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Application of organic fertilizer on swamps pond for catfish (*Pangasius sp.*) culture

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Abstract. Swamp fish pond has a problems related to submerged flat soil and water pH value and result in low productivity of ponds. Fertilization increase productivity of pond water by providing nutrients for fish food organisms, The objective of this research was to determine the best dosage of organic fertilizer to improve water quality and pond productivity and it's effect to survival and absolute growth of catfish *Pangasius sp.* The research was conducted with using completely randomized design with four treatments and three replications. All of ponds unit were limed using dolomite of 10 ton/ha, incubated for 13 days, then gave four difference dosage of organic fertilizer, that were without fertilizer (P0), with fertilizer of 100 g/m² (P1), 170 g/m² (P2), and 240 g/m² (P3). *Pangasius sp.* fish (average body length of 5±0.5 cm) was stocked with the density of 15 fish/m² and cultured for 30 days. The parameters observed were soil (pH, N, P₂O₅, Ca, and C-organic) and water quality (pH, alkalinity, temperature, dissolved oxygen, ammonia, total Phosphate, Ca, and TOC), pond productivity, density of phytoplankton, survival, absolute growth, feed efficiency, and production of fish. The data were statistically analyzed by one-way ANOVA, Least Significant Difference test, and regression models analysis. The results showed that P1 (100 g/m² of fertilizer) was the best dosage indicated by pH 7.60, nitrogen 0.13%, P₂O₅ 0.16%, Ca 2.59%, C-organic 1.49% of pond soil; pH 7.42, temperature 27.3-32.4°C, dissolved oxygen 4.94-5.09 mgL⁻¹, alkalinity 51.33 mgL⁻¹, Ca 55 mgL⁻¹, TOC 12.3 mgL⁻¹, ammonia 0.24 mgL⁻¹, Total Nitrogen (TN) 3.78 mgL⁻¹, Total Phosphate (TP) 0.109 mgL⁻¹ of pond water. Based on TN:TP (10.09) of water showed nutrient was balanced. Productivity of ponds was on eutrophic state based on both TN and TP. Survival rate of catfish was 100%, absolute gain of weight 8.46 g and lenght 3.99 cm, Feed efficiency of fish was 101.55% and the density of phytoplankton was 217 cell/mL.

1. Introduction

Pangasius sp. catfish is the the fourth highest fish production culture in Indonesia [1]. *Pangasius* production in Indonesia has thrived over the past decade increasing from 33,000 tons in 2007 to 437,000 tons in 2016, making Indonesia the second largest pangasius producer in the world [2]. The Ministry of Marine Affairs and Fisheries and the UN's Food and Agriculture Organization (FAO) develop a low-cost catfish (*Pangasius sp.*) culture in Indonesia and South Sumatera became a pilot project for this program [3]. Culture of this fish in swamp area potentially develop, not only for



increase catfish production, but also to optimized the swamp area that is a huge aquatic area in South Sumatera. The major water quality problem for catfish culture on swamp pond is low pH value of soil and water.

The pH of soil is one of the most important factors for maintaining pond productivity since it controls most of the chemical reactions in the environment [4]. Acidic pond soils reduce microbial activity and the availability of nutrient in pond water and may render fertilization ineffective. Fertilization often failed because there is insufficient available carbon on the alkalinity system to support high rates of phytoplankton photosynthesis, and phosphate added in fertilizer tightly bound by muds [5]. Liming of soil at the beginning of culture can improve the pH value [6]. Liming is an important procedure to increase alkalinity and pH of pond soil, maintain pH (7-8) of pond water, provide sufficient CO₂ for phytoplankton growth and enhance good response to fertilization [7]. Application of agricultural limestone to such ponds will neutralize acidity of the mud, increase total hardness and alkalinity of water, therefore increase the effectiveness of fertilizer [4].

