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Correlation of planktonic biomass with other physico-chemical parameters of water quality in fertilized fish ponds

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Abstract
The production of common carp (*Cyprinus carpio*) was studied in pond fertilized with cow-dung @ 0.1 g N/10 g in the presence of planktonic biomass. The correlation of planktonic biomass with water quality physicochemical parameters of three fish ponds, was studied. The parameters such as pH, temperature, dissolved oxygen, total alkalinity, total dissolved solids, total hardness, magnesium, calcium, light penetration, total solids, carbonates and bicarbonates, were analyzed in a laboratory using standard protocols. Data collected at the end of the present experimental study was subjected to an appropriate statistical analysis to appraise the correlation coefficients of planktonic biomass with several physicochemical parameters of three ponds under study. In most cases significant correlations were recorded between biomass and key physico-chemical attributes of the ponds.

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Introduction

Estimated fish production which comes from worldwide aquaculture is 179 million tonnes out of which 156 million tonnes are being consumed by humans at the rate of 20.5 kg per capita (FAO, 2020). The consumption of aquatic organisms is about 46%, while that of fish is 56% (FAO, 2020). Pakistan contribution in fish production was 158.8 thousand tonnes (1%) in 2018. Fisheries and Aquaculture sector provides a source of employment to 59.51 million people (38.98 in fisheries and 20.53 million people in aquaculture) of which 14% are women (FAO, 2020). Asia is the biggest fish producer with the highest percentage of 88.69% (77812.2 thousand tonnes), America with 4.63% (3799.2 thousand tonnes), Europe 3.75% (3082.6 thousand tonnes) and Africa 2.67% (2195.9 thousand tonnes) (FAO, 2020). Aquaculture has become the fastest growing sector which has a very important contribution in animal food production as being a major aquatic food supplier worldwide (Ottinger et al., 2016). Aquaculture has more efficient utilization and management of land and water in comparison with the agriculture sector which cannot utilize barren land and water as well for crop production (Edwards, 2015). Fish is one of the cheapest sources of protein and a best source of international trade commodity in most regions of the global market. It has a vast contribution in the economy of many countries of the world (Ozigbo et al., 2014). Any fishpond or water body like a lake is dominated by a wide variety of omnivore and benthivore fish species (Liu et al., 2018). Fish dominance in any water body depends upon fish diet and available food items (Behrens and Lafferty, 2007).

The maximum fish production in the earthen ponds is fully dependent on the physico-chemical water quality parameters. Therefore, the best management of pond is the actual management of quality

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of its water. The most common water quality parameters include light penetration, water temperature, turbidity, CO_2, pH, alkalinity, hardness and most important the total dissolved solids (TDS), plankton population, biomass, etc. Bhatnagar and Devi (2013) reviewed the principles used in water quality management to develop awareness among environmentalists and especially for fish culturists about the physicochemical water quality parameters that are required to be maintained at their optimum levels to maintain health of fish being cultured in ponds. The optimum levels of these parameters may increase in fish production so that they can meet the needs of the increasing population according to the current scenario when food resources are being depleted rapidly.

Water is the basic critical factor for all life forms of aquatic ecosystems which has a great impact on fish survival, growth, and reproduction of any water body (Boyd, 2003). All physiological activities of fish such as excretion, osmoregulation, respiration, and reproduction also depend upon water quality parameters (Alam and Al-Hafedh, 2006). Water quality parameters must be maintained at their optimum levels as required by body physiology irrespective of fish species being cultured in a specific water body to gain maximum fish production (Boyd and McNevin, 2015). Pond management practices such as daily feed input and pond fertilization for plankton production influence water quality parameters (Das et al., 2005; Sipauba-Tavares et al., 2011). Improvement in pond management practices is very important to increase the aquatic food supply (Edwards, 2015). Poor water quality parameters disturb fish growth badly which ultimately result in less production and less profit (Iwama et al., 2000). Any kind of contamination can cause growth retardation, impair development and less reproduction eventually leading to fish mortality. These changes pressurize fish farmers to manage water quality parameters to reduce fish stress so that fish can overcome physiological changes and get maximum growth (Isyiagi et al., 2009).

