Integration of Aquaculture, Aquatic Plant and Plant Cultivation Systems

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Abstract*—Integrated agricultural systems are very vital to the agriculture country. This study stimulated a natural system that is interdependent among several organism species. The ecosystem consisted of nutrient circulation in the integrated aquaculture systems (*Cyprinus Carpio* Linn. or fancy crap), cultivation of aquatic plants (*Vallisneria asiatica* or spiral tape grass) and plants in soil (*Lactuca sativa var.crispa* L. or green oak). The 14 fancy craps started with 50-500 g in a 5.6 m^3 of pond volume. Used fancy craps waste excretion in the nutrient water was utilized in the circulation system by feeding 40 spiral tape grasses planted in 2.5 m^3 of pond volume and to green oaks in the pot size of 60 x 200 cm^2. The results indicated that water quality in fish pond showed Dissolved Oxygen (DO) ranging from 6.27 to 7.15 mg/L and pH ranging from 7.2 to 8.9. Nitrate, ammonia and phosphate were in the range of 5.52-8.09, 0.195-1.49 and 0.124-0.202 mg/L, respectively. All nutrients tended to continuously decrease from starting the experiment to the end of the experiment. Specific growth rate of fancy craps was 3.45 and survival rate was 100%. The shape of fancy craps was long, slender, cylinder and beautiful color, which did not change from the beginning of typically commercially available fancy craps. The length and weight of spiral tape grasses increased 2.5 times. On the 45th day, green oak yielded was 2,750 g/m^3, which was slightly higher than that of control set by hydroponic system. Therefore, this system can be used by farmers to reduce the use of water resources, fertilizers and cost savings.

***Index Terms*—integrated agricultural system, nutrient circulation, water quality, hydroponic**

I. Introduction

Over the last decades, the rate of global aquaculture production explanation has been increasing at an average of 6.2% with 1.6% of world population growth. Food and agriculture organization of the united nations (FAO) in 2014 reported that by 2030, human consumption of fish supply is more likely to be 62% in the world [1]. The issue of water utilization in aquaculture, therefore, is considered as environmental concerns [2]. The recirculating of aquaculture in integrated systems is considered to be beneficial for sustainable management [3]. General aquaculture system of sustainable resource production is used as an important source of recycled nutrient materials [4]. Fish excretion consists of high nitrogen which is a crucial element in the living organism. In production system, nutrient input for fish food, only 25% of nitrogen is processed via fish biomass and more than 60% is waste from excretion in ammonia form [5]. To concern about water quality in fish pond affecting growth rate, aqua system has been exchanged with recirculation of water. Wastewater is a nitrogen-rich source for utilization of plant productions. Butterworth *et al.* (2010) studied Recirculating Aquaculture Systems (RAS) with mollusca and the integrated culture of abalone and seaweed which are considered to be the aquatic culture of animals and plants [6]. This work made an inspiration among increasing research in this area regarding aquaculture production to reduce cost including resource from wastewater and improve quality of aquatic animal health. Tyson *et al.* (2011) revealed the combination of aquaponics in plant productions with hydroponic system which related to aquaculture fish production is a sustainable system [7]. The recirculating biological cycles provide nitrogen from waste source in order to improve economic benefits which was a good natural nutrient for hydrophobic production. Somerville *et al.* (2014) studied co-cultivation between fish and plants which waste from excretion of fish was converted to nutrient of plants in conventional aquaculture and hydroponic systems [8]. Zhen Hu *et al.* (2015) investigated the nitrogen uptake in plants which was an important role in the prevent of NO_3^- accumulation in aquaculture system [9]. The nitrogen recovery in aquaponics had significant effects to Nitrogen Utilization

