American Journal of Agricultural Science Engineering and Technology

ISSN: 2158-8104 (Online), 2164-0920 (Print)

Volume: 5, Issue: 1

Published by: e-Palli, Florida, USA

The American Journal of Agricultural Science, Engineering and Technology (AJASET) is blind peer reviewed international journal publishing articles that emphasize research, development and application within the fields of agricultural science, engineering and technology. The AJASET covers all areas of Agricultural Science, Engineering and Technology, publishing original research articles. The AJASET reviews article within approximately two weeks of submission and publishes accepted articles online immediately upon receiving the final versions.

Published Media: ISSN: 2158-8104 (Online), 2164-0920 (Print).

Frequency: 2 issues per year (January, July)

Area of publication: Agricultural Science, Engineering and Technology. The subjects covered by the journal includes but not limited to:

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ASSESSMENT OF SUITABLE PLANTS AS BIOLOGICAL FILTER IN ROOFTOP FISH CULTURE

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DOI: http://doi.org/10.5281/zenodo.4818068

ABSTRACT

Exponential growth of urbanization increases the unused rooftop space in the city area. The rooftop fish culture is the alternative way to utilized rooftop space and increases the production. In rooftop fish culture foremost challenge is to maintain water quality deteriorated by feces and leftover feed. The study aim was to identify the suitable plants for evaluating the ability of the plants as a part of the biological filter by extracting toxic compound from the fish tank. Research was designed by setup seven treatments (T_{ws}, T_c, T_{ts}, T_{cs},T_{wc}, T_{ip} and T_m) with three replicates each by using seven locally accessible plants (water spinach, coriander, taro stem, Ceylon spinach, water cress, Indian pennywort and mint) for biological filtration. Plant beds of the filter system were prepared by using sand, brick, coal and coir. In each fish tank 50 post larvae (PL) of prawn was stocked properly and 35-40 plants in each treatment bed. Water samples were collected to measure pH, DO, temperature, ammonia, phosphate and ammonium. The water temperature (24°C to 26°C), pH (7.78 to 8.8) and dissolve oxygen (DO) were in the optimum range for fish culture. Results showed that the significantly ($P<0.05$) highest phosphate absorption was observed in T_{ws} (0.96 ± 0.89 mg/l) which was followed by T_m (0.57 ± 0.33 mg/l), T_{cs} (0.54 ± 0.47 mg/l), T_{ts} (0.38 ± 0.35 mg/l), T_{wc} (0.37 ± 0.23 mg/l), T_c (0.26 ± 0.21 mg/l) and T_{ip} (0.18 ± 0.11 mg/l), respectively. In case of ammonia, the significantly highest ammonia was observed in T_{wc} (0.18 ± 0.19) where lowest in T_{ws} (0.04 ± 0.05) mg/l. On the other hand the highest ammonium was observed in T_{wc} where lowest in T_{ws} & T_c. It was also found that the T_{ws} (water spinach) was absorbed high amounts of phosphate, while T_{wc} (water cress) absorbed high amount of ammonia and ammonium. The T_{cs} showed high yield of plants vegetables (3000 gm/bed), it might be the cause of higher nutrient absorption. The highest yield of the prawn was found in the T_{wc} (321 gm/tank), because this treatment showed highest amount of ammonia and ammonium absorption the most toxic part for fish production. This research demonstrates that using of plants as biological filter provide significant nutrient recycling and increase the prawn and vegetables production.

Keywords: Assessment, Ammonia, Filtration, Suitable plant, Phosphate, Rooftop fish culture.