Fertilizers are applied to ponds to increase inorganic nutrient concentrations, favor greater phytoplankton growth, and ultimately enhance production of fish [8]. Inorganic or organic fertilizers can be used in fish ponds. Organic fertilizers are natural substances such as hay, alfalfa, or manure. Most waste materials have been used at some time or another. These fertilizers tend to accelerate the production of zooplankton or other microscopic animals on which many fish feed more rapidly than inorganic fertilizers [9]. The formulation of fertilizer tells the percent by weight of nitrogen (N), phosphorus (as P₂O₅), and potassium (as K₂O) in the fertilizer [10]. Primary nutrient in fertilizers are present in relatively simple compounds which ionize to give NO₃⁻, NH₄⁺, H₂PO₄⁻, HPO₄²⁻, or K⁺. Meanwhile, calcium, magnesium, and sulfur are called secondary nutrients and trace elements or minor elements are copper, zinc, boron, manganese, iron, and molybdenum [8]. Liming increases productivity by improving the chemical environment, inorganic fertilization would be required after liming to make eutrophic [5]. The best method for preventing soils and other associated water quality problems in aquaculture ponds is to select a site with good soils and adequate supply of high quality water and to maintain moderate levels of prawn and fish production. If this is done, liming, fertilization and aeration can prevent most soil and water quality imbalances [11]. Fertilization will continue to be an important management practice in aquaculture for the foreseeable future [12].

2. Material and methods

Twelve constructed tarpaulin ponds of approximately 1 m × 1 m × 1 m were used in this study. Ponds were filled with swamp soil as thick as 20 cm, limed with 10 tons dolomite per hectare and incubated for 13 days. Four different dosage of commercial granule organic fertilizer were tested (0, 100, 170 and 240 g/m² coded as P0, P1, P2 and P3, respectively) and were replicated three times in a completely random design. The treatment based on the dosage of commercial organic fertilizer for *Chanos chanos* ponds [13]. The fertilizer contents (dry basis) were 1.30% N, 0.52% P, 2.93% K, and 9.70% organic C as determined by Kjeldhal-Titrimetry, Spectrophotometry, Flamephotometry and Walkey & Black, respectively. Based on content list in commercial organic fertilizer packaging, the materials of fertilizer are chicken manure, cow dung, sugar industrial waste, palm mill waste, and other supplements. Eventhough no information about the percentage of each materials. Each pond filled with 500 L of swamp water after incubated for 3 days. *Pangasius* sp. was acclimatized for one week and stocked as many as 15 fish for each pond. The fish were fed to satiation three times per day with an artificial diet containing 30% protein for 30 days culture period starting at 16 day after liming and fertilizing.

Soil sample were analyzed before liming and fertilizing (initial) and day-30 of fish culture. The soil pH was measured in situ with portable pH meters for every day during incubation of liming periods and every 10 days during rearing periods. The parameters of water pH and temperature was measured in initial, incubation time (after liming and fertilizing) and culture period. The parameters of dissolved oxygen, ammonia, total P, Ca, and TOC was measured and observed at initial, day-0, and day-30 of fish culture. Water temperature, dissolved oxygen (DO) concentration and pH were measured in situ

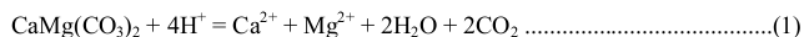
with digital thermometer, DO meter, and portable pH meter, respectively. Water samples were collected from each ponds and for same treatment water samples were combined into a single composite samples for analysis. The analytical determinations of water quality were carried out according to the guidelines presented by Indonesian National Standardization Agency. The fish initial and final body weight and length, survival rate were observed in all experimental units. Pond productivity was observed from productivity criteria based on TN, TP, and ratio of TN:TP [14].

Relationship between time (days of incubation and days of culture) and pH (soil and water) were assessed by regression models. In order to evaluate the effect of treatments, data of soil and water pH at day-0, 10, 20 and 30 culture, soil parameters (nitrogen, P₂O₅, organic-carbon and calcium) at day-30, dissolved oxygen and alkalinity of water at day 0, 15 and 30 of culture, survival rate, growth rate, feed efficiency, and fish production among the fertilizer treatment were subjected to one-way analysis of variance (ANOVA). Differences among treatments were determined using Least Significant Difference (LSD) test at p 0.05. Data of water parameters (temperature, calcium, organic-carbon, ammonia, total nitrogen and total phosphor), and density of phytoplankton was analyzed descriptively.