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Efficiency (NUE) in tomato (*Lycopersicon esculentum*) and pak choi (*Brassica camperstris L. subsp. chinensis*) with 41.3% and 34.4%, respectively. The study done by Jin *et al.* (2010) indicated that nitrogen consumption in different plant species depended on growth characteristic utilization in system [10]. Yina *et al.* (2016) investigated pH and nitrogen effects in aquaponics system during at pH 6.0 to 9.0 [11]. The results showed that utilization of nitrogen was 50.9% at pH 6.0 which pH increased from 6.0 to 9.0 because of the effect on N_2O conversion. Bugbee *et al.* (2013) recommended pH, one factor in aquaculture system, to be approximately 5.5-5.8 [12]. In addition, Kim *et al.* (2007) stated that nitrification was possible with 7.5-8.0 optimal pH [13]. In aqua-system for the growth of fish, Arimoro (2006) [14] and Lemarie *et al.* (2004) [15] reported that fish could live in the presence of wide pH value depending on the species. All these researches examined the role of plant species in aqua-cultivation system, which could apply in new designing systems to reduce cost of plant production. These studies, a green oak (*Lactuca sativa var.crispa* L.), spiral tape grass (*Vallisneria asiatica*) and fancy crap (Cyprinus *carpio* Linn.) aquaculture system, described that reduced water consumption and increase the efficiency of nutrient utilization to compare for growing each individually. This paper is aimed to determine the effects of the irrigation with water from fancy crap fish effluent on green oak and spiral tape grass yield and to evaluate the nutrient budget from integration of aquaculture, aquatic plant and plant cultivation systems as shown in Fig. 1.

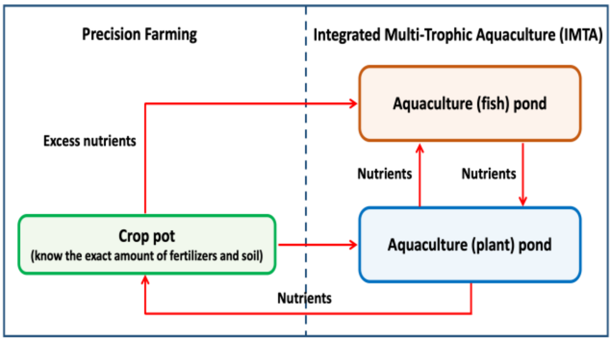

Figure 1. Research overview.

II. Materials and Method

Cultivation system, shown in Fig. 2 and Fig. 3, was studied with 14 fancy craps, initial weight of 176±9.56 g, in a 2.5 x 4.0 x 0.5 m^3 pond with 0.5 hp airlift aeration. Fish formulated by feeding 40% of protein for 20 g per day. Fancy craps excretion in the water was utilized as nutrients to feed both 40 spiral tape grasses in 2.5 x 2.0 x 0.5 m^3 pond and green oaks in the pot size of 60 x 200 cm^2. After 45 days, the final survival and biomass were determined. Dissolved oxygen (DO), temperature and pH were investigated in situ, whereas total Kjeldahl nitrogen (TKN), total ammonia nitrogen (TAN), nitrate (NO_3^-), and phosphate (PO_4^{3-}) were analyzed twice a week from fish and plant ponds.

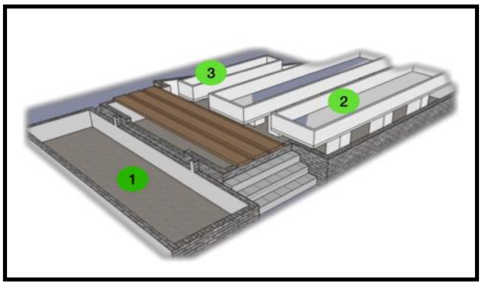

Figure 2. Simulation for the actual location of the experiment consisting of 1) plant pond, 2) green oak and 3) fish pond.

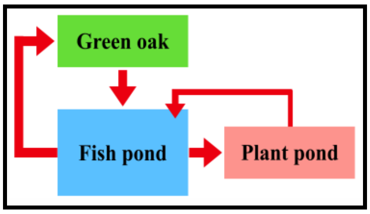

Figure 3. Schematic diagram of integration of aquaculture, aquatic plant and plant cultivation systems.

