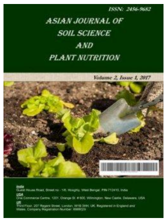

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Nutrients Load in Ponds Both Water and Soil Due to Application of Different Levels of Carbon and Nitrogen with Feeding

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Authors' contributions

This work was carried out in collaboration between all authors. Authors MAI and KAK designed the study, wrote the protocol and wrote the first draft of the manuscript. Authors MAI, NN and MZK analyzed the soil and water sample, reviewed the study design and all drafts of the manuscript. Authors MAI, MSA and KAK undertook the statistical analysis of the data. Authors MAI and SMB managed the literature searches, results and discussion and reference-citations. Finally, all the authors read and approved the final manuscript.

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ABSTRACT

Application of different types of feeds, fertilisers or food based nutrients in ponds results in the accumulation of high levels nitrogen, phosphorous and organic carbon in water and bottom soil. Farmers can use pond water as an irrigation source while soil as a fertility source of agriculture. This study was conducted at *Sahas* village on *Dumuria* upazila at *Khulna* district in Bangladesh for 46 days (from April to May, 2017) with nursery reared tilapia fingerlings in aforementioned earthen ponds using two different composition of commercial fish feed (diet-1 & diet-2) varying crude protein content 24% and 35% with different C and N content respectably as main plot treatment and three

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different amount 0 kg, 3 kg, 6 kg of each diets as sub plot treatment with six replications in split plot experimental design. In this study of aquaculture farming from initial about 6-8% organic carbon, 23-35% total nitrogen, 22-45% total phosphorous stored in pond sediments while 10-20% of available potassium and 2-3% of C/N ratio depleted from it. About 16-20% available nitrogen, 7-10% available phosphorous stored in pond water while about 8-9% dissolved organic carbon, 3-18% available potassium and 2-5% C/N ratio were depleted from it. Nutrient enrichment of pond water and soil during aquaculture production is insufficient to meet crop nutrient demand but fertiliser recommendations for crops should be altered when pond water is used as an irrigation source and pond bottom sediments used as fertility soil for in situ cultivation or excavate it to other field for growing crops and cost may reduce.

Keywords: Aquaculture; feeds; nutrients; ponds; water; soil; irrigation; fertility; cultivation; cost.

1. INTRODUCTION

Bangladesh has about 12,88,222 ponds and ghers which provide a total water area of about 1,46,890 ha. Fisheries sector represent major sectors of Bangladesh agriculture and play a major role in nutrition, employment and foreign exchange earnings. More attention is being devoted to the study of pond soils, and practical aqua culturists are beginning to seek information on pond bottom management. There are scopes for further increase in freshwater aquaculture production through an integrated farming system, fish feed development, improvement of breeding techniques and culture practices for indigenous and endangered fish species. This Bheri or Gher culture or pond aquaculture comprises fish farming and cultivation of Aman paddy in the subsequent crop rotation [1]. The challenge of meeting rapidly growing demand for food from a larger and more affluent global population in ways that are environmentally sustainable, whilst ensuring that the world’s poorest people are no longer hungry, demands sustainable intensification; simply defined as producing more food from the same area of land while reducing the environmental impacts [2]. Integrated agriculture aquaculture (IAA) farming has been advocated to increase land use efficiency under increased population growth, environmental degradation, and land and water scarcity [3]. Moreover, water quality management has been considered one of the most important aspects of pond aquaculture for many years, but less attention has been given to the management of pond bottom soil quality. There is increasing evidence that the condition of pond bottoms and the exchange of substances between soil and water strongly influence water quality [4]. The addition of excessive amounts of nitrogen from anthropogenic sources is contributing to water quality degradation and habitat loss in coastal waters throughout the world, and in many areas, nitrogen loading is one of the most significant long-term threats that must be managed [1]. Non-point source loading of nitrogen to coastal waters has increased with the intensification of land uses on watersheds [5]. Consequently increases in nitrogen results in higher phytoplankton production, hence organic matter load in waters and sediments. The higher organic matter load results in increased oxygen consumption and therefore an increased likelihood for bottom water oxygen depletion [6]. The proper management of soil N, P, and K is necessary to avoid deteriorating the environment while meeting the requirement of high crop productivity. In addition, reducing the losses of nutrients from farmland also can save the costs spent on fertilisers [7].

The importance of integrated agriculture aquaculture (IAA) systems lies within nutrient linkages between on-farm components, leading to farming intensification, food security, income generation and sustainable agriculture. Farmers add many different food-based nutrients to their ponds. The availability of the foods highly depends on season and farming intensity, which differs among areas. When farmers apply larger quantities of nutrients, they tended to discharge more effluents. The main variability in pond water quality and sediment nutrients was related with food inputs and water exchange rates. The pond sub-system should be integrated as much as possible with existing farming activities to maximise production while minimising nutrient discharges. It was assumed that farmers have a limited understanding of linkages between farm components, and therefore fail to maximise benefits of the pond within their IAA-systems [8,9,10]. At the same time, fertilisers are applied to ponds to increase inorganic nutrient concentrations that favor phytoplankton growth, enhancing production of fish and crustaceans [11]. During harvesting, ponds are drained to levels where fish can be recovered via nets. A result of pond draining is effluent discharge [12]. Moreover, intensive feeding of fish results in the accumulation of large quantities of sediments on the pond bottom [13] containing high levels nitrogen, phosphorous and organic carbon [14]. Cumulative build-up of nutrients results in deteriorating water quality, which can trigger stress and diseases in cultured fish, reducing farm productivity [13]. Regular removal of pond sediments is therefore an optimal management practice, but manual excavation after draining and drying ponds is labor intensive [15]. Such effluents are often allowed to run into natural waterways. Effluents from fertilised ponds have relatively high nutrient concentrations and can be potential sources of pollution and eutrophication for receiving waters.

Pond effluents have been applied to crops as irrigation water. Pumping out liquid pond sediments into drainage canals is a more cost effective alternative sometimes employed in Bangladesh, but this unplanned discharge is known to cause problems with local waterlogging, multiplication of disease vectors, eutrophication of receiving rice fields and water bodies, blocked access and conflicts with neighboring farms [16,13]. When pond sediments or effluents are applied in arid and semiarid environments, greater crop returns may be obtained through more efficient application methods. Farm ponds can also serve as water reservoirs for irrigation, drip irrigation could be profitable. The present study was conducted to explore the effects of food input patterns on water quality and sediment nutrient accumulation in ponds. For sustainable agricultural productivity and basic needs of vast population in Bangladesh, it must be needed to sustain a good quality and healthy soil. Soil quality as well as soil fertility mainly influenced by soil physical and chemical properties. But those properties vary with changing spatial locations. So, farmers need to learn about the soil properties for cultivation by conserving soil health. Moreover, fertiliser management is a major consideration in agricultural production. Inadequate fertiliser application results in a decrease of nutrient and causes soil fertility depletion and limits crop yield [17]. An excessive or imbalanced application not only wastes a limited resource, but also pollutes the environment. With consideration of both economic optimisation and environmental concerns, farmers are forced to face with an ever-increasing demand for effective soil fertility management. An approach towards justifying such concerns is site specific nutrient management. Farmer use pond water as irrigation source and pond bottom sediment as fertility soil for in situ cultivation or excavate it to other field for growing crops.