Plankton (zooplankton and phytoplankton) are free-floating microorganisms which make a very important component of food web structure of aquatic ecosystem and constitute a wide variety of groups of organisms (D'Alelio et al., 2016). The plankton have a great significance in a water body (Thakur et al., 2013; Chattopadhyay, 2014). The supply of manure used for production of organic matter is vital for planktonic production (Sevilleja et al., 2001). Multiple factors such as available nutrients, dissolved oxygen, temperature, pH, and light have a great impact on the development and growth of plankton in any water body (Dhar et al., 2012). The size of plankton determines the structure of the aquatic community and also affects dynamics of a food web (Maranon, 2015). Distribution of planktonic biomass among all life forms depends upon the relationship of planktonic size and abundance (Sprules et al., 2016). Plankton are key indicators for physicochemical parameters (Cadotte et al., 2011; Jiang et al., 2014; Stevenson, 2014; Liu and Stevenson, 2017). Plankton abundance and water quality depend on pond management (Abdel-Wahed et al., 2018).

Phytoplankton are believed to be primary producers of aquatic ecosystem (Anetekhai et al., 2018; Cunha et al., 2019), they are very important in fisheries and aquaculture sector as primary and basic producers (Yisa, 2006; Bwala et al., 2009). All kinds of life in aquatic ecosystem depends upon phytoplankton because they make the base of all food chains of water bodies (Verlencar and Desai, 2004). Phytoplankton synthesize organic matter by photosynthesis and provide oxygen for all organisms of a whole water body (Lv et al., 2011). Phytoplankton occupy the most basic trophic level of food of the water body, while zooplankton are at second being primary consumers of phytoplankton (Malik et al., 2013). Plant-like autotrophs and microalgae are main classes of phytoplankton that are influenced by environmental conditions (George et al., 2012). They have a short time of generation and show quick responses against changes in their environment (Siddika et al., 2012; Manickam et al., 2020). For example, the diversity and abundance of phytoplankton depend upon the concentrations of nitrogen and phosphorus in water and soil of a pond (Saeiam et al., 2020).

Zooplankton also have great importance as being primary consumers since they make the second trophic level of a food web of water body (Rahman and Hassain, 2008). Zooplankton make primary level of consumers as being herbivore and have a central position in the food web of any aquatic ecosystem (Deng et al., 2020). Fish grazing, high nutrient load, high temperature, cyanobacterial biomass (Li et al., 2017) and their interactions have a great impact on zooplankton body size (He et al., 2018). Selective fish feeding influences zooplankton body size (Lemmens et al., 2018). Zooplankton make the system dynamic and sensitive to environmental changes. Relationship between plankton and water quality parameters has a great significance which is very important for fish culture (Islam et al., 2008). Zooplankton interconnect fishes and phytoplankton in a food chain of a pond aquatic ecosystem. These are considered very important organisms of a fishpond which indicate health of the pond environment. Zooplankton occupy a wide range of habitats as they transfer energy from phytoplankton to higher trophic level (Litchman et al., 2013; Mitrovic et al., 2014). Interactions and combinations among biological, chemical, and physical factors influence variation, distribution, and community structure of plankton in a fishpond (Sabo et al., 2008; Cisneros et al., 2011; Lancelot and Muylaert, 2011) such as rainfall, water discharge, light, temperature (Bussi et al., 2016; De-Sousa et al., 2016), organic matter, nutrient enrichment, and grazing (Mariania et al., 2013; Lucas et al., 2016), etc. While multiple economic and ecological problems have occurred due to dominance and abundance of cyanobacteria, resulting due to high nutrient level, and warming of surface water (Paerl et al., 2014).