III. Results and Discussion

During the study period, survival rate in aquaculture systems including fancy crap (*Cyprinus carpio*), spiral tape grass (*Vallisneria asiatica)* and green oak (*Lactuca sativa var.crispa* L.) were 100%. In the system, 3 parts of water were recirculated; fish pond, plant pond and green oak in pot of hydroponic culture. The input nitrogen related to fish formulated fed by 40% protein for 20 g per day which affected on nitrogen in system from fish excretion into surrounding environment. Water from fish culture was a nutrient source for growing green oak in 2 plots of 60x200 cm^2 which watering for 20 L/week. Excess water flow out through the prepared hole above the fish pond so that the remaining nutrients from the plant needed was released into the fish pond. To maintain water quality in fish pond, the results presented the data for each experiment that was DO (6.26-7.15 mg/L), pH (7.2-8.9), NO_3^- (7.71-9.07 mg/L), PO_4^{3-} (0.124-0.202 mg/L) and TAN (0.195-1.49 mg/L). In addition, plant pond was investigated of DO (5.08-6.59 mg/L), pH (7.7-9.3), NO_3^- (5.52-8.09 mg/L), PO_4^{3-} (0.12-0.20 mg/L) and TAN (0.16-0.86 mg/L). Particularly nitrate (NO_3^-) concentration, total ammonia nitrogen (TAN) concentration and phosphate (PO_4^{3-}) concentration in system of 45 experimental days were shown in Fig. 4, Fig. 5 and Fig. 6, respectively. The recirculating aquaculture system without water exchange indicated NO_3^- concentration which accumulated in fish pond was in the range of 5.53 to 8.09 mg/L. The attribution of plant growth was observed in aquaponic systems with slightly increased and decreased during experimental period. The decrease of NO_3^- concentration at some stages was caused by the maturation of spiral tape grass and green oak. Total ammonia nitrogen concentration in Fig. 5 continued declining from 1.49 mg/L to 0.195 mg/L in plant pond because of the use of energy sources for plants received nutrients from fish ponds. Phosphate (PO_4^{3-})

concentrations in the system were in range of 0.124 to 0.202 mg/L as shown in Fig. 6. The principle of sustainable development suggests that system of living thing should not generate any waste to others. In aquaculture pond, there are 4 main sources of waste generation i.e., 1) waste excretion from aquatic animal, 2) oversupplied food from aquatic animal feeding, 3) food that cannot digest, and 4) remains of dead life such as plankton and aquatic animals etc. It could be said that animal food is the main factor affected to the amount of waste in system, which normally known as source of nitrogen-based waste. Nitrogen compounds can be found in aquaculture ponds in form of ammonia (NH_3), ammonium ion (NH_4^+), nitrile (NO_2^-), nitrate (NO_3^-) and nitrogen gas (N_2). Total ammonia nitrogen (TAN) measured ammonia in water in both forms, NH_3 and NH_4^+. Ammonia found in water is toxic to aquatic animals because its size is small enough to transfer into the animal body cells. However, microbial activity that changed nitrogen compounds in an oxygenated state would result in ammonification and nitrification by *nitrosomonas* bacteria to reduce ammonia to nitrile and then nitrate forms in water. Nitrates is a toxic to aquatic animals when they exposed in long periods of time and high concentrations. From the experiment, integration cultivation systems were approached. The system used nutrient sources for green oak and spiral tape grasses by the water that passed through the crop system with suit for fish growth. The circulating water system did not lose water in the seepage process, which was a system that can save water and also treat water.

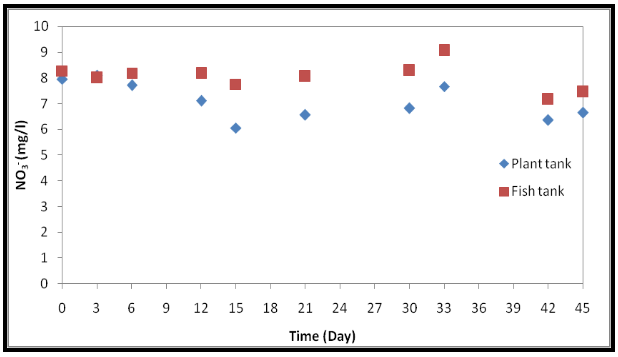

Figure 4. Nitrate (NO_3^-) concentrations in the systems.

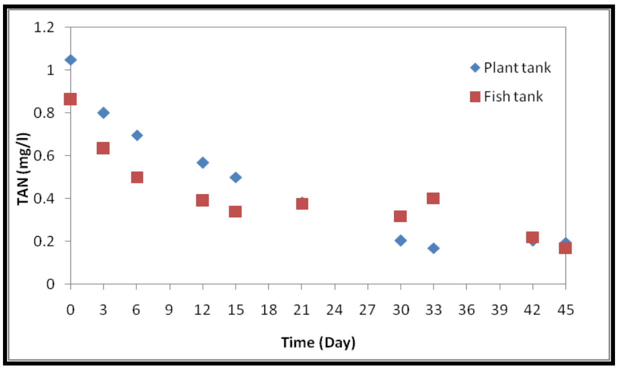

Figure 5. Total ammonia nitrogen (TAN) concentrations in the systems.