As nutrients store in pond water and sediments or soil during fish feed application in integrated agriculture aquaculture systems which is beneficial for maintaining the fertility of soil and act as supplementary nutrient sources of successive crop cultivation through irrigational application of water and excavated soil so the main objectives of the study were-

- ✓ To observe the quality of soil and water of different ponds due to application of various level of C and N.
- ✓ To analyse the amount of nutrient build up in soil and water of those ponds which will be used as additional nutrients sources of the next crop *i.e.* Rice cultivation.

2. MATERIALS AND METHODS

2.1 Site Selection

This research work was conducted at Sahas village on Dumuria upazila at Khulna district in Bangladesh (Fig. 1) for two months (from April to May, 2017). The study area, occupying approximately 454.23 km^2, was located in the southwestern part Bangladesh between 22°39′ N to 22°56′ N and 89°15′ E to 89°32′ E. There were two major rivers, Shipsha and Shangrail. The physiographic zone of this upazila is Ganges Tidal flood plain [18]. The mean temperature and rainfall at the study period was 33°C and 72.4 mm, respectively. The climate was characterised by a tropical monsoon climate [19]. A laboratory investigation was done in the laboratory of Soil, Water and Environment Discipline, Khulna University, Khulna.

2.2 Pond Preparation

Twelve Ponds were dug. All ponds were rectangular in shape with a maximum depth of about 1.5 m and size $12m^2$ (6m X 2m). Each pond is separated by net into three compartments being sized $4m^2$ (2m X 2m) in Fig. 2 to allow the movement of water and nutrient flow. Ponds were cleaned, dried and liming was done at 200 kg ha^{-1}. After liming ponds were filled with freshwater and allowed to stabilise for two weeks and then the experiment was started with applying different doses of diets, feeding levels and water level was maintained as required. All the ponds were fully exposed to prevailing sunlight. This study was conducted with nursery reared tilapia fingerlings in aforementioned earthen ponds using two different diets of varying C and N contents. After the completion of fish production the amount of nutrients stored in water and sediment was determined and subsequently this water can be used for irrigation and sediment for crop cultivation through excavation it or in situ rice cultivation.

2.3 Pond Experimental Design

The ultimate goal of this study was to observe how changing the C/N ratio impacts the nutrient build up at the system. It might be more towards nutrients input vs nutrients especially carbon, nitrogen, phosphorus and potassium build up in the system. Commercial fish feed was used s diet source. Two different composition of feeds (Table 1) as main plot treatment (diet-1 & diet-2) and 3 different amount (Table 2) of feeding level as subplot treatment (0, X & XX levels) was provided which given in Fig. 3. Diets were separated by ponds and feeding levels (amounts) were separated through compartments within a pond divided by nets. So, the possibility of mixing the nutrient was allowed within the system to see its influence in the compartment where didn't put anything. Experiment was completely randomized design with six replicates (ponds) in a split plot in time scheme, with two treatments in the plots and three samples times in the subplots. Differences among means were tested through analysis of variance (ANOVA) with SAS 6.12 software.

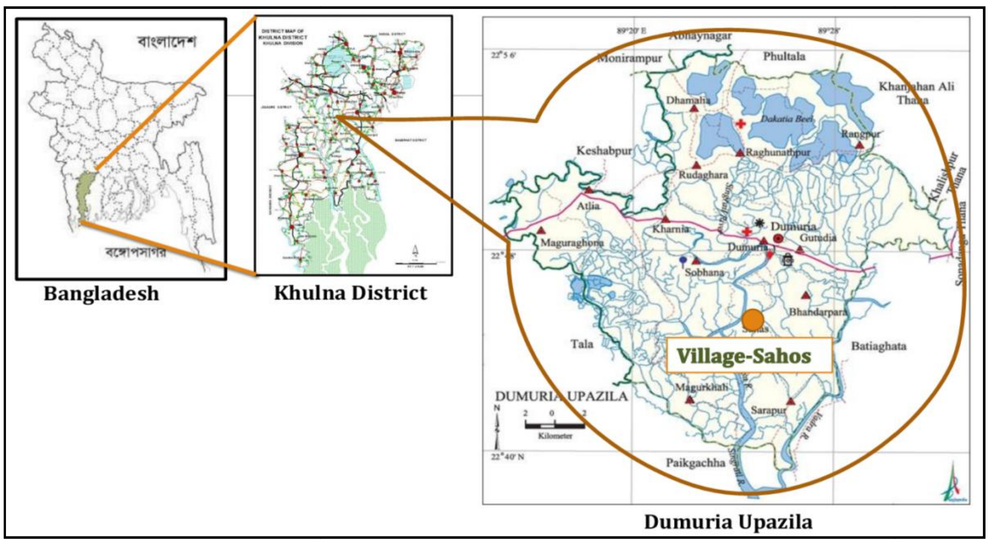

Fig. 1. Study area

Pond 06	Pond 05	Pond 04	Pond 03	Pond 02	Pond 01	
					P-1	C1
					P-2	C2
					P-3	C3
Pond 12	Pond 11	Pond 10	Pond 09	Pond 08	Pond 07	
						C1
						C2
						C3
Pond (6m X 2m); Each ponds has three partitions (2m X 2m) divided by net i.e. P-1, P-2, P-3.....						

Fig. 2. Ponds and compartments outline of the experiment design

Table 1. Composition of diets

Ingredients	Diet-1	Diet-2
% Moisture	13.54	12.39
% lipid	10.8	7.39
% crude protein	24.01	34.84
% ash	16.17	17.28
% crude fiber	6.31	6.85
% Carbohydrate	29.13	21.25
C (g kg^{-1})	397.5	413.7
N (g kg^{-1})	40	44
P (g kg^{-1})	9	9.4
C/N ratio	9.4	9.94

Table 2. Applied C and N content into experiment

Diet/Feeding level	Diet-1			Diet-2		
	Amount (kg)	C (g)	N(g)	Amount (kg)	C (g)	N(g)
0	0	0	0	0	0	0
X	3	1192.50	120	3	1241.10	132
XX	6	2385.00	240	6	2482.20	264

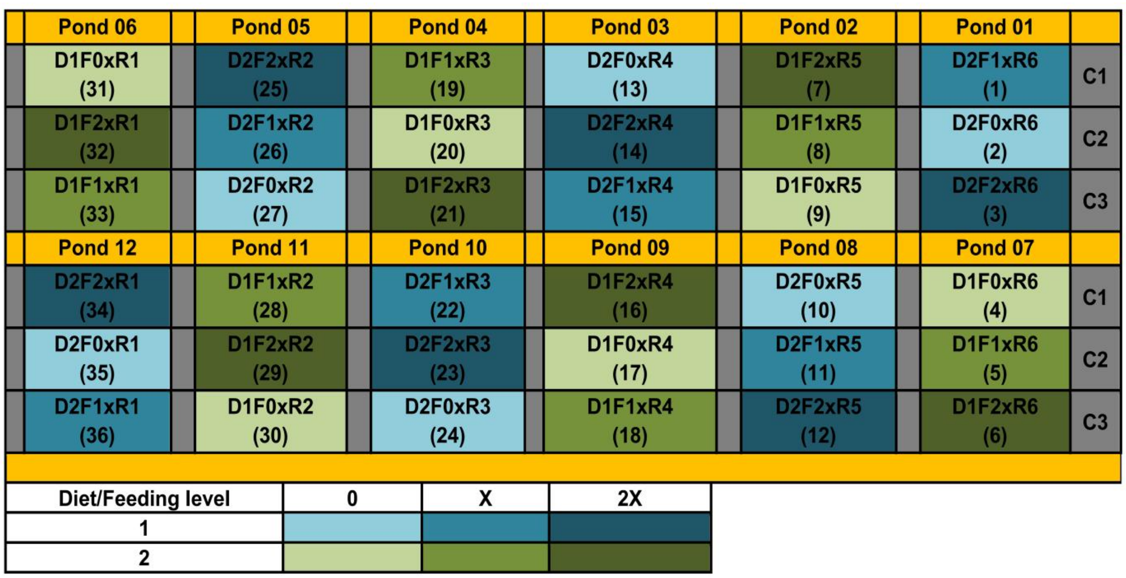

Fig. 3. Treatment labeling

D1: Diet-1, D2: Diet-2, F0: Feeding level 0, F1: Feeding level X, F2: Feeding level XX, R: Replication