3. Results and discussion

3.1. Soil and water pH

Soil pH of ponds after liming by dolomite dosage 10 ton/ha was increased until neutral pH value during incubation time (Figure 1). The liming of fish ponds using same kinds and dosage of lime before fertilization process showed the same pattern of increasing of pH value. According to [11] sediment containing calcium carbonate in had pH values between 6.9 and 8.1. The best pH for pond soils is considered to be 6.5 to 7.5, and pH 5.5 to 8.5 is considered acceptable [16]. Generally, the recommended pH range of water for aquaculture is 6.5-9.0 [17]. Dolomite react with acidity as follows:



This reaction neutralises acidity, increases pH and total hardness of water, and results in an increase in total alkalinity [18]. The water passing over acid soil tends to be acidic with low alkalinity and hardness. Acid ponds do not respond well to fertilization [11]. Water pH after liming and fertilizing at incubation periods increased until optimal for fish culture (Figure 2). Liming stimulates the microbial decomposition of organic matter, supplies calcium and/or magnesium to the pond, increase nitrate content in the pond and maintain sanitation in the pond environment.

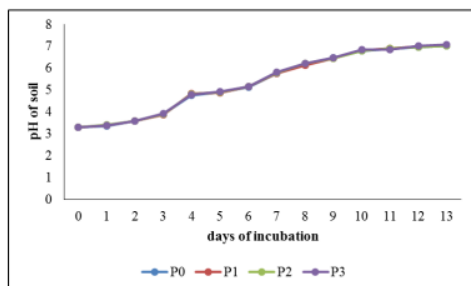


Figure 1. Soil pH at incubation periods

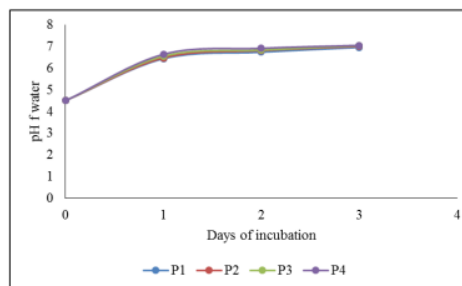


Figure 2. Water pH at incubation periods

Regression models of days culture and pH (soil and water) showed polynomial quadratic (Figure 3 and 4). Soil and water pH on fertilized pond with dosage 240 gm⁻² (P3) was highest and significantly difference from soil and water pH at others treatments except water pH at day-0 that was insignificant difference among treatments. The highest dosage of fertilizer (P3) resulting in the highest pH value be expected caused by availability of calcium as secondary nutrient of fertilizer [5]. The concentration of

calcium of soil in pond is 2,58 mgL⁻¹ higher than P0 and P2, eventhough less than P1 (2,59 mgL⁻¹) (Table 2). The higher pH in P3 than P1 could be influenced by lower organic Carbon in P3 than P1 (Table 2). As organic matter decays, it releases carbon dioxide [19]. The free CO₂ released during respiration reacts with water, producing carbonic acid (H₂CO₃), and pH is lowered [17] as reaction :

$$\text{H}_2\text{O} + \text{CO}_2 = \text{H}_2\text{CO}_3 = \text{H}^+ + \text{HCO}_3 \dots\dots\dots(2)$$

Liming refers to the application of various acid-neutralizing compound of calcium or calcium and magnesium [26]. This results supported by the research of [21], that showed fertilized ponds were more saline, better buffered and richer in nutrient than the unfertilized ponds.

