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Research Article

The Effect of Water Quality on Rice Growth Performance and Nutrient Accumulation in Integrated Aquaculture-Agriculture

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- Fish cum rice culture
- Water quality
- Rice plant

Abstract

This experiment was conducted to evaluate the effect of Water Quality in fish cum rice integrated system on rice growth. The experimental system was conducted on rice paddy surrounded by a trench which serves as culture for fish. Oryza sativa (FARO 49) was planted in nursery bed and transplanting of seedlings was done after 15 days at a spacing of 10cm by 10cm. Rice growths were accessed by measuring morphometric stage: plant height, leaves as well as reproductive stage: yield throughout productive period. Pond water quality and sediment nutrient accumulation were monitored.

Rice plant height measured after sixteen weeks was 146.98±11.65cm and yield recorded was 2666.7kg/ha. Water quality parameters such as pH, temperature, dissolved oxygen, NO_3-N, NH_3 were recommended range for the culture. Rice growth analysis shows a significant difference through improved physical-chemical parameters and revealed that NO_3-N, NO_2-N and NH_3 are strongly correlated positively and thus significant. There was significant different ($p>0.05$) during production between rice plant and nitrogen content present in soil. Sediment accumulated shown high nutrient received manure with supplementary feed in the period of study. The results showed that the patterns of pond water and nutrient flows were strongly influenced by fish farming activities.

Hence, integrating fish pond with crop has strengthened nutrient recycling between Integrated Aquaculture-Agriculture which enhanced better farm outputs and safeguarding the environment.

INTRODUCTION

Aquaculture continues to grow rapidly, and this influence the industry output yearly [1]. It was described as a growth industry striving to satisfy a growing market and currently one of the fastest growing sectors of agriculture in Egypt [2]. Growing public demand for healthy, tasty and affordable food is stimulating the "boom" in this industry. Globally, aquaculture has become the fastest growing food production sector involving animal species. This tremendous growth has provided a number of opportunities for greater food security, improved livelihoods and reduced poverty [3].

Integrated aquaculture strategies could be regarded as an option for efficient utilization of available resources, waste recycling, energy saving and maintaining ecological balance and circulation in aquaculture subsystem [4]. It has been known to advocated increase land use efficiency under increased population growth, environmental degradation, land and water scarcity [5]. This system is a sustainable farming system known for diversification of agriculture towards nutrient linkages through interconnected flows of nutrients in aquaculture components while reducing environmental impacts [6].

The nutrient linkage makes use of off-farm bio-resources originating from another farm agro-industrial activities [7] contributing to farming intensification, efficient use of natural resources, food security, income generation, environmental protection and sustainable agriculture [8]. The integrated pond sub-system is made possible with existing farming activities to maximize production while minimizing nutrient discharges [2].

Ponds are nutrient traps as a high proportion of added nutrients accumulate in the sediment, and this prevents from flowing into drainage waters [9]. These agricultural wastes; livestock manure, waste water can be used to fertilize vegetable crops and to restore soil fertility [10]. Potential benefits from integrating aquaculture in farming systems include: enhanced employment and income generation through additional or off-season production; food security, availability of high-value protein food, promoting organic farming through sustainable production and environmental protection. Sustainable aquaculture depends upon eco-friendly and economically and socially viable culture systems which offers tremendous potential for food security and poverty alleviation [11].

Aquaculture- agriculture is consequently facing some challenges of producing more food for this growing population, conserving the environment and ensuring food security [12]. However, the sector's growth threatens its ability to continue to provide increasing yield in a sustainable manner and concerns with the ecological damage resulting from fish farming. The objective is to increase farm productivity through maximized synergies and minimized antagonisms between components there by increasing the contribution of aquaculture to economic growth. The pond sub-system should be integrated as much as possible with existing farming activities to maximize production while minimizing nutrient discharges [13,14].

MATERIALS AND METHODS

The Study area and Experimental designs

The experiment was conducted at the fish farm, University of Ibadan, Ibadan, Nigeria. The research was conducted for 16 weeks at the integrated pond with surface area of 227.5m^2. The fish trench has an area of 178m^2 and the rice paddy with an area of 49.5m^2 with depth 0.4m.