2.4 Sample Collection, Processing and Preparation

Considering time for testing of the target soil parameters, total three times (Initial-7th April, second- 30th April and last- 24th May, 2017) sampling were done with 23 days interval during the study. Soil and water samples were collected from each compartment. A portable global positioning system (GPS) was used to record locations of sampling site. Soil samples were collected from two points of each compartments with at a depth of 6-10 inch of the pond bottom and mixed equally. Approximately 1 kg samples were collected from each pond in labeled tight plastic bags and transported to the laboratory. The collected samples were air dried, hammered and sieved to 2 mm to separate the coarse (>2 mm) and fine (<2 mm) fractions. The sieved soils were then preserved in plastic container and labeled properly for analysis. On the contrary, water sample was collected into plastic pot from each compartment with at a depth of 10-11 inch within surface and air tied and conserved it in the refrigerator.

2.5 Analysis of the Soil Samples

Soil organic carbon (SOC) was determined by Walkley and Black's wet oxidation method [20]. Total Nitrogen of the soil was determined by Micro-Kjeldahl's method following H_2SO_4 acid digestion and alkali distillation procedures [21]. Total Phosphorus of soil was determined colorimetrically by Vanado-molybdo-phosphoric yellow color method in nitric acid system [22]. The color intensity was determined by spectrophotometer at 470 nm light wavelength [23]. The Exchangeable Potassium was determined after extraction the soil samples with 1N NH_4OAc, pH-7.0 solution followed by the measurement of extractable K^+ by Flame emission spectrophotometer (Model: Jenway, PEP-7) at 766 nm wave length using Potassium filter [20].

2.6 Analysis of the Water Samples

The dissolved organic carbon content of the water was determined by Tyrine's method as water commonly contains relatively smaller amount of organic matter. As under dilute conditions Tyrine's method does not function well, water sample is needed to be dried first [24]. Available Nitrogen (Ammonical + Nitrate Nitrogen) of water was determined by Micro-Kjeldahl's method [25] and alkali distillation procedures [21]. Available Phosphorus of water was determined colorimetrically by molybdo-phosphoric blue color method [26]. The available Potassium of water was determined by a flame analyzer at 589 nm wavelength [27].

3. RESULTS AND DISCUSSION

In fish culture, different properties of bottom soil especially chemical properties are very important because it greatly influences the properties of water and ultimate fish production. When a new technology like a new feed treatment is applied to a culture system it is necessary to investigate the soil quality parameters because introduction of the feed may affect soil quality that has co-relation with water quality and plankton abundance. The various soil quality parameters, so far recorded in the present study are discussed below. Different observational and estimated data of water and soil parameter *viz.* organic carbon, total nitrogen, total phosphorus, available potassium and C/N ratio both initial value and yield value from initial is shown in Table 3 and Table 4 respectively.

3.1 Soil Organic Carbon

The results show that the mean yield of soil organic carbon content due to application of diet-1 is 0.0783% with standard deviation of 0.21 while in case of diet-2 0.0822% with standard deviation of 0.15 (Table 4).

Table 3. Initial nutrients of soil and water of different ponds

Properties	Soil					Water				
	OC	TN	TP	AK	C/N	DOC	AN	AP	AK	C/N
Unit	%	%	%	$\mu g\ g^{-1}$	-	%	mgL^{-1}	mgL^{-1}	mgL^{-1}	-
P-1	0.82	0.07	0.10	765.70	11.71	0.03	20.67	41.90	76.12	14.51
P-2	0.82	0.07	0.03	767.50	11.71	0.02	19.60	45.98	76.55	10.20
P-3	0.85	0.07	0.03	729.29	12.14	0.02	20.07	41.74	76.55	9.97
P-4	0.82	0.07	0.06	797.40	11.71	0.02	19.00	44.83	79.74	10.53
P-5	0.75	0.07	0.05	701.71	10.71	0.02	21.00	48.07	79.74	9.52
P-6	0.78	0.07	0.05	774.13	11.14	0.03	20.60	44.26	76.55	14.56
P-7	0.86	0.07	0.07	765.50	12.29	0.02	19.60	46.25	76.12	10.20
P-8	0.89	0.08	0.04	761.19	11.13	0.02	19.80	46.52	76.55	10.10
P-9	0.80	0.07	0.04	765.50	11.43	0.02	19.80	44.83	76.55	10.10
P-10	0.68	0.06	0.10	765.50	11.33	0.02	20.07	42.71	76.55	9.97
P-11	0.78	0.07	0.05	765.50	11.14	0.02	19.60	43.98	76.55	10.20
P-12	0.77	0.07	0.13	733.60	11.00	0.03	21.07	45.95	76.55	14.24

OC: organic carbon, TN: Total nitrogen, TP: Total phosphorus, AK: Available potassium, C/N: Carbon nitrogen ratio, DOC: Dissolved organic carbon, AN: Available nitrogen, AP: Available phosphorus, P: Pond

Table 4. Mean yield of nutrients due to application of diet after completion the experimental period

Sample	Properties	Diet-1	Diet-2
Soil	OC (%)	0.0783 ± 0.2167	0.0822 ± 0.14936
	TN (%)	0.0171 ± 0.0104	0.02044 ± 0.0267
	TP (%)	0.0243 ± 0.0381	0.0496 ± 0.0247
	AK (µg g^{-1})	-58.47 ± 9.22	-143.53 ± 8.168
	C:N	-2.73 ± 0.22	-2.936 ± 0.59
Water	DOC (%)	-0.0005 ± 0.009	-0.005 ± 0.007
	AN (Ammonical + Nitrate) (mgL^{-1})	4.24 ± 0.89	3.05 ± 0.51
	AP (mgL^{-1})	3.45 ± 0.10	4.07 ± 0.39
	AK (mgL^{-1})	-7.44 ± 2.52	-9.04 ± 0.94
	C:N	-2.417 ± 0.92	-3.12 ± 0.41

OC: organic carbon, TN: Total nitrogen, TP: Total phosphorus, AK: Available potassium, C/N: Carbon nitrogen ratio, DOC: Dissolved organic carbon, AN: Available nitrogen, AP: Available phosphorus, Values are the mean ± SD

Diet-2 stores more organic carbon than diet-1 as diet-2 contains more carbon than diet-1. Organic carbon is the most imperative factor determining the fertility status of soil. Aquaculture pond soil with less than 0.5% organic carbon is low productive, 0.5 to 1.2% average productive, 1.5 to 2.5% high productive and greater than 2.5% as less productive [28]. Moreover, these F values (Table 5) indicate non-significant yield difference of soil organic carbon due to diet application as well as different feeding level. There also is a non-significant Diet*Feeding and Ponds*Diet interaction. Differences among ponds are not significant.