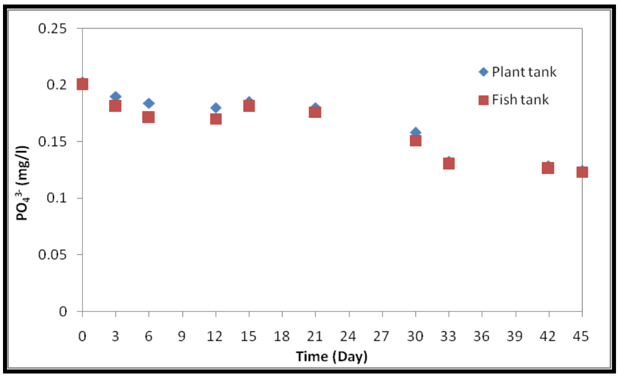

Figure 6. Phosphate (PO_4^{3-}) concentrations in the systems.

The concentration of DO in fish pond and aquatic plant cultivation pond on the soil cultivation stage by collecting water samples 3 days/week was investigated. The results showed that the concentration of DO in fish and plant ponds were in the range of 6.27-7.15 mg/L and 5.08-6.59 mg/L, respectively. Oxygen was the most important factor in life because both plant and animal organisms need oxygen for breathing and growth. Oxygen in water depended on many factors such as temperature, altitude and salinity. The pH in fish and plant ponds were in the range of 7.2-8.9 and 7.7-9.3, respectively. The pH value in fish pond was mostly lower than aquatic plant, but the value was higher than the recommended for raising fish, which pH was not more than 8. Excessive pH caused fish to have hemorrhage, causing red spots around the body, with a high pH for consecutive periods of time, which may cause the fish die. In general, the appropriate pH value should be around 6.5-7.5. Although, fish could live at pH 6 to weak acid or to base up to 8-8.5, the pH value must not too swing until fish could not adaptation which may cause shock. In case of acidic water in the fish pond, it can inhibit the working mechanism of nitrogen bacteria in the system. On the other hand, the basic water can increase the toxicity of ammonia. Consequently, the internal system of fish was irregular such as eat less, produce a large amount of mucus in their body, isolate from others, and often float on the water surface. In addition, another factor that was examined as the temperature. It was found that the water temperature in the fish pond was in the range of 27.0-27.7 ^{o}C and the water temperature in the aquatic plant pond was in the range of 27.2-28.0 ^{o}C.

The performance showed the fancy crap with appropriate shape in length, slender and cylinder and flashy colors as shown in Fig. 7. The fancy craps excretion in fish pond was utilized as the natural nutrients for aquatic plant and soil plant without additional fertilizers. The results indicated a proper yield that green oak was 2,750 g/m^3 with 22 cm/plant average length (fresh weight 150g/plant and dry weight 6.3 g/plant) as shown in Fig. 8 (left). The case of spiral tape grass yielded to 4,500 g/m^3 with 50 cm/plant length (fresh weight 100 g/plant and dry weight 15.16 g/plant) as shown in Fig. 8 (right).

Figure 7. The shape and color of fancy crap fish after 45 experimental days.

Figure 8. The production of spiral tape grass (left) and green oak (right).

IV. CONCLUSIONS

In summary, the study of integrated agricultural system determined the relationship among ecosystem of fancy craps, spiral tape grass and green oak. The results indicated the data after 45 experimental days that water quality in fish pond exhibited DO (6.27-7.15 mg/L), pH (7.2-8.9), NO_3^- (7.17-9.07 mg/L), PO_4^{3-} (0.124-0.202 mg/L) and TAN (0.195-1.49 mg/L). The natural nutrient water was circulated to the system for feeding the aquatic plant (spiral tape grass) and the soil plant (green oak). Water quality in plant pond was DO (5.08-6.59 mg/L), pH (7.7-9.3), NO_3^- (5.52-8.09 mg/L), PO_4^{3-} (0.12-0.2 mg/L) and TAN (0.16-0.86 mg/L). The trend of nutrient depletion was related to the growth of aquaculture system. Specific growth rate of fancy crap was 3.45±0.76% per day and survival rate was 100%. Length and weight of spiral tape grasses increased 2.5 times with yield of 4,500 g/m^3. Green oak yield was 2,750 g/m^3 which was slightly higher than the control experiment in hydroponic system. This case study was to develop the design and operation of an integrated agricultural system for sustainable food production in the future.

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