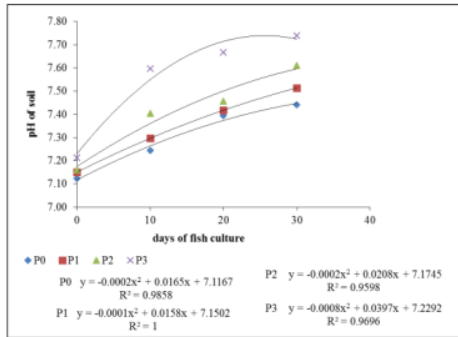


Figure 3. Soil pH at days of fish culture

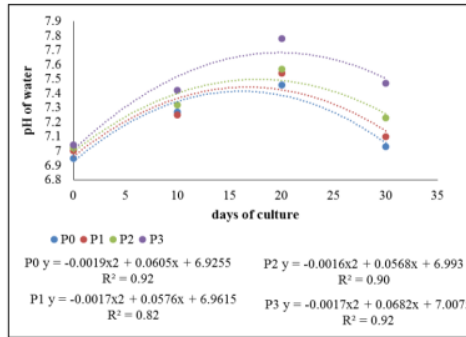


Figure 4. Water pH at days of fish culture

Table 1. Least Significant Difference test for soil and water pH

	P0	P1	P2	P3
Soil pH				
Day-0	7.12 ± 0.03 ^a	7.15 ± 0.03 ^a	7.16 ± 0.03 ^a	7.21 ± 0.04 ^b
Day-10	7.24 ± 0.03 ^a	7.30 ± 0.02 ^a	7.40 ± 0.04 ^b	7.60 ± 0.06 ^c
Day-20	7.39 ± 0.02 ^a	7.42 ± 0.02 ^{ab}	7.46 ± 0.01 ^b	7.67 ± 0.03 ^c
Day-30	7.44 ± 0.04 ^a	7.51 ± 0.01 ^b	7.61 ± 0.02 ^c	7.74 ± 0.03 ^d
Water pH				
Day-0	6.95 ± 0.09 ^{ns}	7.00 ± 0.04 ^{ns}	7.02 ± 0.01 ^{ns}	7.04 ± 0.04 ^{ns}
Day-10	7.27 ± 0.01 ^a	7.25 ± 0.02 ^a	7.32 ± 0.08 ^a	7.42 ± 0.05 ^b
Day-20	7.46 ± 0.04 ^a	7.54 ± 0.01 ^{bc}	7.57 ± 0.03 ^c	7.78 ± 0.04 ^d
Day-30	7.03 ± 0.10 ^a	7.10 ± 0.04 ^a	7.23 ± 0.04 ^b	7.47 ± 0.04 ^c

3.2. Nitrogen, P₂O₅, carbon-organic and calcium of soil ponds

Based on statistical analysis showed that mean of nitrogen, P₂O₅ and C-organic were insignificant difference among treatment (Table 2). The soil nitrogen decrease at day-30 comparing to initial explained that nitrogen is lost through volatilization of ammonia during periods of high pH [8]. When inorganic nitrogen is added to ponds in fertilizers, high concentration present immediately after application quickly decline. Some of nitrogen added to waters obviously is assimilated by plants and when the plants die, the nitrogen is deposited in bottom muds as a component of the organic matter [8].

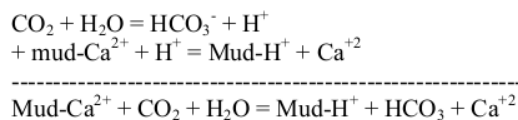
Table 2. Soil parameters

Parameters	Initial	Day- 30 of culture			
		P0	P1	P2	P3
Nitrogen (%)	0.31	0.11±0.07	0.13±0.00	0.11±0.02	0.15±0.02
P ₂ O ₅ (%)	0.20	0.16±0.02	0.16±0.02	0.17±0.05	0.16±0.01
Ca (%)	4.33	2.08±0.03 ^a	2.59±0.03 ^b	2.54±0.06 ^b	2.58±0.03 ^b
Organic-C (%)	1.26	1.06±0.14	1.49±0.59	1.26±0.32	1.35±0.36

Initial: before liming and fertilizing

However, the soil nitrogen 0.11-0.15% (1100 – 1500 mg/kg) and P₂O₅ 0.16-0.17% (1600 – 1700 mg/kg) showed that ponds categorized as high fertility ponds. Ponds with less than 250 mg/kg available soil nitrogen are considered to have low productivity while concentration in the range 250-500 mg/kg and above 500 mg/kg are considered to be medium and highly productive respectively [11]. Available nitrogen below 25 (mg N per 100 g of soil) speaks of poor production, in the range 25-75 mg/g production is high, average or low, and few ponds have nitrogen level above 75 mg/g. Ponds with 30 mg/kg, 30-60 mg/kg, 60-120 mg/kg and more than 120 mg/kg available phosphate (P₂O₅) are considered to have poor, average, good and high productivity, respectively. The fertilizing process increase soil phosphorus but the liming that is increasing pH caused decreasing phosphorus in soil. Orthophosphate concentrations will probably decline faster with hard or alkaline waters and mud than in ponds with acidic waters and muds because of the direct precipitation of phosphorus under condition of high pH and calcium concentration.

