach varieties in all stages of testing about statistical significance. In addition, in term of productivity criteria and growth criteria on the 7th, 14th and 21st dates of testing, no significant difference were observed between two Water Spinach varieties. Finally, the advice of the study does not choose the treatment [Floating Raft Hydroponic culture subsystem and Kangkung Unggul Bika^{R} variety] due to the poor result for the height of the shoot, length of petiole and reality of yield of Kangkung Unggul Bika^{R} variety are probably at the 21st test date.

1. Introduction

Water Spinach [*Ipomoea aquatica*], belonging to family *Convolvulaceae*, is widely cultured as an edible green leafy vegetable in Asia [1]. It is well known for its essential biochemical and nutritional importance [2], comparable to conventional foodstuffs such as soybean or whole egg. It has also been used as traditional medicine, reduce the serum glucose concentration anticancer [1], anti-inflammatory [3], antiviral [4]. Some studies proved that water spinach can be considered as a potential functional food and has economic value. Therefore, the water spinach culture system for better plant growth and productivity is necessary to be improved.

In modern agriculture, researchers found hydroponic culture subsystems as media bed using a sand/gravel/aggregate culture bed and both floating raft and nutrient film technique [NFT] within an aquaponic system, where plant nutrients were supplied from fish wastes and plants stripped nutrients from the wastewater before it was returned to the fish. Therefore, there is some choice of hydroponic culture subsystems. Maucieri *et al*. [5] reviewed more than 120 publications on AP [aquaponic] of the last 30 years and only 9% of them compared different types of hydroponic subsystems and giving of results different [6]. This study is aimed to examine the growth and yield of water spinach species on various hydroponic subsystems in an aquaponic system.

2. Materials and methods

This research was conducted outdoors from October 1 - January 30, 2018 – 2019 follow randomized complete block design [RCBD] of two factors [two water spinach varieties x two hydroponic subsystems] and four replications include one rearing tank [4,500 L], one Mech-filter; one Bio-filter; one [A] and one [B] sump plastic barrels [220 L each] and sixteen hydroponic tanks [30 L] [Figure 1].

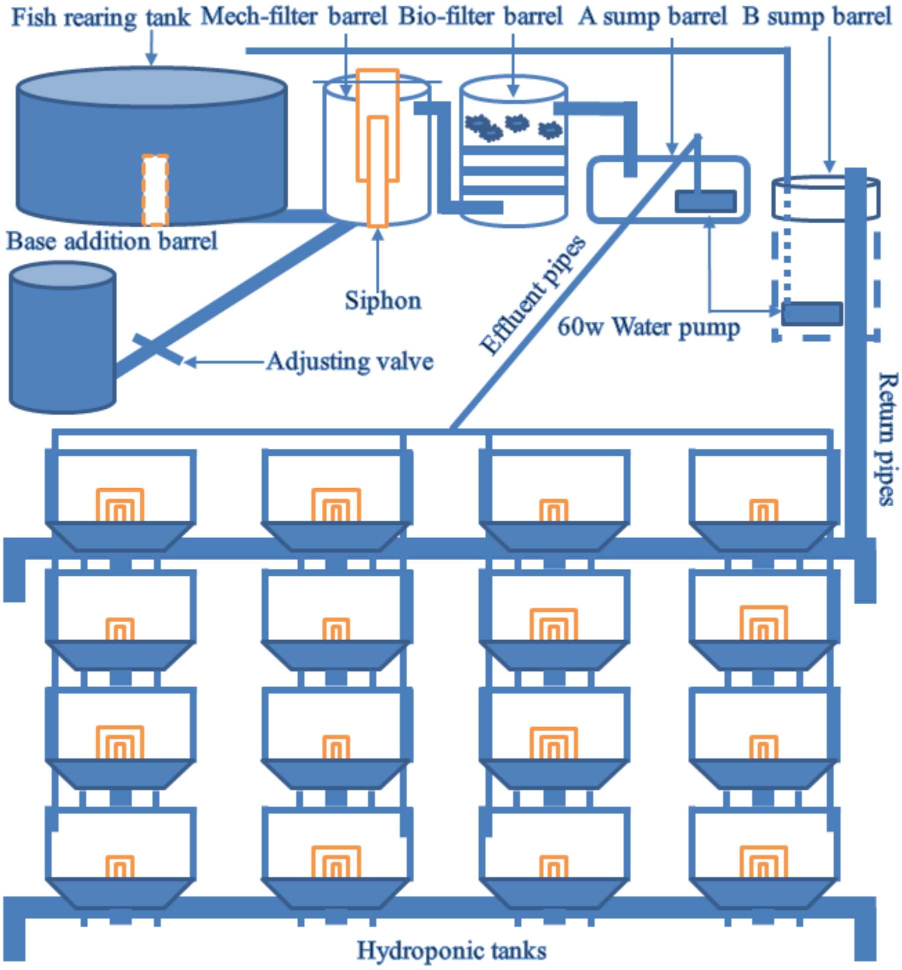

Figure 1. Diagram of the Aquaponic system [not drawn to scale].