Organic carbon content of soil due to application of different feeding levels of diet ranged from 0.02% to 0.11% for diet-1 and 0.04 % to 0.12% for diet-2. There have noticeable change according to feeding levels of diet. In case of feeding level 0 where we didn't apply any diet store lower amount of organic carbon while highest amount of organic carbon store in highest feeding level (Fig. 4). Although the concentration of organic carbon is increased lower concentration of it may be caused by temporary suspension of feeding and subsequent reduction of the quantities of feed. Reduction of organic carbon inputs coupled with consumption of organic matter by respiration is likely to have contributed to the decrease in organic carbon. During respiration, the sediment's organic carbon is consumed and converted mostly to CO_2 that is released from the water to the atmosphere and does not accumulate in the pond [4].

Table 5. F value in ANOVA table for the yield of nutrients from the aquaculture pond

Sample	Properties	Ponds	Diet	Ponds*diet	Feeding level	Diet*feeding level
Soil	OC (%)	1.99^{ns}	0.01^{ns}	0.87^{ns}	1.37^{ns}	0.48^{ns}
	TN (%)	1.56^{ns}	0.27^{ns}	0.94^{ns}	2.19^{ns}	0.56^{ns}
	TP (%)	21.24**	31.34**	11.91**	1.82^{ns}	0.34^{ns}
	AK (µg g^{-1})	8.58*	11.64*	2.8*	0.86^{ns}	0.59^{ns}
	C:N	3.29^{ns}	0.04^{ns}	0.43^{ns}	1.64^{ns}	1.02^{ns}
Water	DOC (%)	48.4**	34.85**	36.29**	3.83*	0.74^{ns}
	AN (Ammonical + Nitrate) (mgL^{-1})	9.09*	3.43^{ns}	12.99**	2.41^{ns}	1.28^{ns}
	AP (mgL^{-1})	1.4^{ns}	0.27^{ns}	0.79^{ns}	1.7^{ns}	1.78^{ns}
	AK (mgL^{-1})	14.98**	0.98^{ns}	10.63**	0.11^{ns}	0.33^{ns}
	C:N	17.9**	5.19^{ns}	14.89**	0.19^{ns}	2.51^{ns}

*OC: organic carbon, TN: Total nitrogen, TP: Total phosphorus, AK: Available potassium, C: Carbon, N: Nitrogen, DOC: Dissolved organic carbon, AN: Available nitrogen, ns: Non significant, *.Significant at the 0.05 level, **. Significant at the 0.01 level*

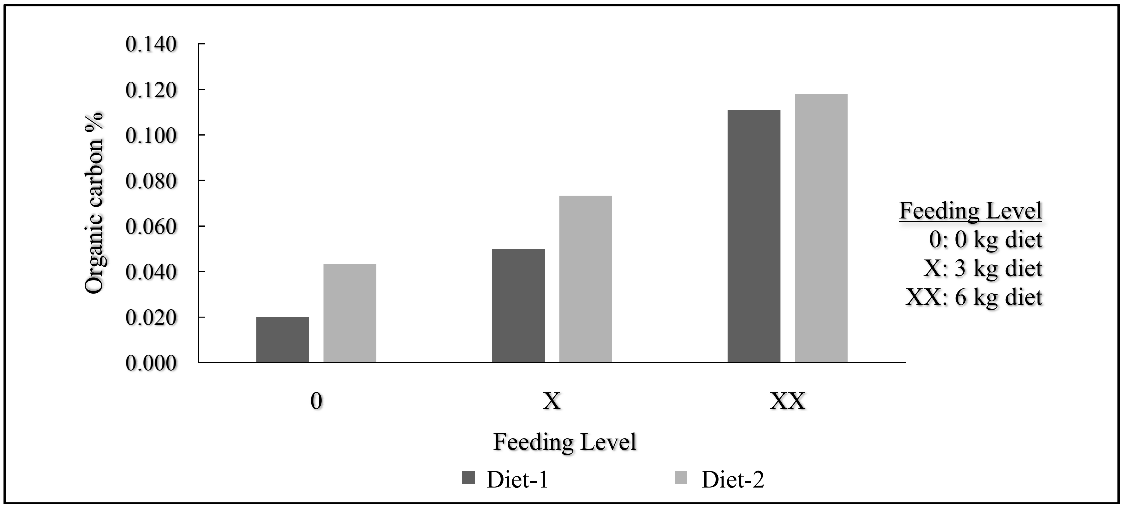

Fig. 4. Organic carbon of soil due to application of different feeding levels of diet

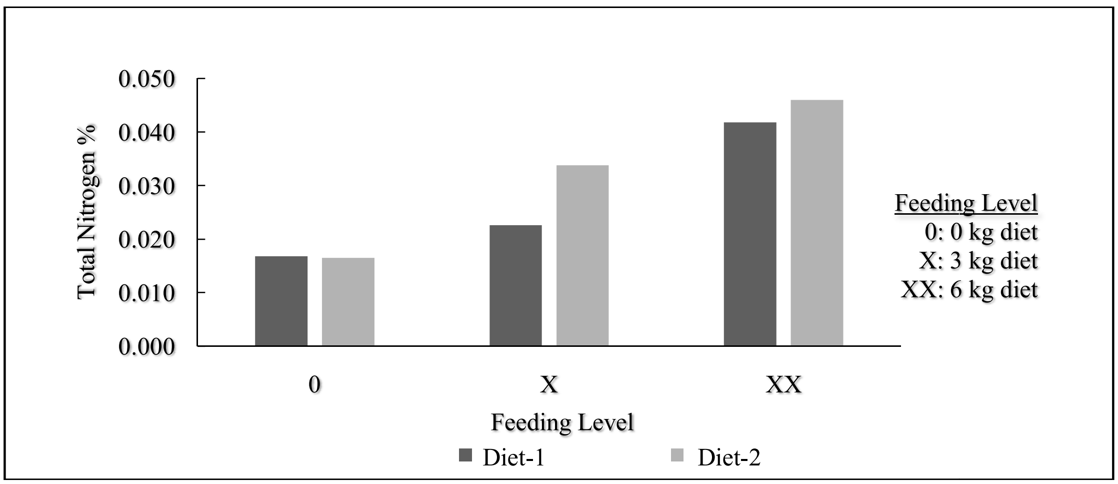

Fig. 5. Total Nitrogen of soil due to application of different feeding levels of diet

3.2 Total Nitrogen in soil

The mean yield of total nitrogen content of soil due to application of diet-1 is 0.0171% with standard deviation of 0.010 while in case of diet-2 0.02044% with standard deviation of 0.0267 (Table 4). Diet-2 stores more nitrogen than diet-1 as diet-2 contains more nitrogen than diet-1. Moreover, these F values (Table 5) indicate non-significant yield difference of soil nitrogen due to diet application as well as different feeding level. There also is a non-significant Diet*Feeding and Ponds*Diet interaction. Differences among ponds are not significant.