Calcium (Ca) is major ion of soil ponds. The research [15] showed that average calcium concentration of 58 catfish ponds in Alabama was 3.563%. The Ca-soil increase influenced by liming and fertilizing process but the decrease of Ca soil at day-30 compare to Ca-soil at initial time caused of exchange reaction between water and pond soil as illustrated below [8] :



Mean soil organic carbon for each treatments ponds (Table 2) showed that soil categorized as mineral soil, moderate organic matter content and categorized as the range for aquaculture according to classification of soil organic carbon concentration for pond aquaculture [22]. The acceptable range of soil organic carbon for aquaculture ponds is from 0.5 to 2.5 percent, and the optimum range is 1.5 to 2.5 percent. Based on organic-C, soil categorized as medium tend to high fertility status [16]. The organic-C of soil <0.75 %, 0.75-1.5% and 1.5-2.5% considered to low, medium, and high fertility, respectively [11].

3.3. Temperature, dissolved oxygen, alkalinity, calcium, organic-carbon and ammonia of water

Temperature of water range 26.2-32.5°C was within an acceptable range for culture of *Pangasius* sp. Optimal range of temperature of fish is 25-30°C [23]. Dissolved oxygen range 4.00 – 5.30 mgL⁻¹ was within optimal range DO for *Pangasius hypophthalmus* based that is ≥ 4.00 mgL⁻¹ [23]. There is no significant difference for DO among treatment for day-0, day-15 and day-30 (Table 3). Aeration at all ponds keep the DO still in optimal range. Nevertheless, the DO at fertilized ponds tend to higher than unfertilized ponds. The fertilization could increase nutrient concentration to support photosynthesis process that will produce oxygen.

Table 3. Temperature, dissolved oxygen and total alkalinity of water

Parameters		P0	P1	P2	P3
Temperature range (°C)		27.4-32.5	27.3 – 32.4	27.2 – 32.3	27.2 – 32.2
Dissolved Oxygen (mgL ⁻¹)	Day-0	4.89 ± 0.02	5.00 ± 0.05	5.16 ± 0.03	5.26 ± 0.02
	Day-15	4.00 ± 0.08	4.94 ± 0.03	5.13 ± 0.02	5.24 ± 0.02
	Day-30	4.96 ± 0.05	5.09 ± 0.02	5.21 ± 0.02	5.30 ± 0.03
Total Alkalinity (mgL ⁻¹)	Day-0	34.67 ± 3.06 ^a	38.67 ± 1.15 ^{ab}	41.33 ± 3.06 ^b	50.67 ± 4.16 ^c
	Day-15	40.67 ± 3.06 ^a	43.33 ± 1.15 ^{ab}	49.33 ± 4.62 ^b	56.67 ± 4.16 ^c
	Day-30	47.33 ± 2.31 ^a	51.33 ± 1.15 ^{ab}	54.67 ± 4.16 ^b	65.33 ± 4.62 ^c

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Total alkalinity concentration for all water samples more than 20 mgL⁻¹. Total alkalinity is a measure of carbonate, bicarbonate and hydroxyl concentration in water and expressed as CaCO₃ mgL⁻¹ equivalent. Alkalinity in all ponds influenced by liming process that increases of alkalinity. When pond alkalinity concentrations are below 50 mgL⁻¹, agricultural limestone can be used to raise alkalinity and hardness [17]. The high fertilizer caused high alkalinity appropriate with the research that total alkalinity (mgL⁻¹ as CaCO₃) in fertilized ponds higher than fertilizer ponds [8]. Adding phosphorus to ponds immediately after applying gypsum can result in phosphorus combining with calcium, causing both to drop out of solution as calcium phosphate [17]. Most suitable range alkalinity for fish farming is 80-200 mgL⁻¹[11], 75-200 mgL⁻¹ CaCO₃ [17]. Moyle (1946) in [16], from a study of a large number of lakes and ponds in Minnesota, gives the range of total alkalinity as 0.0 - 20.0 mgL⁻¹ for low production, 20.0 - 40.0 mgL⁻¹ for low to medium and 40.0 - 90.0 mgL⁻¹ for medium to high production. Pond pH can swing widely during the day, measuring from 6 to 10, when alkalinity concentrations are low this level. Large daily changes in pH can cause stress, poor growth and even death of the fish. Alkalinity has indirect effects on primary productivity. In low alkalinity, certain nutrient are unavailable to aquatic plant life. Phosphorus fertilizer are relatively insoluble when alkalinity concentration are below 20 mgL⁻¹ [17].