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INTRODUCTION

Numerous farmers of the developing countries along Bangladesh are faces tight problem of impoverishment, inclination and innutrition (Rusowo et al., 2008). The poor farmers of the developing countries are struggling for their livelihood. They tried to earn their livelihood from different small scale agricultural sectors (Dey et al., 2010). Among the agricultural sectors the fish culture plays a significant role in meeting the demand of animal protein for population of the developing countries like Bangladesh. Therefore, aquaculture increased in an outbreak meets the demand of the fish protein for the population (Roosta, 2014). Rapid growth of urbanizations the lands spaces for the agricultural production are decreasing now-days. There are great amounts of unused space in the rooftop of the urban area. The researchers tried to utilize the unused rooftop space. That's why it was found that a huge number of urban agricultural farming projects are being developed in existing building of the urban area. The projects are established in the rooftop space or unused building of the urban households (Thomaier et al., 2014). We can include fish culture along with agriculture in this type of multi-culture. On this concern present research work started on rooftop fish culture to fulfill the demand of the fish protein and utilize the abandoned space of the rooftop. In the rooftop fish culture system some challenge are found. The main challenge is to maintain the water quality. The maintaining of the water quality is very hard and costly by exchanging water or setting the mechanical instrument. To maintain the proper use of the water biological filter system by using plant is the best way which helps to filtering the water as well as adding the vegetables. There are different elements involved in recirculation system which established for waste water filtration in the fish culture including fish and plant growing bed. Combining both fish and vegetables in this system helps to produced fish and vegetables together and reduced the risk. This is a very low cost and effective system like aquaponics and recirculating aquaculture system to get both fish and cash crops and fruitful utilizations of the resources. The integration of aquaculture and hydroponics together is denoted as aquaponics which was the suitable way of deletion the risk in agricultural production. Better utilization of nutrients produced by wastage into the fish tank, increasing the profit and lowers the cost of the maintenance and also included fish and vegetables in the small-scale system. It also reduced the environmental pollution and all of those are possible by good maintenance of the aquaponics system (Tyson et al., 2011). In the fish tank of the rooftop fish culture there are different types of toxic compound produced by fish feces and leftover feed cause critical condition for the fish. The increasing ammonia concentration in the fish tank is devastating and hazardous. If the concentration reached at 1 ppm, it would create toxic condition and the fish will collapse within few moments. Using plants in the bio-filter reduced the problem in the fish tank because the plants used the toxic compound of the fish tank as nutrient and cleaning polluted water of the tank and recycle the water into the tank (Liang & Chien, 2013). But choosing the suitable plants for filtration system is very important. Because the chosen plants must have the high amount toxic compound reduction as well as added economical valuation in the combine culture system. So, this research will help to identification of the suitable plants to filter water for rooftop fish culture and increase the production.

MATERIALS AND METHODS

Exploratory site and design

Conducting the research in the rooftop, it was crying need to select a suitable space for rooftop fish culture. Because in rooftop fish culture the crucial challenge was temperature and water availability. Considering that problem the selected site was the teachers building beside VC residence of the Chattogram Veterinary and Animal Sciences University (CVASU). The entire research was taken for 6 months from July to December 2018 and it was divided into several segments including structure preparation, plant bed ground work, plantation for bio-filter and stocking of fish and culture management. The plant and fish sampling data was collected for 4 weeks in 7 days interval. In the study, seven treatments (T_{ws}, T_c, T_{ts}, T_{cs}, T_{wc}, T_{ip} and T_m) with three replications each by using seven locally accessible plants (water spinach, coriander, taro stem, Ceylon spinach, water cress, Indian pennywort and mint) for biological filtration.

Structure preparation

The structure of the technology was established by using easily available equipment and cheaply into the market includes 21 plastic drum (250 L water holding capacity) as fish tank, 21 half drum (34.86 ft^2) for plant bed preparation, 2 plastic drum as reservoir tank, 2 pump (0.5 HP), clamps, iron, T pipe, nipple pipe, plastic pipe, break, sand, coal, coir, etc. The fish rearing tank was set in the ground of the iron rack and plant bed was setup on the top of the rack for better filtration performance. The whole structure was prepared by using those mentioned equipment's by joining them into the required site. The plant bed was prepared by using four layer filter media like break (50 mm), sand, coal (50 mm) and coir.

(a) (b)

Figure 1. Partial structures of rooftop fish culture technology (a & b)

Plantation and fish stock

The plantation into the plant bed was done by using 14 days old seedlings of locally accessible plants (water spinach, coriander, taro stem, Ceylon spinach, water cress, Indian pennywort and mint) for biological filtration. Each plant bed consist with 35-40 plants seedlings. The growth of plants fully depended on the nutrients uptake from the wastage water of the fish tank. There was zero inorganic fertilizer utilization for the plant growth. Similar-sized disease-free 50 PL of freshwater prawn species (*Macrobrachium rogenbergii*) were stocked in each tank. During the experimental period the prawn was fed by commercial feed @3% body weight.