Lowland FARO 49 (Oryza sativa) rice seeds were placed in nursery beds and covered with compost. The beds were kept damp until germination after 15 days at 2-leaf stage. Transplanting of seedlings into properly tilled soil of rice paddy at a spacing of 10cm intra and 10cm inter rows, planted in lines. Water in the integrated pond was kept minimum and maintained during vegetative growth period. Weed was manually removed frequently. Rice growth was accessed by measuring morphometric stage: plant height, leaves as well as reproductive stage: yield throughout productive period performed according to IRRI (2002) [15].

Culture water samples were collected at two different locations from integrated pond between 8-9am. Samples were collected bi-weekly in clean plastic bottles and taken to laboratory for physic-chemical analysis. Water quality parameters measured were Dissolved oxygen, pH, ammonia (NH_3), nitrate (NO_3-N), nitrite (NO_2-N), hardness and alkalinity. These parameters were determined by using PONDLAB 200 kits in line with standard methods APHA (1995) [16]. The water quality temperature was monitored the same time using thermometer at 20 cm below water surface.

Soil samples were collected at two different sampling points, A and B from the rice paddy at a depth of 10-15cm; initial sampling was also carried out, before start of the study. The soil nutrients were analysed using LaMotte garden soil test kit Model EL and in Laboratory to determine the nutrients. Chemical analysis was done for the following parameters of the soil, Nitrogen, phosphorus, potassium, pH and Total organic carbon. Two physical properties of the soil; the particle size (texture) and bulk density were also determined and measured in the laboratory.

Statistical analysis; Correlation and regression were carried out. Correlation coefficients investigate relationships of rice growth and water quality nutrient data.

RESULTS AND DISCUSSION

Results

Physic-chemical characteristics of water play an important role in regulating the various activities. These parameters are essential for the better survival and growth of fish. The results of the water quality parameters evaluated in this study are presented in Table 1. Mean water temperature records 28.03±1.03. pH value of 7.2±0.44 range with moderate fluctuations. Dissolved oxygen fluctuates with a mean value of 5.13±1.04mg/l. Ammonia concentration ranged within 2.75±2.32mg/l and increased towards the end of the rearing cycle. Ammonia peak was observed on the ninth week of the rearing followed by increase in nitrite-nitrogen, this suggests that the system established nitrification process. Mean nitrate-nitrogen recorded 6.40±3.60. Mean nitrite-nitrogen records as 0.66±0.4 and showed an increasing trend in the later part at 1mg/l. The alkalinity and hardness of pond water varied with mean value of 135.16±9.97mg/l and 140.84±12.14 mg/l respectively.

Rice growth analysis shows a significant difference through improved physical-chemical properties of rice paddy. The results of rice growth stages observed in this study are presented in Table 2. The plant height in the experimental plot ranged from 8 to 158cm after transplanting. The number of leaves ranged from 2 to 11 with a total rice strand at 1034 cm at the end of production. Total yield recorded 15.2kg/49.5m2 from the experimental study.

Discussion

The water quality parameters determined for this study were within the limit recommended to support culture of fish and cultivation of rice, although there were variations. pH evaluated recommended range all through the rearing cycle, thus good pond productivity [17]. Manure and urine raise the pH level and accelerate the decomposition of organic matter and activity. Water temperature fluctuation may be due to surrounding water/air temperature and shading by rice plants which also maintains the water favorable for activities Lemma et al., (2015) [11] reported that the optimal water temperature for rice field was also similar to the findings. According to Wahab et al; (2008) [18] dissolved oxygen support good production in agreement with period of study and also essential for growth of bacteria which decompose organic detritus and release of nutrients which is shared by the paddy. It was observed high level of dissolved oxygen may be as a result of Photosynthesis activities by phytoplankton and lowest probably due to decomposition and feed remains. Ahmed et al. (2010) [19] stated Perturbation of the soil leads to high dissolved oxygen needed for the nutrient cycling by the soil microorganisms. Nitrate-nitrogen, Nitrite-nitrogen and Ammonia concentration fluctuated largely and records high values. This may be as a result from high biological activities with inorganic loading in pond water as result of low water exchange in the presence of bacteria, dead phytoplankton, decaying organic matter, accumulation of left-over protein-rich feed accumulate in the system which may support growth and yield of rice [20].