All hydroponic tanks have the siphons to keep the mineral water up and down from 3 cm to 12 cm in the tanks. Hydroponic tanks have the hydroponic subsystems of floating raft have 2 inches styrofoams [length: 54 cm x width: 42 cm] were gouged of 1.5 inches with the density of 15 cm x 15 cm and the hydroponic subsystems of pumice bed was changed as styrofoams become pumice stones. Pumice stones were brought from the beach with the rate [3 cm x 4 cm] and then soaked two months in water to cleanse. Pumice stones were dropped into tanks until full tanks. The hydroponic culture subsystems are available for operation.

The Aquaponic circulatory system was produced from the 80g *Pangasius hypophthalmus* fingerling with a stock of 80 fish/m^3 and a fish feed ratio of 81.4 g/date/m^2. The pH is monitored daily and maintained at 7.0-7.5. Water lost removal is replenished with rainwater. Bacillus and [Nitrosomonas and Nitrobacter] bacteria are added 200 ml once a week [Figure 2].

A b C

Figure 2. Bottles to feed the main *Bacillus* and [*Nitrosomonas* and *Nitrobacter*] bacterias [not to scale]. [a] Plastic 500 ml water bottle: polymer clay, 300 ml distilled water and soft plastic 4 x 6 mm oxygen pump hose. [b] Plastic 20 l water bottle: polymer clay and soft plastic 4 x 6 mm oxygen pump hose. [c] Plastic 1.5 L water bottle: polymer clay, 1 L $KMnO_4$ 0.1 N [1 L distilled water + 3.161 g $KmnO_4$], soft plastic 4 x 6 mm oxygen pump hose, 4 x 4 mm motorcycle air filter. [d] Air pump [5w - 8 1/min]: polymer clay, soft plastic 4 x 6 mm oxygen pump hose and 4 x 4 mm tube glass.

Bacillus bacteria were prepared from 3 boxes of yogurt, white sugar [250g] and coconut water [10 L]. *Nitrosomonas* and *Nitrobacter* bacterias were prepared from red sugar [250g], 10 L soya water [1 L water + 1 kg beans] and nitrogen cycling bacteria 200 ml.

After the aquaponic system had been operated continuously on one month and seedlings nursery were on one week, seedlings were transplanted into hydroponics tanks follow the layout of treatments with density [15 cm x 15 cm]. The trial is begun for tracking criteria of growth and productivity of two water spinach varieties [Kangkung Unggul BikaR and Kangkung Bangkok LP-1R] into two different hydroponic subsystems [Floating Raft and Pumice Bed] on the 7th, 14th, and 21st test dates.

Statistical analysis of the data was performed using R [Version i386 3.6.0] statistical and graphical programming language. For statistical comparison, the two-way ANOVA was used to confirm significant differences. Post-Hoc analysis was performed using the HSD Tukey test.

3. Results and discussion

After transplantation on the hydroponic subsystems until the harvest, there were no significant differences between the two water spinach vegetables and interactions between hydroponic subsystems and varieties in any of the growth and productivity criteria at the $p > 0.05$ in all stages of testing about the statistical significance [data not showed].

Notwithstanding, the study is interesting to highlight the functions of the hydroponic subsystems achieved when considering the development of these parameters in the crop cycle from on the 7th date of testing. There was no significant differences in all of the growth criteria [data not shown] until there was a significant difference in any of the characteristics [height of shoot, length of petiole and width of leaf] on the 14th day [Table 1] and all of the productivity criteria [fresh weight, the theory of yield and reality of yield] and the growth criteria [height of shoot, length of petiole, length of leaf, the number of leaf and length of root]. On the 21st test date [Table 2] at $p \leq 0.05$ of the hydroponic subsystem of pumices bed is better than the hydroponic subsystem of the floating raft.

Table 1. Mean values [± SD] of the growth criteria on the 14th date of testing. Means with the same letter in each column are not significantly different at the $p < 0.05$ level according to the Tukey HSD test.

Criteria for growth	Pumice Bed	Floating Raft
Height of shoots [cm]	18.03 ± 1.94^a	12.73 ± 2.33^b
Length of petioles [cm]	2.11 ± 0.38^a	1.65 ± 0.33^b
Width of leaves [cm]	0.87 ± 0.31^a	0.56 ± 0.13^b

The significance level [P Value] was determined by analysis of variance [ANOVA]. ns: not significantly different at the p>0.05, *: significantly different at the 0.01<p<0.05, **: significantly different at the p<0.01, CV: Coefficient of Variation.