Procedure of sampling and data collection

On this system the fish tank water was polluted by the fish feces and leftover feed. The waste water from the fish tank pumped to the reservoirs tank and after that the water distributed into the each plant bed by setup pipe. The plant roots trap the waste for nutrients from the polluted fish tank water after that it channeled back clean water to the fish tank. The sampling was done during the culture period of 28 days after 7 days intervals by collecting water without filter and with the filter from the system. Water temperature was determined by using a Celsius thermometer, pH by using a pH meter and Dissolve Oxygen by using a Dissolve Oxygen meter. Other water quality parameters ammonia, ammonium and phosphate was measured by using Model T 80 spectrophotometer by setting different program for different parameters and using different reagents (VARIO Phos 3F10, VARIO Ammonia Salicylate F10, VARIO Ammonia Cyanurate F10, VARIO Nitri3 F10, VARIO Nitrate Chromotropic powder, NH_4-1, NH_4-2, NH_4-3.

Data analysis

Data analysis was done to evaluate the performance of the plants to maintain the water quality. The data of the water quality were analysis by using IBM SPSS 18.0 and Microsoft Excel 2007. To test the significance ($p<0.05$) differences among the treatment one-way ANOVA analysis was done. Turkey HSD test used to evaluate the statistical differences among the treatments.

RESULT AND DISCUSSION

Water Temperature, pH and Oxygen

On that rooftop fish culture the water quality parameter was in optimum range. Selected plants were significantly removed the wastage from the fish tank water. In the rooftop fish culture the water of the fish tank mostly deteriorate by feces of fish and unutilized feed. For that reason the culture of fish was in the risk and creates hazardous condition for fish survival and growth. The researchers found that to obtain maximum growth of the fish for getting highest profit from the recirculating aquaculture system maintaining favorable water quality

was mostly important. Maintaining optimum level of dissolve oxygen, near about neutral pH, lower concentration of ammonia and nitrite compound into the fish tank helps to increase the fish growth and survival rate (Losordo et al., 1998).

The mean water temperature, pH value and DO of fish tank under different treatments are presented in the Table 1. In this research showed that the pH of the fish tank was ranges from 7.34 to 8.8 (Highest mean 8.30 in T_m and lowest mean 8.21 in T_{ws}) which was comfortable for fish culture. In the first stage the pH was high because of liming in to the fish tank to prevent the fish disease. The pH range was suitable within the acceptable level, as recommended for fish culture (Boyd, 1982).

Table 1. Mean and standard deviation of temperature and pH values under plant based filter treatment system.

Treatment	Temperature (^oC)	pH	DO (mg/l)
T_{ws}	24.57 ± 2.16	8.21 ± 0.51	4.6± 0.05
T_c	24.53 ± 2.06	8.28 ± 0.51	5.0± 0.01
T_{ts}	24.59 ± 2.15	8.22 ± 0.51	4.4± 0.35
T_{cs}	24.56 ± 2.06	8.24 ± 0.52	4.5± 0.21
T_{wc}	24.56 ± 2.15	8.27 ± 0.50	5.1± 0.43
T_{ip}	24.63 ± 2.09	8.22 ± 0.53	4.9± 0.56
T_m	24.50 ± 2.06	8.30 ± 0.52	4.8± 0.56

Here, T_{ws}=Water spinach, T_c=Coriander, T_{ts}=Treatment having taro stem, T_{cs}=Ceylon spinach, T_{wc}=Water cress, T_{ip}=Indian pennywort and T_m=Mint

The water temperature of the study varied from 24°C to 26°C which was optimum range for fish culture. The highest and lowest mean values of water temperature in the fish tank were observed 24.63 ± 2.09 and 24.50 ± 2.06°C in T_{ip} and T_m, respectively (Table 1). The water temperature were more or less similar in all treatments. The water temperature was cooperatively lower in all cases and decreased slightly at the end of the experiment as conducted in the coldest month of the year. The winter season was the reason for temperature fall and also sudden rain cause the fall of water temperature. However, the present study showed that the temperature was optimum both for fish and vegetables. The dissolve oxygen was found in the range of 4.4 to 5.1 mg/l, where highest in T_{wc} and lowest in T_{ts} treatment. The observed oxygen level is suitable for fish culture. In this research the fish tank of the plant based bio-filters was always oxygenated by continuous circulation of the water into the plant bed and passing the sprinklers on return to the fish tanks, so that the concentration of the oxygen was in optimum level for fish growth. However, water temperature, pH and dissolve oxygen were recorded without any significant variation during the experimental period. In the present study, all the water quality parameters were within the acceptable limits, as recommended for tropical aquaculture (Boyd & Tucker, 1998).