Table 1: Physico-chemical parameters of water in Integrated Fish pond.

Parameters	Weeks				
	1	4	8	12	16
Temp °C	29.0	29.0	28.0	27.5	27.0
pH	7.0	8.0	7.0	7.0	7.0
DO (mg/l)	6.0	5.5	4.8	6-0	5.0
NH_4 (mg/l)	0.2	0.2	2.5	3.5	3.5
NO_2-N (mg/l)	0.25	0.25	0.5	1.0	1.0
NO_3-N (mg/l)	2.5	2.5	5.0	10.0	10.0
Alkalinity (mg/l)	124.6	133.7	124.6	133.7	142.4
Hardness (mg/l)	142.4	160.2	142.4	133.7	124

Abbreviations: Temp-Temperature; DO- Dissolved Oxygen; NH4-Ammonia,NO2-N- Nitrtrite Nitrogen, NO3-N- Nitrate Nitrogen; mg/l-milligram per liter; °C- Degree Celsius

Table 2: Mean values of selected water quality parameters in the integrated Fish cum rice culture pond.

Parameter Obtained	Mean values	Range	Acceptable range
Dissolved Oxygen (mg/l)	5.13±1.04	4.0-7	
Temperature (°C)	28.03±1.03	23-32	
Ammonia (mg/l)	2.75±2.32	5-0.5	0.02- 0.03
Nitrate - nitrogen (mg/l)	5.40±2.60	8- 2.8	2-2.5
Nitrite - nitrogen (mg/l)	0.66±0.36	1.0-0.3	0.2-0.5
Alkalinity (mg/l)	135.16±9.97	145-125	79-80
Hardness (mg/l)	140.84±12.14	128-152	79-81

Source Boyd, 1998; 2007 and Omitoyin, 2007

Tables 3: Rice paddy soil characteristics and nutrients in Fish cum Rice and Pig production system.

Parameters (units)	Before cultivation (initial)	Final Acceptable range
Texture:		
Sand (%)	84.2	83.6
Silt (%)	12.4	7.0
Clay (%)	3.4	9.4
Texture	Loam	Loam
Organic carbon (mg/kg)	1.03±0.1	0.80±0.7
Organic matter (mg/kg)	1.77±0.2	1.37±0.2
Total nitrogen (mg/kg)	12.2±3.7	11.2±14.1 9.0 -13
Available phosphate (mg/kg)	9.52±14	2.39±0.3 5.0 -10
Potassium (mg/kg)	31±42	17±28.3 30 - 80
pH (mg/l)	6.5±0.1	6.7±0.2 5.0 -7.0

Source: African Rice Center (WARDA)

Rice growth analysis shows a significant difference through improved physical-chemical parameters in integrated pond culture. The study revealed that ammonia, nitrate-nitrogen, nitrite-nitrogen are strongly correlated positively and thus significant to rice growth. pH is said to have a low correlation; the relationship between rice growth, dissolved oxygen and temperature had negative correlation hence not significant. There was significant different ($p > 0.05$) during production between rice plant and nitrogen content present in soil. Plant height measured may be influenced by external factors; status of soil fertility, also increase may be due to improved nutrient availability resulting from the excrement produced by fish as well as to aeration of the growth medium as the fish moved around [21]. The seedlings after transplant showed best growth rate and no record of disease or pest attack on the plants known as the effective method of biological control of insect pests, weeds and diseases [2]. The rice plant has long panicle, high tillering rate, more grain and less number of empty grains as against rice monoculture. The present study reveals an increase in rice and straw yield than monoculture due to the high number of tillers developed on the plants which resulted in an increase in the total biomass of the plants [19]. Rice-fish culture gave significantly higher yield this could be attributed to the more favorable growing conditions.

The yield from integrated pond shows an additional nutrients from fish feed and feces which aids in nutrient recycling and also play an important role in improving the soil health, it can act as a buffer in water nutrient concentration helps in minimizing loss from the system.