Calcium concentration ranged between 21.2 and 30.6 mgL⁻¹ (day-0) and 38.3 and 53.3 mgL⁻¹ (day-30) (Figure 5). The increasing of Ca concentration influenced by liming and fertilizing process. As described above in reaction dolomite and acidity resulting Ca²⁺. It's caused of increasing Ca at all treatments (P0, P1, P2, and P3). Calcium as secondary nutrients in fertilizer, it's caused the fertilized ponds (P1, P2 and P3) has higher Ca than unfertilizer pond (P0). There are not specific recommendations for optimum calcium concentrations for pond fish culture [15]. Calcium and magnesium are the source of water hardness, and it usually is recommended should contain at least 50 mgL⁻¹ total hardness. A recommended range for free calcium in culture waters is 25 to 100mgL⁻¹ (63 to 250 mgL⁻¹ CaCO₃ hardness) [17].

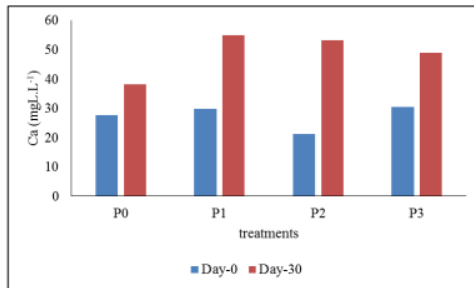


Figure 5. Ca concentration at day-0 and day-30

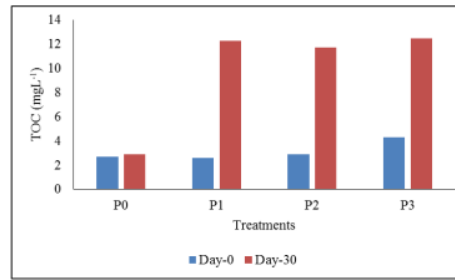


Figure 6. TOC concentration at day-0 and day-30

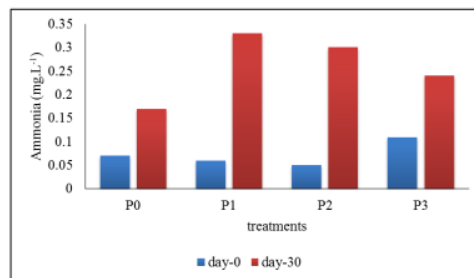
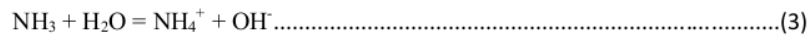


Figure 7. Ammonia concentration at day-0 and day-30

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Carbon (C) is also important in aquaculture pond because it is a main source of all organic carbon in aquatic ecosystems can be categorized as particulate organic carbon (POC) and dissolved organic carbon (DOC). POC is the accumulation of C in animal (fish), zooplankton, insects, phytoplankton, plants, bacteria, and detritus. DOC consists of C in carbohydrates, protein, peptides, amino acids, fats which resulted from the decomposition of particulate organic matters [24]. The organic-C in this research (Figure 6) categorized as high concentration [25]. The TOC of fertilized ponds (P1, P2, and P3) was tend to decrease and higher than unfertilized ponds (P0) influenced by TOC from fertilizer. As mentioned above that the fertilizer contain 9.70% of TOC.

Ammonia ranged between 0.05 mgL⁻¹ and 0.11 mgL⁻¹ (day-0) and 0.17 mgL⁻¹ and 0.33 mgL⁻¹ (day-30) (Fig. 7). Ammonia increase at all ponds influenced by increasing of water pH. According to [8], when ammonia is dissolved in water, the following equilibrium is established:



The ratio of NH₄⁺ : NH₃ will increase as pH decrease and decrease as pH increase. The fertilized pond has higher ammonia than unfertilized ponds at day-30 influenced by fertilization process. According to [23], common nitrogen fertilizers are anhydrous ammonia, ammonium nitrate, ammonium sulphate, ammonium phosphate, diammonium phosphate, sodium nitrate, potassium nitrate, urea, and ammonium polyphosphate. Fish are very sensitive to unionized ammonia (NH₃) and the optimum range is 0.02-0.05 mgL⁻¹ in fish pond water, but in the case of high dissolved oxygen and high carbon dioxide concentration, the toxicity of ammonia to fish is reduced. Ammonia concentrations as low as 0.06 mgL⁻¹ have slightly reduced growth in channel catfish; 0.52 mgL⁻¹ caused a 50% reduction in growth in this species; no growth occurred at 0.97 mgL⁻¹ [26].