Table 2. Mean values [± SD] of the productivity criteria and the growth criteria on the 21st test date. Means with the same letter in each row are not significantly different at the $p < 0.05$ level according to the Tukey HSD test.

Tracking criteria	Pumice Bed	Floating Raft
Criteria for growth		
Height of shoots [cm]	21.65 ± 2.12^a	15.94 ± 3.26^b
Length of petioles [cm]	2.16 ± 0.21^a	1.54 ± 0.38^b
Length of leaves [cm]	6.82 ± 0.61^a	5.08 ± 1.33^b
The number of leaves [unit]	8.95 ± 1.06^a	7.35 ± 1.28^b
Length of roots [cm]	12.55 ± 2.44^a	9.81 ± 0.90^b
Criteria of yield		
Fresh weights [g]	4.21 ± 1.04^a	2.80 ± 1.24^b
Theory of yields [g/m^2]	463.38 ± 115.28^a	308.36 ± 136.75^b
The reality of yields [g/m^2]	476.88 ± 97.72^a	307.89 ± 84.87^b

The significance level [P Value] was determined by analysis of variance [ANOVA]. ns: not significantly different at the p>0.05, *: significantly different at the 0.01<p<0.05, **: significantly different at the p<0.01, CV: Coefficient of Variation.

Finally, the floating raft hydroponic subsystems and Kangkung Unggul Bika[R] treatment have the shortest shoot height on the 14th and 21st test dates, respectively [Figure 3] and the lowest petiole length and actual productivity on the 21st date [Table 3] in all treatments at the $p \leq 0.05$.

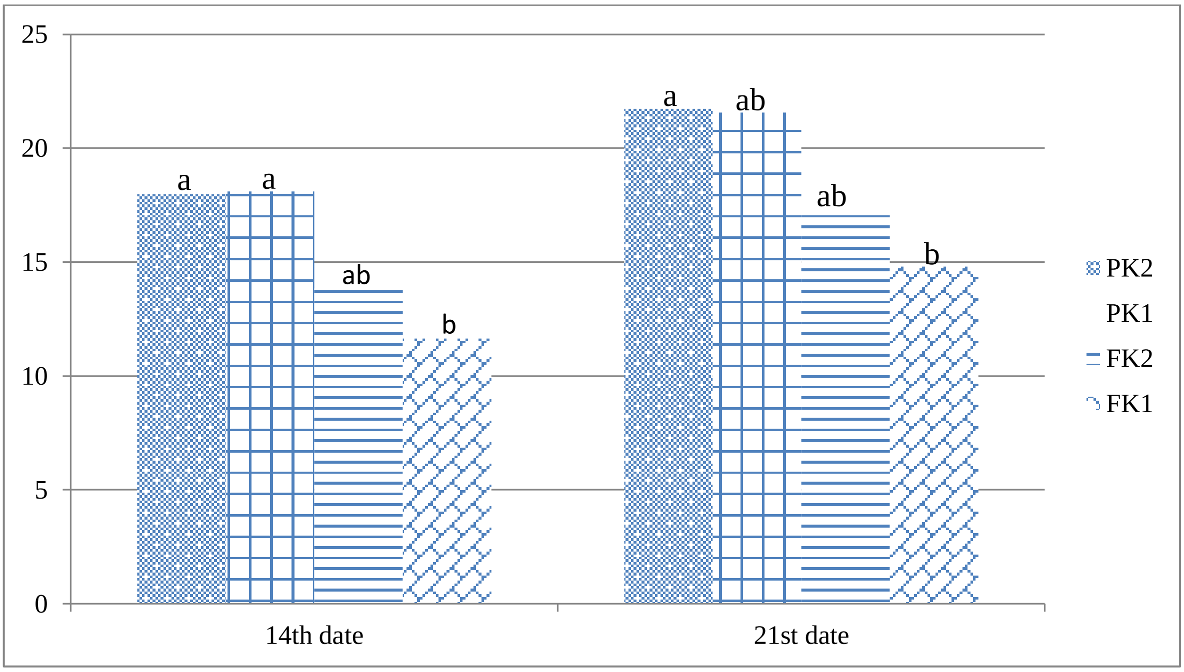

Figure 3. Evolution of average shoots height [cm] of treatments [Pumice Bed & Kangkung Bangkok LP-1R [PK2], Pumice Bed & Kangkung Unggul BikaR [PK1], Floating Raft & Kangkung Bangkok LP-1R [FK2] and Floating Raft & Kangkung Unggul BikaR [FK1]] on the 14th and 21st test date. Means with the same letter in each date are not significantly different at the $p < 0.05$ level according to the Tukey HSD test.