Phosphate absorption

Toxic compound of the fish tank was produced by fish feces and leftover feed into the fish tank mostly by nitrogenous compound. The seven treatments showed great amount of nitrogenous compound reduction and phosphate reduction. Phosphate is very much important nutrient for the plant. The results showed that the phosphate absorption were 0.96 ± 0.89, 0.26 ± 0.21, 0.38 ± 0.35, 0.54 ± 0.47, 0.37 ± 0.23, 0.18 ± 0.11 and 0.57 ± 0.33 mg/l in seven treatments T_{ws}, T_c, T_{ts}, T_{cs}, T_{wc}, T_{ip} and T_m, respectively. Different plant treatment showed different phosphate absorption from the fish tank. The significant level ($P< 0.05$) of highest phosphate absorption (0.96 mg/l) was observed in T_{ws} which was followed by T_m, T_{cs}, T_{ts}, T_{wc}, T_c and T_{ip}, respectively (Figure 2), which indicates that the water spinach absorbed highest level of phosphate and it was mostly suitable for filtration system in rooftop fish culture. Salam et al. (2020) reported that the highest value of phosphorus (P) was 1.69 (±0.11) ppm in influent, which reduced to 1.19 (±0.11) ppm in the effluent water of 'Tilapia powered aquaponics' from the rooftop.

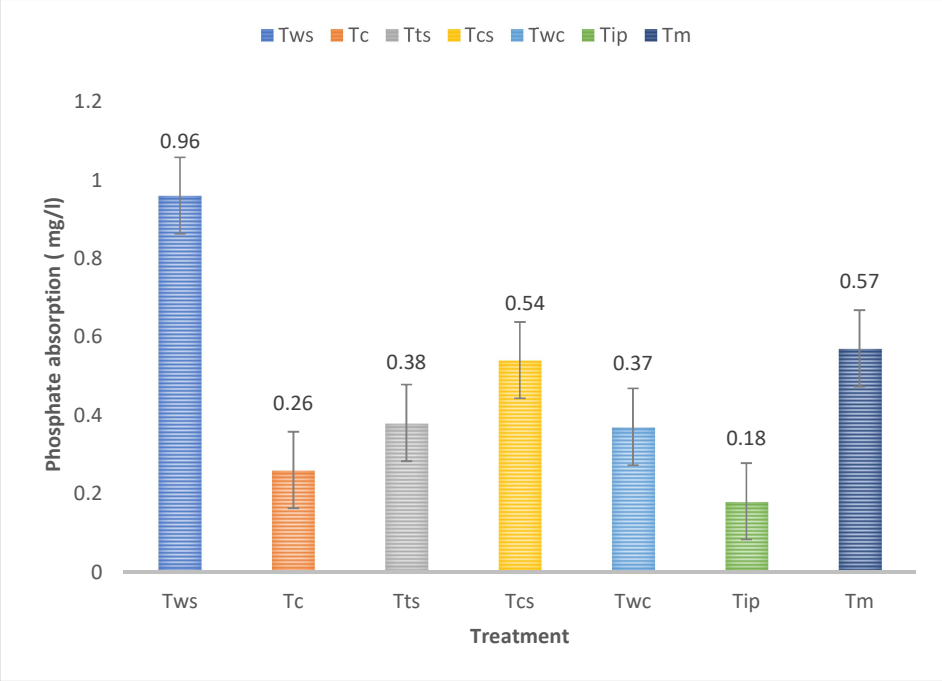

Figure 2. Mean phosphate (PO_4^+) absorption by treatment plants in rooftop fish culture.

Ammonia absorption

In this study, the ammonia absorption was 0.04 ± 0.05, 0.09 ± 0.08, 0.05 ± 0.03, 0.11 ± 0.13, 0.18 ± 0.19, 0.10 ± 0.11 and 0.07 ± 0.04 mg/l in T_{ws}, T_c, T_{ts}, T_{cs}, T_{wc}, T_{ip} and T_m, respectively (Figure 3). The researchers found that the amount of the ammonia concentration should be less than 1.00 mg/l for recirculating aquaculture system (Nijhof & Bovendeur, 1990). Ammonia of the filtration system was reducing by seven selected plants treatment but mostly

by the T_{ws} (water cress) which showed significantly highest level of ammonia absorption (0.18 ± 0.19 mg/l) which was followed by T_{cs} (0.11 ± 0.13 mg/l), T_{ip} (0.10 ± 0.11 mg/l), T_c (0.09 ± 0.08 mg/l), T_m (0.07 ± 0.04 mg/l), T_{ts} (0.05 ± 0.03 mg/l) and T_{ws} (0.04 ± 0.05 mg/l), respectively ($P< 0.05$). It may be assumed that the lower values of ammonia absorption in this study was found due to plant absorption, assimilation of water microorganisms and association of biofilms with root mats vegetables.