Mean Total nitrogen concentration was recorded as 12.2±3.7mg/kg at initial stage. The nitrogen concentration in rice paddy before transplant ranged between 8.5-15.7mg/kg followed by an increased during the study period at the final stage ranged between 2.9-25.3mg/kg. This was also in line with Lani et al., (2013) [22] for the recommended range for cultivation of rice. According to Nwilene et al., (2017) [23] the concentration is in the same range of concentration during the study period. Nitrogen concentration increased trend in the later part of the study, which showed highest concentration at the final stage. This can be due to the nutrient accumulation from ammonia present in water. The nitrogen value recorded in integration production system throughout the period of the experiment showed significant difference ($p>0.05$) and it was seen that there was a strong positive relationship. On the whole, the mean soil nutrients recorded in this study were within the range reported by Nwilene et al., (2008) [24] for optimum growth and rice production.

Available phosphorus concentration in paddy fluctuated with trend during the period of study. Mean phosphorus concentration in rice paddy before transplant was 9.52±14 mg/kg showed a decrease during the rearing period and highest phosphorus concentration was recorded as23.52mg/kg and lowest at 4.48

Table 4: Mean production indices of rice paddy in integrated production system.

Production (units)	Initial	Final
Mean height cm	10.12±2.12	146.98±11.65
Mean leaves (n)	2.39±0.49	9.16±0.62
Rice strand/49.5m^2	1058	1034
Yield (kg/49.5m^2)		15.2
Yield (kg/ha)		2666.7

Abbreviations: cm- centimeter meter; n- number; m^2- meter square, kg- kilogram; ha- hectare mg/kg. Mean phosphorus concentration at the final stage was 2.39±0.3mg/kg, recorded highest at 2.69 and lowest at 2.09mg/kg. Phosphorus obtained in this study showed no significant difference ($p<0.05$) and it was seen that there was a positive relationship. On the whole, the mean soil nutrient recorded in this study was within the range reported by Nwilene *et al.,* (2008) [24] for optimum growth and rice production at the early stage of planting. Rice plant being a low demanding crop, the observed plant available phosphorus value would satisfy the phosphate demand by the rice. In addition, the availability phosphorus in rice paddy is a function of soil pH [25,26]. Hence the availability of the soil phosphorus may be negatively affected by the high pH values of the soils.

Mean potassium concentration in rice paddy before transplant recorded 31±42mg/kg showed an increase during the rearing period, highest recorded 73mg/kg and lowest at 11mg/kg. Mean nitrogen concentration was recorded at the final stage records 17±28.3mg/kg, highest records45.3mg/kg and lowest records 11.3mg/kg. Potassium concentration showed sharp decline and surge throughout the study period at the end of rearing cycle. The potassium recorded in integrated production system through the period of experiment study showed significant difference ($p>0.05$). On the whole, the mean soil nutrients recorded in this study were within the range at early rearing stage reported by Nwilene et al., (2008) [24] for optimum growth and rice production.

Organic carbon concentration was recorded as 1.03±0.1/kg over the study period organic carbon concentration in rice paddy before transplant followed by a decline toward the end of the rearing cycle. Organic carbon contents translate to organic matter contents in the soils. The organic matter present in rice paddy before transplant and at harvest was 0.80±0.7mg//kg; it showed a steady increase and decline towards the rearing cycle. This variation in organic matter in soil influence physical, chemical and biological properties of soil such as soil texture, water retention, nutrient content and retention and microbial activities in soil (Frei et al., 2007). The application of livestock manure increases soil organic matter content, and this leads to improved water infiltration and water holding capacity as well as an increased cation exchange capacity. Rasowo et al., (2008) reported that manure and urine raise the pH level and accelerate the decomposition of organic matter and activity [21].

The rice paddy pH values ranged from (slightly moderate acidic) to (neutral soil reaction) with a mean pH of 6.5±0.1. The optimum soil pH for rice production is 5.5 to 8 [27]. pH values remained within the recommended range all through the rearing cycle. The pH value before planting was 6.45 and at the last planting season pH was recorded as 6.74. The pH value obtained in this study showed significant difference ($p>0.05$) and it was seen that there was a positive relationship. It is reported that cultivation of rice is even possible with the ph up to 9.0 but high pH values of the soil could negatively influence the availability of the micronutrient as well phosphorus [26].