Total Nitrogen content of soil due to application of different feeding levels of diet ranged from 0.015% to 0.045% for diet-1 and 0.016 % to 0.046% for diet-2. The figure (Fig. 5) shows that, there have noticeable change according to feeding levels of diet but no significant changes found among the diets. In case of feeding level 0 where we didn't apply any diet store lower amount of nitrogen while highest amount of nitrogen store in highest feeding level. It denotes that stocking of nutrient depends on the feeding level and composition of diets. About 99% of the combined nitrogen in the soil is contained in the organic matter (Humus) in the form of amino acids, peptides and easily decomposed proteins. It may also be in the form of inorganic compounds such as NH_4^+ and NO_3^- which are utilised by green plants (Phytoplankton). Anaerobic organisms (Bacteria) help in the decomposition of organic matter into simple inorganic forms forming products such as CO_2 water and ammonia which influences directly or indirectly in pond productivity. Nitrogen fixation rate is ranging from 6-57 mg N $m^{-2}d^{-1}$ in tropical fish ponds [29].

3.3 Total Phosphorus in Soil

The mean yield of total phosphorus of soil due to application of diet-1 is 0.0243% with standard deviation of 0.0381 while in case of diet-2 0.0496% with standard deviation of 0.0247 (Table 4). Diet-2 stores more phosphorus than diet-1. Moreover, F values (Table 5) indicate highly significant yield difference of soil phosphorus due to diet application as well as in different ponds and Ponds*Diet interaction. But, there is a non-significant Diet*Feeding interaction. Differences among feeding level are not significant.

Total Phosphorus content of soil due to application of different feeding levels of diet ranged from 0.016% to 0.0305% for diet-1 and 0.0456% to 0.0523% for diet-2. There have no noticeable change according to feeding levels of diet but significant changes found among the diets. In case of feeding level 0 where we didn't apply any diet store lower amount of phosphorus while highest amount of phosphorus store in highest feeding level (Fig. 6). It denotes that stocking of nutrient depends on the feeding level and composition of diets. It is implying that pond sediments store total phosphorus during the culture period. The main reason for phosphorus accumulation in sediments is due to its adsorption by mud. The yellow ferric iron compound chiefly the hydroxide at the oxidised surface layer are usually in a very finely divided on colloidal state and this colloidal ferric hydroxide together with colloidal humic substances make a mud which have highly absorptive properties [30]. Soil phosphorus (unit- mg of P_2O_5 per 100 gm of soil) level below 3 might be considered indicative of poor production, between 3 and 6 of average production and ponds having available phosphorus above 6 are productive [28].

3.4 Available Potassium in Soil

Potassium content decreases from both soil and water. The mean losses of potassium from soil due to application of diet-1 is 58.47 µg g^{-1} with standard deviation of 9.22 while in diet-2 143.53 µg g^{-1} with standard deviation of 8.168 (Table 4). This is caused by the leaching loss of potassium. Moreover, F values (Table 5) indicate significant yield difference of soil available potassium due to diet application as well as in different ponds and Ponds*Diet interaction. There is a non-significant Diet*Feeding interaction. Differences among feeding level are also not significant.

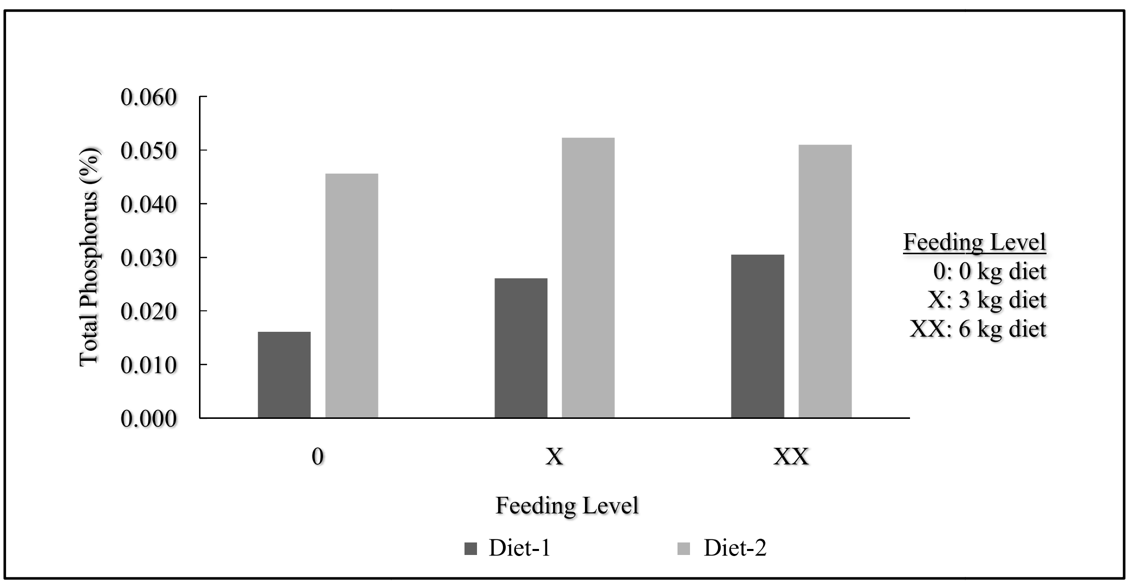

Fig. 6. Total phosphorus of soil due to application of different feeding levels of diet

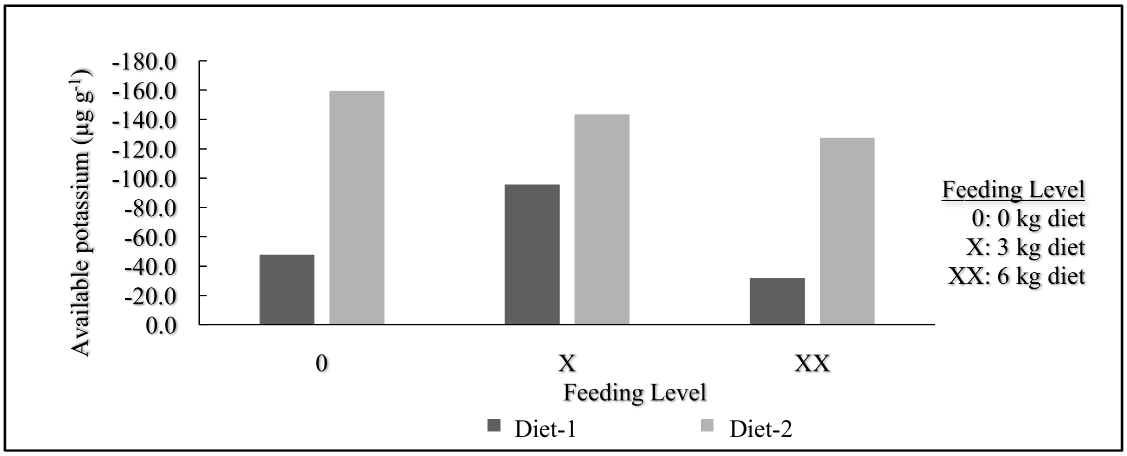

Fig. 7. Available potassium of soil due to application of different feeding levels of diet