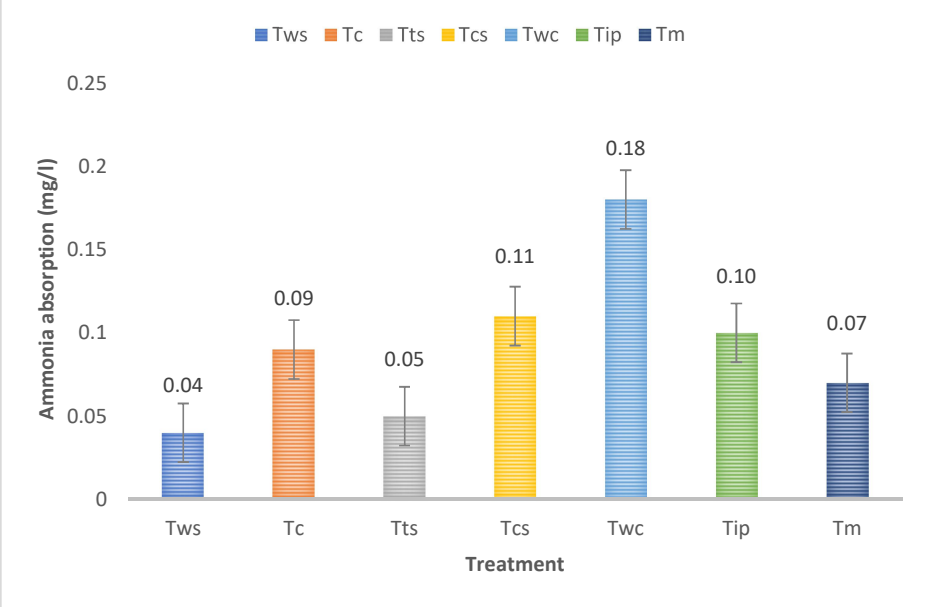

Figure 3. Mean ammonia (NH_3) absorption by treatment plants in rooftop fish culture.

Ammonium absorption

The results showed that the reduction of ammonium for seven treatments were 0.08 ± 0.06, 0.08 ± 0.07, 0.10 ± 0.04, 0.25 ± 0.24, 0.41 ± 0.46, 0.21 ± 0.23 and 0.11 ± 0.10 mg/l in T_{ws}, T_c, T_{ts}, T_{cs}, T_{wc}, T_{ip} and T_m, respectively (Figure 4). Aquaculture integrated with wetlands system helps to remove 86-98% of the ammonium nitrogen from the waste water of the aquaculture (Lin et al., 2002). It was found that the water spinach (*Ipomoea aquatica*) showed maximum percentage of nutrient removal with good fish (Poly-cultured of koi carp and gold fish) growth. The water flow rate was 0.8 l/min on that system (Nuwansi et al., 2016).

To eliminate the toxic concentration (ammonia and nitrite) accumulation from the fish culture, it is very much important to integrate the water treatment system with the recirculating aquaculture system like different types of physical and biological systems (El-Shafai et al., 2007b). The results showed that significantly ($P<0.05$) highest ammonium absorption in T_{wc}(0.41 ± 0.46 mg/l) than T_{ws}(0.08 ± 0.06 mg/l), T_c(0.08 ± 0.07 mg/l), T_{ts}(0.10 ± 0.04 mg/l) and T_m(0.11 ± 0.10 mg/l), respectively. Ammonium was absorbed mostly by T_{wc} (water cress), T_{cs} (Ceylon spinach), T_{ip} (Indian pennywort) and T_m (mint) in this study. The scientists suggested that ammonium (NH4+) plays major source of the inorganic nitrogen

which was easily taken up by the roots of the plants from the waste water of the fish tank (Vaillant et al., 2004).