3.4. Productivity of ponds

Nitrogen concentration ranged between 0.61 mgL^{-1} (day-0) and 1.89 mgL^{-1} (day-30) (Figure 8). Dissolved nitrogen below 0.1 mgL^{-1} does not indicate a productive condition. While in the range $0.1-0.20 \text{ mgL}^{-1}$ an average production is expected, above 0.2 mgL^{-1} ($0.2-0.5 \text{ mgL}^{-1}$) may be considered favourable or optimal for fish ponds [11, 16]. The fertilizing process add nitrogen to waters pond and assimilated by plants (phytoplankton). The higher nitrogen at P1 to be expected that densities of phytoplankton in P1 less than P2 and P3.

Phosphorus concentration ranged between $0.105-0.109 \text{ mgL}^{-1}$ (day-0) and $0.107-0.109 \text{ mgL}^{-1}$ (day-30) (Figure 9). Phosphorus is the most important single element responsible for aquatic productivity. Dissolved phosphorus below 0.05 mgL^{-1} may be considered insufficient while $0.05-0.20 \text{ mgL}^{-1}$ and above 0.20 mgL^{-1} may be indicative of medium to high and highly productive fish ponds [11]. Phosphorus at day 0 and 30 tend to changeless. The liming and fertilizing could increase the phosphorus but plants, can absorb phosphorus quickly. Some plants can absorb more phosphorus than they need for growth and store it. These phenomena in has been shown in phytoplankton and is termed luxury consumption.

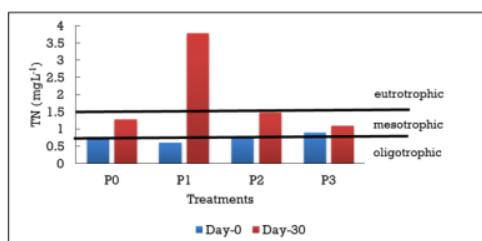


Figure 8. Total nitrogen at day-0 and day-30

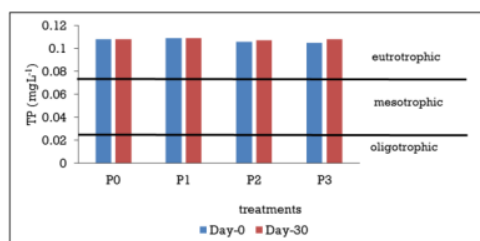


Figure 9. Total phosphor at day-0 and day-30

Fertilization is a basic means for increasing pond productivity. That productivity can be increased three to four times more than a nonfertilized pond, depending on natural soil and water characteristics [26]. Classification of ponds productivity based on total nitrogen and total phosphor [14], ponds categorized as mesotrophic and eutrophic (Figure 10). $\text{N}/\text{P}_2\text{O}_5$ ratio above 2.6 is strictly indicative of poor production, 1.3-2.6 is not strictly optimal [11].

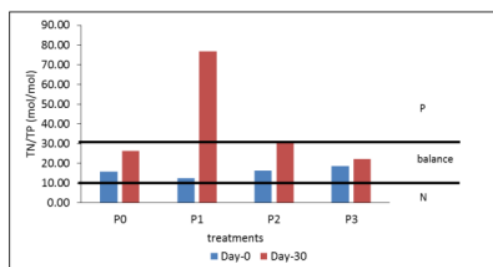


Figure 10. Ratio of total nitrogen and total phosphor at day-0 and day-30

3.5. Survival rate, growth rate of fish, and phytoplankton density

Survival rate was insignificant different among treatments (Table 4). The P0 tend to be the lowest survival rate, but the average 96 to 100% is categorized as high survival rate for catfish. The highest absolute growth was on P3 even though not differ with P2. The highest fish production was on P3 but insignificant difference with P1 and P2. Meanwhile, phytoplankton density among treatments were

shown in Figure 11. Results showed that phytoplankton density was higher at higher dosage of organic fertilizer.