The nature of soil component was measured during the paddy growing period. The composited soil samples in the rice fish field after 16 weeks of culture period showed increase in the amount of silt and reduction in clay content in line with (Frei et al. 2007).

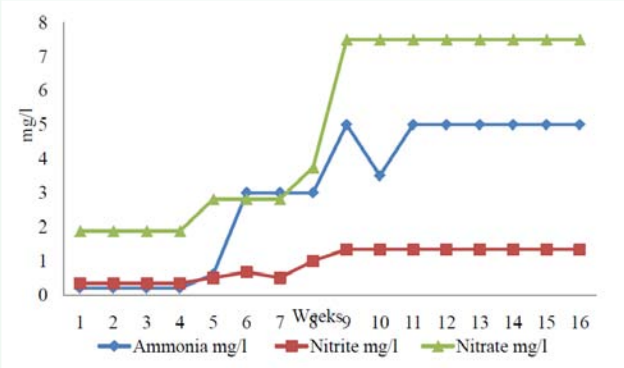

Figure 1 Variation in mean values of nitrogenous waste parameters in pond water during the study period.

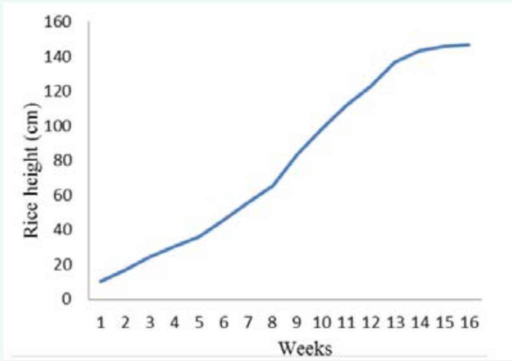

Figure 2 Weekly mean height of rice in integrated production system.

Plate 1 A view of Lowland (FARO 49) rice nursery bed.

In this study the textual classes of the soil ranged from sandy clay loam to loamy sand. It has being recorded that clay content is suitable for rice production because of their capacities to retain plant nutrient and soil water (moisture) these high clay content restrict the percolation of water through soil hence encouraging ponding of bunded fields [26]. Thus extends and improve the water use efficiency of the harvested rainwater by the rice plant.

CONCLUSION

In order to meet the soaring demand for food, there is a

Plate 2 A view of Fish-Rice Integrated Production System during the study period.

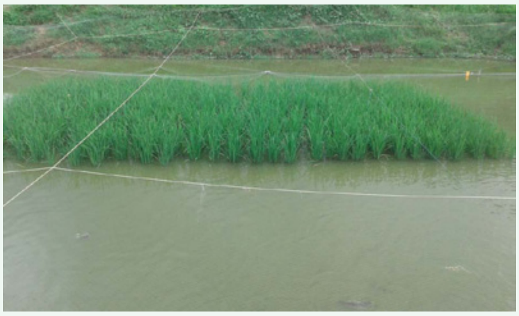

Plate 3 A view of Fish-Rice Integrated Production System during the study period.

Plate 4 Harvested O.sativa (FARO 49) from integrated production system.

need to increase Integrated Agriculture Aquaculture. This study concludes that integrated farming could be a viable option for diversification thereby ensuring food security and poverty alleviation. Integrated rice-fish increases rice yields there by established the relationships between pond management practices and pond nutrient accumulation and environmental impacts through strengthening nutrient recycling between component enhancing farm outputs for consumption all year round. This can be done through environmentally sustainable system in terms of resource utilization, diversity, productivity and efficiency. In addition integrated farming system can reduce the nutrient loss through pond effluent and thus minimize the environmental impact. Development of nutrient budgets would permit quantification of potential pollution impact of a specific pond management strategy.

Based from the findings and conclusions of this study regular soil testing should be conducted to monitor soil fertility level of rice primarily for nitrogen, phosphorus and potassium levels.

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