Table 3. Mean values [± SD] of the petiole length and the actual productivity on the 21st date of testing. Means with the same letter in each row are not significantly different at the $p < 0.05$ level according to the Tukey HSD test.

Treatments	Length of petioles [cm]	The reality of yields [g/m^2]
Pumices Bed & Kangkung Bangkok LP-1R [PK2]	2.13±0.22^{a}	463.75±126.78^{ab}
Pumices Bed & Kangkung Unggul BikaR [PK1]	2.18±0.22^{a}	490.00±75.83^{a}
Floating Raft & Kangkung Bangkok LP-1R [FK2]	1.77±0.45^{ab}	293.75±42.50^{bc}
Floating Raft & Kangkung Unggul BikaR [FK1]	1.38±0.18^{b}	315.00±121.24^{c}

The significance level [P Value] was determined by analysis of variance [ANOVA]. ns: not significantly different at the $p>0.05$, *: significantly different at the $0.01<p<0.05$, **: significantly different at the $p<0.01$, CV: Coefficient of Variation.

Information for growth and productivity of Kangkung Unggul Bika^{R} and Kangkung Bangkok LP-1^{R} varieties purchased from PT East-West Seed Indonesia and PT. Agri Makmur Pertiwi companies are still limited. Therefore, the study was conducted. Nonetheless, the result showed that the growth and productivity of both varieties are not different. Consequently, the choice for water spinach varieties is easy for farmers while it had been planted on the subsystems of the aquaponic system, where nutrients of the plants were absorbed from biochemical processes occurring in wastes of fish and excess feeds from rearing tank flow into the filter barrels [biological and mechanical filters]. As Somerville *et al.*, [7] found most fish only retain 30–40 percent of the food they eat, meaning that 60–

70 percent of what they eat is released as waste. Of this waste, 50–70 percent is dissolved waste and released as ammonia. The remaining waste is an organic mix containing proteins, carbohydrates, fats, vitamins and other minerals. Ammonias are converted into nitrite, which is done by the ammonia-oxidizing bacteria [AOB] then convert nitrite to nitrate by the nitrite-oxidizing bacteria [NOB]. Nitrate entering the subsystems and the plants can absorb nutrients that it does not need to support subsystems. Similarly, other authors have the same aquaponic system filter design with this study showed that nitrification provides mineral nutrients available for Basil's survival rate of 84.7%. Also, the water spinach adapts very well to the environment. This says that the aquaponic system provides enough essential nutrients and does not affect the subsystem. So, there was no interaction of growths and productivities between hydroponic subsystems and varieties in all stages of testing.

Nevertheless, the experiment reached a hydroponic subsystem of pumices bed had better growth and productivity than by hydroponic subsystem of the floating raft. This makes the study more accurate compared with the results obtained by Maucieri *et al.* [6] and Estim *et al.* [8]. This is due to mineral nutrients from the biochemical processes of microorganisms within both the hydroponic subsystems unit, which is dissolved in the water and absorbed by the plants. Yan *et al*, [9] investigated that the addition of NO_3^- N [1.0% per g N] brought a great response to plant growth. Similarly, other authors studied the functional activity of the photosynthetic apparatus showed a dependent feature on the availability of nitrate in plants. The nitrate ion by itself is known to be involved in the signal of a variety of physiological processes mainly related to nitrogen reduction and assimilation, but also with the architecture of the root. Nitrogen nutrition also affects the synthesis and translocation of cytokines that affect morphogenesis.

The above processes depend on many factors as the time for operating and design of the system, surface area, bacteria strain, water quality, wastes of fish and fish feed, variety of plant and many other factors. The floating raft hydroponic subsystem design, which consists of tanks [with 16 cm of water depth] covered by floating sheets of polystyrene for plant support. A significant amount of nitrification occurs on the undersides of the polystyrene sheets, especially in the areas exposed to strong currents where the biofilm is noticeably thicker [10]. Somerville *et al*., [7] reviewed that the surface area about 300 m^2/m^3, depending on the particle size and almost completely chemically inert, not dusty, non-toxic and it has a neutral pH and inert will not leach out any potentially toxic substances therefore not to affect the water quality. The water flows up and down in the tanks, the air is brought into the gravel. The high oxygen content of air allowing the bacteria to act for nitrifying bacteria from the decomposition of organic matter in the gravel and the plant's roots to breathe.

4. Conclusions

The floating raft is less efficient than the pumice bed and the treatment floating raft and Bika^R variety is the worst.

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