The chronological variability of patterns observed in aquatic communities including phytoplankton and zooplankton is a great source of information to ascertain as to which has a dominant effect (Huber and Gaedke, 2006). Zooplankton and phytoplankton comprise high protein level about 40-60% based on dry weight and thus are a great source of increased fish production of a pond as a feed source (De Silva and Anderson, 1995; Pillay, 1995; Wu, 2000). Planktonic algae are consumed as a food source by fish as well as by zooplankton, which in turn also becomes a potential feed for fish (Javed et al., 1990; Hassan and Javed, 1999).

Chowdhury and Mamun (2006) observed positive correlation between phytoplankton population and each of other factors such as zooplankton population (r= 0.944), DO (r= 0.951), transparency (r= 0.962) and phosphate contents (r= 0.967), while significantly negative correlations with each of the factors such as calcium hardness (r= -0.976), BOD (r= -0.949) and chlorides (r= -0.9920). In the same study, the authors reported that zooplankton have a significant positive correlation with DO (r=0.935) and transparency (r=0.983), but a significant and negative correlation with BOD (r= -0.948).

According to annual mean percentage of planktonic biomass in the water column of a pond, phytoplankton normally constitute 80% of the total planktonic biomass, while zooplankton only 15%. The bacterioplankton and ciliate represent less than 7% of the planktonic biomass. Lineal metazooplankton-phytoplankton chain has the highest carbon content irrespective of rotifers having C contents, while microbial loop components have lower carbon content. However, the microbial loop components contribute relatively higher carbon content in the winter mixing period (Rojo et al., 2007). In a study by Hayat and Javed (2008), a regression analysis showed 77.37% variations in productivity of plankton due to temperature, dissolved oxygen, total hardness, and total alkalinity, however, a negative but significant (P < 0.01) regression coefficient was resulted by the regression analysis of total hardness of the of pond water. So, it is essential to observe changes in a pond environment and also variation in population of food organisms of the pond at the time when the pond is fertilized with inorganic or organic fertilizers.

Thus, in the present research, it was felt important to observe environmental changes in relation to the food organisms present in the water body when the pond ecosystem was fertilized with organic or inorganic fertilizers.

Material and Methods

Experimental site

The present experimental study was conducted in three earthen ponds in two replicates having uniform dimensions (8 x 25 x 1.5 m, width x length x depth) at the Fisheries Research Farms and Laboratory, University of Agriculture, Faisalabad. These three selected ponds were designated as control, T_1 and T_2.

Preparation of ponds

The three selected earthen ponds were disinfected and filled with turbine water. The pH of these ponds was stabilized by the liming process with CaO (Hora and Pillay, 1962). Each pond was watered up to a level of 1.5 meter after one week of these steps. This water level was maintained throughout the whole experimental period.

Application of fertilizers

For fertilization. cow dung was applied at the rate of 0.10 g N/100 g of wet fish body weight daily as fertilizer in all the ponds.

Water quality parameters

The DO and water temperature were measured on fortnight basis with a Microprocessor DO (Dissolved Oxygen) meter (HANNA-HI 9143) after fixing the temperature factor at "°C" while light penetration into the pond water was measured with the help of "Secchi disc" at the spot of the pond and the water samples for analysis of the following water quality parameters of physicochemical properties e.g. pH, temperature, dissolved oxygen, total alkalinity, total dissolved solids, total hardness, magnesium, calcium, light penetration, carbonates, total solids, bicarbonates and planktonic biomass were taken to the laboratory. The pH was measured by the Microcomputer pH meter (HANNA-HI 98107) and total alkalinity, calcium, magnesium, total hardness, carbonates, and bicarbonates were calculated after analyzing the samples by the titration method as recommended by A.P.H.A. (APHA, 1971). Total dissolved

Table 1. Correlation coefficients among various physicochemical parameters in control pond