Available potassium concentrations of soil are decreased after application of feed. Available potassium content of soil losses due to application of different feeding levels of diet ranged from 31.89 µg g^{-1} to 95.68 µg g^{-1} for diet-1 and 127.58 µg g^{-1} to 159.48 µg g^{-1} for diet-2. There have no noticeable change according to feeding levels of diet but significant changes found among the diets. In case of feeding level 0 of diet-1 where we didn't apply any diet losses lower amount of potassium while highest amount of potassium losses in feeding level X. But, in case of feeding level 0 of diet-2 where we didn't apply any diet losses higher amount of potassium while less amount of potassium losses in highest feeding level (Fig. 7). The decrease in sediment potassium concentration after treatment may be attributed to ion exchange reactions [31]. Potassium concentration in the sediment may have been higher than that in the overlying pond water, hence potassium ions were released from the pond sediment to the water column until equilibrium was established and maintained afterwards. In the nutrients, higher total losses than total inputs imply that there was another source of exchangeable potassium other than feed/fertiliser, stocked fish and inflow. It is possible that part of the potassium was leached to the deeper layers of the pond sediments. Other factors that can affect K release from soils are leaching, redox potential (Eh), and temperature. Leaching promotes the K release from K-bearing minerals by carrying away the reaction products. Soil solution K is either leached or sorbed by soils. A number of factors influence the movement of K in soils, including the CEC, soil pH, liming, method and rate of K application, and K absorption by plants [32,33,34]. The ability of a soil to retain K is very dependent on the CEC of the soil. Thus, the amount of clay and SOM in the soil strongly influences the degree of K leaching. Soils with higher CEC have a greater ability to retain added K, whereas leaching of K is often a problem on sandy soils [35].

3.5 C/N Ratio of Soil

C/N ratio of soil decreased from initial value. The mean losses of C/N ratio from soil due to application of diet-1 is 2.73 with standard deviation of 0.22 while in diet-2 2.94 with standard deviation of 0.59 (Table 4). Moreover, these F values (Table 5) indicate non-significant yield difference of C/N ratio of soil due to diet application as well as different feeding level. There also is a non-significant Diet*Feeding and Ponds*Diet interaction. Differences among ponds are not significant.

The C/N ratio of the soil decreases due to application of different feeding levels of diet ranged from 1.46 to 3.85 for diet-1 and 1.8 to 4.76 for diet-2 indicating the more or less stable condition of decomposition. There have noticeable change according to feeding levels of diet and among the diets. In case of feeding level 0 of diet-1 where we didn't apply any diet has lowest value of C/N ratio while highest value of C/N ratio in highest feeding level. But, in case of feeding level X of diet-2 had lowest value of C/N ratio while lowest value of C/N ratio in highest feeding level (Fig. 8). C/N ratio is one of the factors that influence the activity of microorganisms. During decomposition of organic materials by soil organisms, mineralisation and immobilisation of carbon and nitrogen take place. With the passage of time, the rate of mineralisation of carbon almost equals that of nitrogen, the results being near constancy of C/N ratio in the vicinity 10 to12, which is an indication of the formation of stable products under the prevailing environment [36].

3.6 Dissolved Organic Carbon of Water

The organic carbon content in water is decreased due to application of diet. About 0.0005% with standard deviation of 0.009 and 0.007 respectively for diet-1 and diet-2 (Table 4) indicating the lower amount of organic matter [37]. This decreases of organic carbon caused by addition of rain water during experiment. The generally low organic matter content is thought to be due to its rapid decomposition caused by high rainfall and temperature conditions and vigorous microbial activity. F values (Table 5) indicate highly significant difference of dissolved organic carbon in water due to diet application as well as in different ponds and Ponds*Diet interaction. There is a non-significant Diet*Feeding interaction. But, differences among feeding level are significant.

Dissolved organic carbon of water decreased after application of feed at different feeding levels of diet it ranged from 0.0001% to 0.002% for diet-1 and 0.003% to 0.006% for diet-2. There have no noticeable change according to feeding levels of diet. In case of feeding level 0 where we didn’t apply any diet decreased highest amount of organic carbon while lowest amount of organic carbon decreased in highest feeding level. In case of feeding level X of diet-2 had highest value of organic carbon while lowest value of organic carbon in feeding level 0 (Fig. 9).

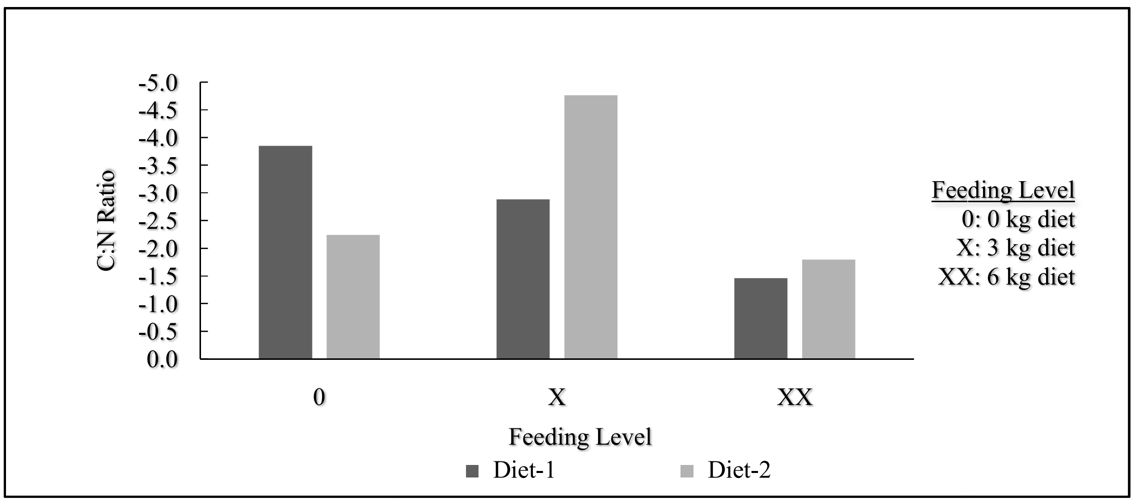

Fig. 8. C/N ratio of soil due to application of different feeding levels of diet

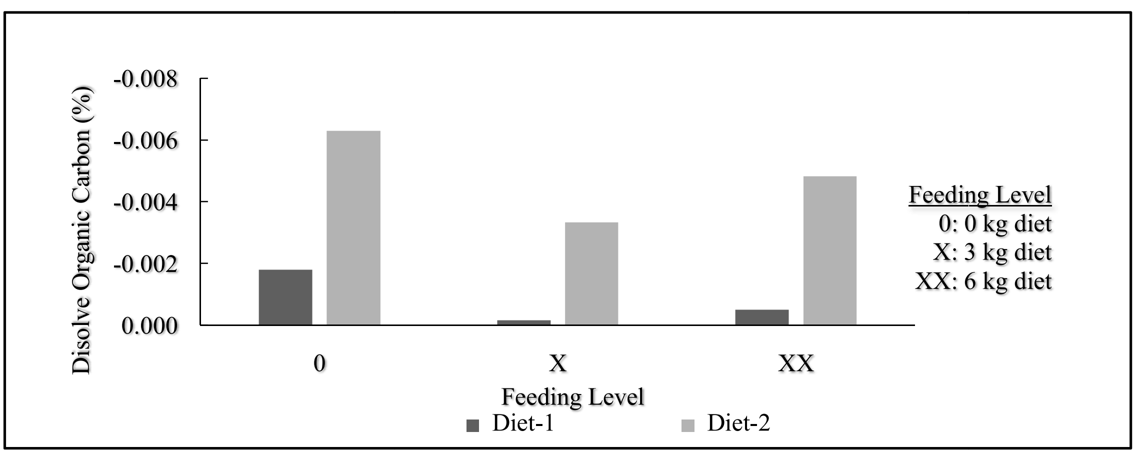

Fig. 9. Dissolved organic carbon of water due to application of different feeding levels of diet