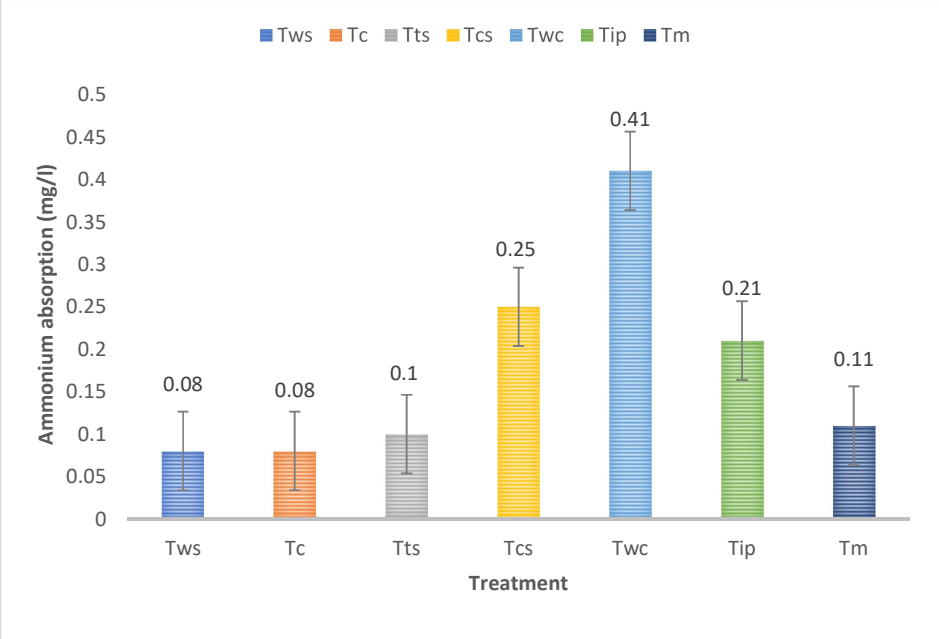

Figure 4. Mean ammonium (NH_4^+) absorption by treatment plants in rooftop fish culture.

Plant growth and yield

The growth of plants dependent on the sufficient nutrient availability in the culture media. The nutrient absorbed from the fish tank helps the plants showed better growth performance and the quantity of the plants vegetables. The T_{cs} showed high yield (3000 gm) followed by T_{ws} (2100 gm), T_{wc} (1200 gm) and T_{ip} (750gm) because of higher nutrient absorption (Table 3). The toxic compound creates hazardous condition into the fish tank and cut back the growth of fish. The average crop yields at harvest ranged from 1.45 to 1.85 kg/trough and 1.71 to 2.50 kg/trough for mustard green and water spinach, respectively depending on the seed quantity (Salam et al., 2020).

Prawn production

The results showed that the highest yield of the prawn was found in T_{wc} (321 gm) because this treatment showed the highest amount of ammonia reduction, the most toxic part for fish production (Table 3). It was found that the highest yield of production was obtained from integrated culture of fish and vegetables than culture of fish individually. It was found that the yield was increased 13 to 14 times more annually (Hussain et al., 2014). One of the most important advantages of the aquaponics culture system was found highest amount of plants biomass. In a single fish cycle, it was possible to obtain several plants cycles because of continuous circulation of the nutrient from the fish tank (Rakocy et al., 2004).

Table 3. Harvested plants and prawn under plant based filter treatment system.

Treatment	Harvested plant (gm/bed)	Harvested prawn (gm/tank)
T_{ws}	2100	195
T_c	600	165
T_{tS}	600	180
T_{cs}	3000	195
T_{wc}	1200	321
T_{ip}	750	315
T_m	600	315

Here, T_{ws}=Water spinach, T_c=Coriander, T_{ts}=Treatment having taro stem, T_{cs}=Ceylon spinach, T_{wc}=Water cress, T_{ip}=Indian pennywort and T_m=Mint

Results of the research showed that the T_{ws} (water spinach) was absorbed the high amount of phosphate, and T_{wc} (water cress) absorbed high amount of ammonia and ammonium. The T_{wc} (water cress) showed better ammonia, ammonium and phosphate absorption. The T_m (mint) and T_{ip} (Indian pennywort) also showed better absorption power ammonia, ammonium and phosphate reduction. Considering the economic value, the T_m (mint) and T_{ip} (Indian pennywort) may be recommended for filtration system.

CONCLUSION

The plants have the ability to reduce the pollutant of aquaculture wastewater. The research showed that the integration of the plants as biological filter in the rooftop fish culture reduced great amount of the toxic compound from the fish tank (nitrogenous compound and phosphate) which helps better growth and survival rate of the fish. The importance of rooftop fish culture can ensure the demand of animal nutrition and ensure potential utilization of the water. Concerning the toxic compound removal from the fish tank and addition of the economic value into the rooftop fish culture, selection of suitable plants for filtration system is most important issue. There is a shortage of information on suitable plant selection for filtration system in rooftop fish culture. Therefore, further large scale research will be recommended to establish rooftop fish culture in the urban unutilized rooftop space and this culture system.

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