	PB	WT	LP	DO	TA	CO_3	HCO_3	TH	Ca	Mg	pH	TS
WT	0.1170 P= 0.359											
LP	-0.9484 P= 0.000	-0.0673 P= 0.418										
DO	-0.1164 P= 0.359	-0.9193 P= 0.000	0.0261 P= 0.468									
TA	0.3252 P= 0.151	-0.1122 p= 0.364	-0.2600 p= 0.207	0.0124 P= 0.485								
CO_3	0.1080 P= 0.369	-0.2565 p= 0.210	-0.1580 p= 0.312	0.2253 P= 0.241	0.5766 P= 0.025							
HCO_3	0.3218 P= 0.154	0.0437 P= 0.446	-0.2067 p= 0.260	-0.1439 p= 0.328	0.8170 P= 0.001	0.000 P= 0.500						
TH	0.5292 P= 0.038	-0.0321 p= 0.461	-0.5539 p= 0.031	0.0116 P= 0.486	0.6525 P= 0.011	0.5025 P= 0.048	0.4440 P= 0.074					
Ca	0.0933 P= 0.387	0.966 P= 0.383	-0.0804 p= 0.402	-0.1670 p= 0.302	0.3947 P= 0.102	0.3297 P= 0.148	0.2504 P= 0.216	0.7437 P= 0.003				
Mg	0.6513 P= 0.011	-0.1727 p= 0.296	-0.7042 p= 0.005	0.2345 P= 0.232	0.4388 P= 0.077	0.3044 P= 0.168	0.3222 P= 0.154	0.4916 P= 0.052	-0.2164 p= 0.250			
pH	-0.2811 P= 0.188	-0.4269 p= 0.083	0.1708 P= 0.298	0.4121 P= 0.092	-0.2498 p= 0.217	0.3593 P= 0.126	-0.5594 p= 0.029	0.2063 P= 0.260	0.2636 P= 0.204	-0.0420 P= 0.448		
TS	0.8379 P= 0.000	-0.3153 p= 0.159	-0.8073 p= 0.001	0.2026 P= 0.264	0.1733 P= 0.295	0.0817 P= 0.400	0.1545 P= 0.316	0.3720 P= 0.117	0.0329 P= 0.460	0.5005 P= 0.049	-0.0903 p= 0.390	
TDS	0.0486 p= 0.440	-0.7405 p= 0.003	-0.0875 p= 0.393	0.5338 p= 0.037	-0.1789 p= 0.289	-0.0141 p= 0.483	-0.2090 p= 0.257	-0.0908 p= 0.389	-0.0757 p= 0.408	-0.034 p= 0.458	0.2761 P= 0.192	0.5833 p=.023

p= values of probability and other values in each cell are of "*r*". p>0.05 NS, p<0.05*, p<0.01** (NS= Non-significant, *= Significant at 0.05 probability level, **= Significant at 0.01 probability levels)

WT=Water Temperature; LP=Light penetration; DO=Dissolved Oxygen; TA=Total Alkalinity;CO_3 =Carbonates; HCO_3=Bicarbonates; TH=Total Hardness; TS=Total Solids; TDS=Total Dissolved Solids; PB=Planktonic Biomass