3.7 Available Nitrogen (Ammonical + Nitrate) in water

Available nitrogen (Ammonical + Nitrate) content in water is increased due to application of diet. About 4.24 mgL^{-1} and 3.05 mgL^{-1} with standard deviation of 0.89 and 0.51 respectively for diet-1 and diet-2 (Table 4). Moreover, these F values (Table 5) indicate non-significant difference of Ammonical + Nitrate nitrogen content of water due to diet application as well as in different feeding level and Diet*Feeding interaction. There is a highly significant Ponds*Diet interaction. But, differences among ponds are significant.

Available nitrogen (Ammonical + Nitrate) content of water due to application of different feeding levels of diet ranged from 2.78 mgL^{-1} to 5.31 mgL^{-1} for diet-1 and 2.33 mgL^{-1} to 3.85 mgL^{-1} for diet-2 (Fig. 10). It shows that, there was not found noticeable change according to feeding levels of diet. In case of feeding level 0 where we didn't apply any diet store lower amount of nitrogen while highest amount of nitrogen store in highest feeding level. It denotes that stocking of nutrient depends on the feeding level and composition of diets. Several factors can contribute to increase to the ammonia nitrogen compounds in the water, such as the application of nitrogen fertilisers, organic matter decomposition, nitrogen excretion by fish and the use of artificial feed [4].

3.8 Available Phosphorus in Water

Available phosphorus in water is 3.45 mgL^{-1} and 4.07 mgL^{-1} with standard deviation of 0.10 and 0.39 respectively for diet-1 and diet-2 (Table 4). Moreover, these F values (Table 5) indicate non-significant yield difference available phosphorus in water due to diet application as well as different feeding level. There also is a non-significant Diet*Feeding and Ponds*Diet interaction. Differences among ponds are not significant. Almost all of the phosphorus (P) present in water is in the form of phosphate (PO_4^{3-}) and in surface water mainly present as bound to living or dead particulate matter and in the soil is found as insoluble $Ca_3(P0_4)_2$ and adsorbed phosphates on colloids except under highly acid conditions. It is an essential plant nutrient as it is often in limited supply and stimulates plant (algae) growth and its role for increasing the aquatic productivity is well recognised.

Available phosphorus content of water due to application of different feeding levels of diet ranged from 1.74 mgL^{-1} to 5.67 mgL^{-1} for diet-1 and 1.99 mgL^{-1} to 6.97 mgL^{-1} for diet-2. There have noticeable change according to feeding levels of diet and non-significant changes found among the diets. In case of feeding level 0 where we didn't apply any diet store lower amount of phosphorus while highest amount of phosphorus store in highest feeding level (Fig. 11). The capability of sediment to retain or release phosphorus is one of the important factors which influence the concentration of inorganic and organic phosphorus in the overlying water [38].

3.9 Available Potassium in Water

Available potassium decreased from water by 7.44 mgL^{-1} and 9.04 mgL^{-1} with standard deviation of 2.52 and 0.94 respectively for diet-1 and diet-2 (Table 4). Moreover, these F values (Table 5) indicate non-significant difference of available potassium concentrations of water due to diet application as well as in different feeding level and Diet*Feeding interaction. There is a highly significant Ponds*Diet interaction. Differences among ponds are also highly significant.

Available potassium concentrations of water are decreased after application of feed. Available potassium content of soil losses due to application of different feeding levels of diet ranged from 6.379 mgL^{-1} to 7.97 mgL^{-1} for diet-1 and 7.38 mgL^{-1} to 9.59 mgL^{-1} for diet-2. There have no noticeable change according to feeding levels of diet. In case of feeding level 0 of diet-1 where we didn't apply any diet losses highest amount of potassium while lowest amount of potassium losses in feeding level X. But, in case of feeding level 0 of diet-2 where we didn't apply any diet losses higher amount of potassium while lower amount of potassium losses in highest feeding level (Fig. 12). It is possible that part of the potassium was leached to the deeper layers of the pond sediments.

3.10 C/N Ratio of Water

The C/N ratio decreased from water by 2.42 and 3.12 with standard deviation of 0.92 and 0.41 respectively for diet-1 and diet-2 (Table 4). As, nitrogen stores more than carbon into soil and water, C/N ratio decreased. Moreover, these F values (Table 5) indicate non-significant difference of C/N ratio of water due to diet application as well as in different feeding level and Diet*Feeding interaction. There is a highly significant Ponds*Diet interaction. Differences among ponds are also highly significant.

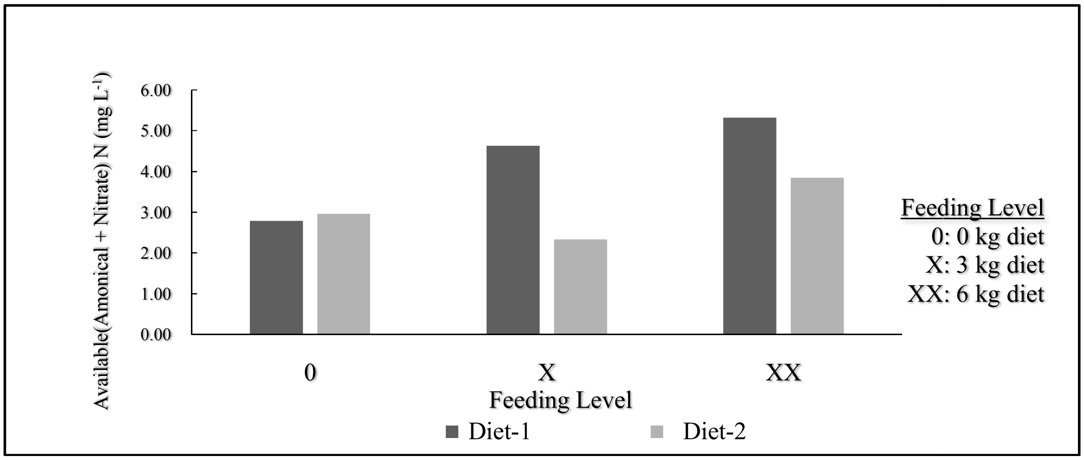

Fig. 10. Available Nitrogen (Ammonical + Nitrate) of water due to application of different feeding levels of diet