Table 4. The survival rate, absolute growth, feed efficiency, and fish production

Treatments	Survival Rate (%)	Absolute growth		Feed efficiency (%)	Production (g/m ²)
		Length (cm)	Weight (g)		
P0	96 ± 3.46	3.72 ^a ± 0.13	7.99 ^a ± 0.21	71,73 ^a ± 7.43	125.42 ^a ± 7.14
P1	100 ± 0.00	3.99 ^a ± 0.33	8.46 ^b ± 0.12	90,25 ^b ± 5,68	141.55 ^b ± 2.11
P2	98 ± 3.46	4.14 ^{ab} ± 0.24	8.98 ^c ± 0.04	92,59 ^b ± 5.69	142.67 ^b ± 11.40
P3	100 ± 0.00	4.53 ^b ± 0.21	9.00 ^c ± 0.21	101,55 ^b ± 8.16	148.70 ^b ± 3.31

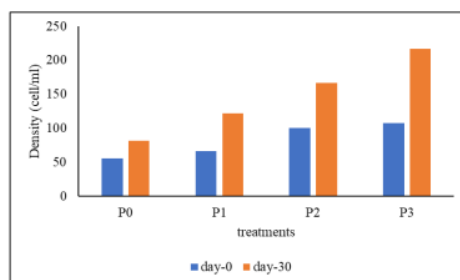
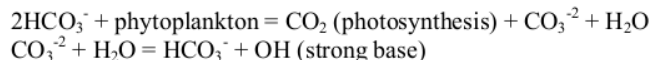
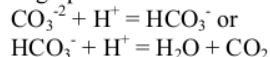


Figure. 11. The phytoplankton density for each treatments

The fertilization program increasing pond productivity [12]. Phytoplankton represent the base of food web finally affected availability of natural feed for fish. The higher dosage of fertilizer the higher phytoplankton density, feed efficiency and fish growth. Phytoplankton are microscopic or near microscopic, aquatic plants which are responsible for most of the oxygen (photosynthesis) and primary productivity in ponds. By stabilizing pH at or above 6.5, alkalinity improves phytoplankton productivity (pond fertility) by increasing nutrient availability (soluble phosphate concentrations) [17]. Alkalinities at or above 20 mgL⁻¹ trap CO₂ and increase the concentrations available for photosynthesis. Because phytoplankton use CO₂ in photosynthesis, the pH of pond water increases as carbonic acid (i.e., CO₂) is removed. Also, phytoplankton and other plants can combine bicarbonates (HCO₃⁻) to form CO₂ for photosynthesis, and carbonate (CO₃⁻²) is released:



High pH could also be viewed as a decrease in hydrogen ions (H⁺):



The release of carbonate converted from bicarbonate by plant life can cause pH to climb dramatically (above 9) during periods of rapid photosynthesis by dense phytoplankton (algal) blooms.

The unfertilized aquaculture ponds usually will produce between 50 and 500 kg/ha/crop of fish shrimp, meanwhile, ponds fertilized with chemical fertilizers produce 1000–3000 kg/ha/crop [27]. A well-managed fertilized recreational pond can produce three to four times the fish production that can be obtained without fertilization [10]. One of study that reported was Boyd (1981) in [8] showed none of the values for net production rates of sunfish differed significantly, even though there were considerable in N, P₂O₅ and K₂O application rates among treatments, but significantly difference with

control (unfertilized ponds). Study of [28] showed survival rate of giant gouramy insignificant difference between control (unfertilized ponds) and fertilizer treatments (low, medium and high). Meanwhile the growth rate and net production were insignificant difference between control and low fertilizer treatments but significantly difference with medium and high fertilizer treatment. The fertilizer treatments were 0, 6, 9 and 12 kg N plus 0, 3, 4.5 and 6 kg P₂O₅/ha referred as control, low, medium, and high fertilizer treatments.

4. Conclusions

Soil and water quality for both unfertilized (P0) and fertilized ponds (P1, P2 and P3) were on tolerance and optimal range for catfish. Even though, fertilized ponds has better quality than unfertilized ponds. Ponds categorized medium to high fertility/productivity for both unfertilized (P0) and fertilized ponds (P1, P2 and P3). Addition of 100 g/m² organic fertilizer was sufficiently to obtain high production of *Pangasius* sp.

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