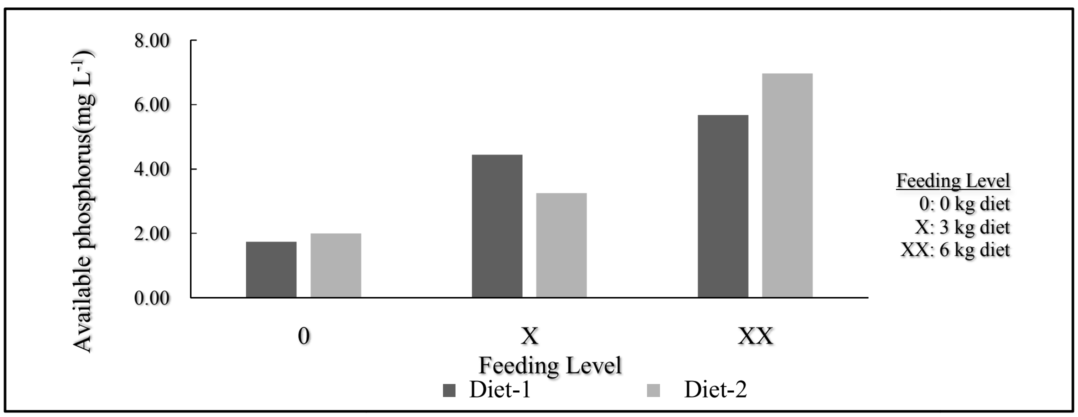

Fig. 11. Available phosphorus of water due to application of different feeding levels of diet

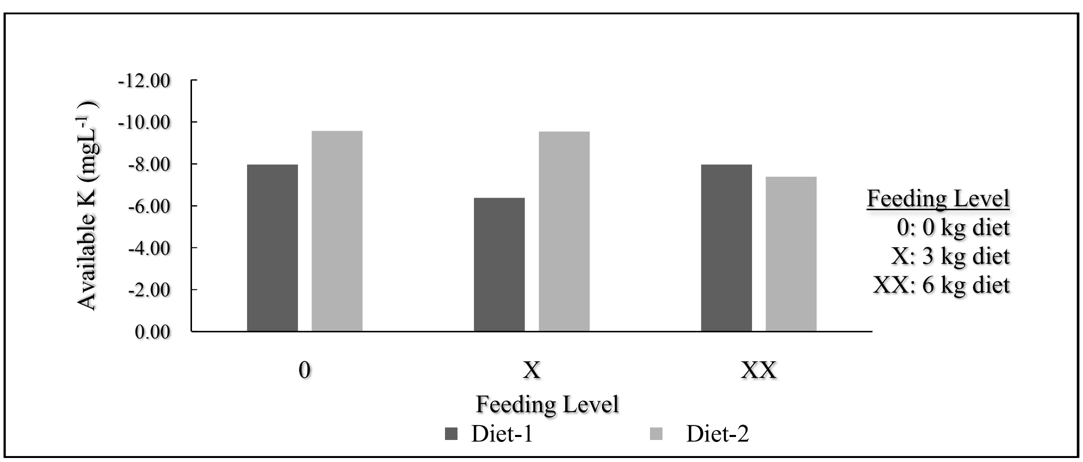

Fig. 12. Available potassium of water due to application of different feeding levels of diet

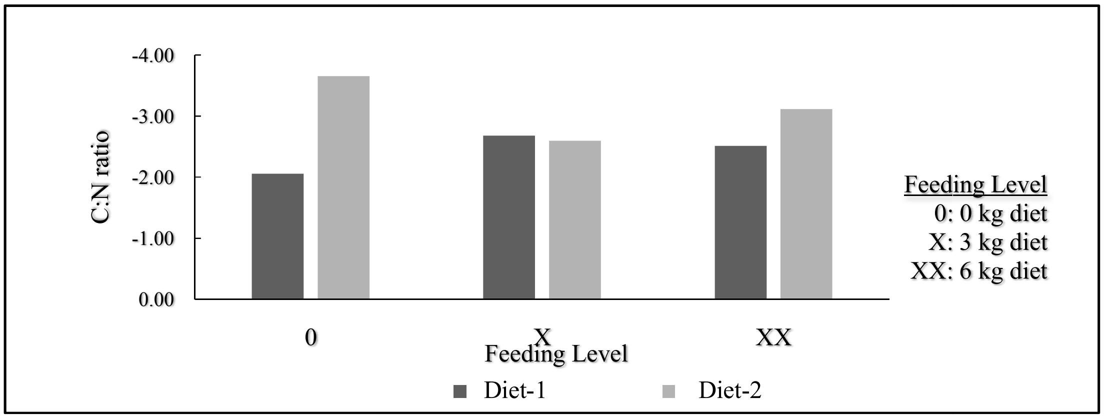

Fig. 13. C/N ratio of water due to application of different feeding levels of diet

Table 6. Accumulation and depletion of nutrients in soil and water after completion aquaculture

Sample	Parameters	Store	Depletion
Soil	Organic Carbon (%)	6-8 %	
	Total Nitrogen (%)	23-35 %	
	Total Phosphorus (%)	22-45 %	
	Available Potassium (μg g^{-1})		10-20 %
	C/N ratio		2-3 %
Water	Dissolved Organic Carbon (%)		8-9 %
	Available Nitrogen (Ammonical + Nitrate Nitrogen) (mgL^{-1})	16-20 %	
	Available Phosphorus (mgL^{-1})	7-10 %	
	Available Potassium (mgL^{-1})		3-18 %
	C/N ratio		2-5 %

The C/N ratio of water decreases due to application of different feeding levels of diet ranged from 2.05 to 2.68 for diet-1 and 2.59 to 3.69 for diet-2 indicating the more or less stable condition of decomposition. There have no noticeable change according to feeding levels of diet and among the diets. In case of feeding level 0 of diet-1 where any diet had not applied was highest value of C/N ratio while lowest value of C/N ratio in feeding level X. But, in case of feeding level X of diet-2 had lowest value of C/N ratio while lowest value of C/N ratio in feeding level 0 (Fig. 13).

In this study of aquaculture farming, about 6-8% organic carbon, 23-35% total nitrogen, 22-45% total phosphorous was stored in pond sediments while 10-20% of available potassium and 2-3% of C/N ratio was depleted from it. On the contrary, about 16-20% available nitrogen, 7-10% available phosphorous was stored in pond water while about 8-9% dissolved organic carbon, 3-18% available potassium and 2-5% C/N ratio was depleted from it (Table 6).

4. CONCLUSION

When feeds are applied into pond, fishes consume it and somehow increase the activities of phytoplankton and zooplankton and rest of it stored at the bottom sediments. So, suitable bottom soil condition and high quality water are essential ingredients for successful pond aquaculture. In this study of aquaculture farming, organic carbon, total nitrogen, total phosphorous was stored in pond sediments while available potassium and C/N ratio was depleted from it. In case of water, there found depletion of dissolved organic carbon although diets provide carbon source. This caused by the excessive rainfall during the experiment. Noticeable changes were found to build up nitrogen and phosphorus in water due to the application of different types of feed but there was the depletion of available potassium and C/N ratio. It denotes that stocking of nutrient depends on the feeding level and composition of diets. Regular removal of pond sediments is, therefore, an optimal management practice. When fish are recovered from ponds, the sediment is often drained, presenting both an environmental challenge and an agricultural opportunity. Application of pond water to crops during fish grow-out is feasible, but filters capable of removing particulates will be required if it is to be delivered through an irrigation system. Nutrient enrichment of pond water during aquaculture production is insufficient to meet crop nutrient demand but fertiliser recommendations for crops should be altered when pond water is used as an irrigation source and pond bottom sediments used as fertility soil for in situ cultivation or excavate it to other field for growing crops.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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