Table 2. Correlation coefficients among various physicochemical parameters in T1

	PB	WT	LP	DO	TA	CO_3	HCO_3	TH	Ca	Mg	pH	TS
WT	0.366 p= 0.121											
LP	-0.8446 p= 0.000	-0.2351 p= 0.231										
DO	-0.2338 p= 0.232	-0.7493 p= 0.003	-0.1072 p= 0.373									
TA	-0.1873 p= 0.280	0.2133 p= 0.253	0.1047 p= 0.373	-0.2424 p= 0.224								
CO_3	-0.1285 p= 0.345	0.0573 p= 0.430	-0.0336 p= 0.459	0.0799 p= 0.403	0.5750 p= 0.025							
HCO_3	-0.1253 p= 0.349	0.2137 p= 0.252	0.1542 p= 0.316	-.03585 p= 0.126	0.7575 p= 0.002	-0.0986 p= 0.380						
TH	-0.2557 p= 0.211	-0.6897 p= 0.007	0.2904 p= 0.180	0.2156 p= 0.250	-0.0095 p= 0.488	-0.0750 p= 0.408	0.0483 p= 0.441					
Ca	-0.1669 p= 0.302	-0.6063 p= 0.018	0.1983 p= 0.268	0.3188 p= 0.156	-0.3696 p= 0.118	-0.3276 p= 0.149	-0.1882 p= 0.279	0.7693 p= 0.002				
Mg	-0.2178 p= 0.248	-0.4194 p= 0.087	0.2379 p= 0.288	-0.0080 p= 0.490	0.3829 p= 0.110	0.2359 p= 0.230	0.2775 p= 0.191	0.7262 p= 0.004	0.1194 p= 0.356			
pH	-0.1937 p= 0.273	-0.6637 p= 0.009	0.0979 p= 0.381	0.3587 p= 0.126	-0.2910 p= 0.179	-0.1579 p= 0.312	-0.2279 p= 0.238	0.4408 p= 0.076	0.5741 p= 0.025	0.0672 p= 0.418		
TS	0.9595 p= 0.000	0.1671 p= 0.302	-0.8687 p= 0.000	-0.0683 p= 0.416	-0.2896 p= 0.181	-0.1673 p= 0.302	-0.2187 p= 0.247	-0.1671 p= 0.302	-0.0767 p= 0.406	-0.1772 p= 0.291	-0.0239 p= 0.471	
TDS	0.1842 p= 0.283	-0.4622 p= 0.065	-0.2922 p= 0.178	0.3389 p= 0.141	-0.3208 p= 0.155	-0.1554 p= 0.315	-0.2662 p= 0.202	0.0779 p= 0.405	0.0169 p= 0.479	0.1030 p= 0.375	0.4677 p= 0.063	0.4373 p= 0.078

P= values of probability and other values in each cell are of "*r*". $p>0.05$ NS, $p<0.05$*, $p<0.01$** (NS= Non-significant, *= Significant at 0.05 probability level, **= Significant at 0.01 probability levels

WT=Water Temperature; LP=Light penetration; DO=Dissolved Oxygen; TA=Total Alkalinity; CO_3 =Carbonates; HCO_3 =Bicarbonates; TH=Total Hardness; TS=Total Solids; TDS=Total Dissolved Solids; PB=Planktonic Biomass

Table 3. Correlation coefficients among various physicochemical parameters in T2

	PB	WT	LP	DO	TA	CO_3	HCO_3	TH	Ca	Mg	pH	TS
WT	0.1579 p= 0.312											
LP	-0.9007 p= 0.000	-0.0110 p= 0.487										
DO	0.1839 p= 0.284	-0.7315 p= 0.003	-0.3928 p= 0.103									
TA	0.1169 p= 0.359	-0.1269 p= 0.347	0.0296 p= 0.464	-0.3928 p= 0.103								
CO_3	0.1931 p= 0.274	-0.3176 p= 0.157	-0.2147 p= 0.251	0.1360 p= 0.337	0.5605 p= 0.029							
HCO_3	0.0495 p= 0.439	-0.0041 p= 0.495	01337 p= 0.339	-0.5269 p= 0.039	0.9248 p= 0.000	0.2032 p= 0.263						
TH	0.4096 p= 0.093	-0.1350 p= 0.338	-0.2277 p= 0.238	-0.0128 p= 0.484	0.6875 p= 0.007	0.4704 p= 0.061	0.5967 p= 0.020					
Ca	0.2669 p= 0.201	-0.0691 p= 0.416	-0.1209 p= 0.354	-0.2951 p= 0.176	0.8523 p= 0.000	0.6102 p= 0.018	0.7273 p= 0.004	0.7932 p= 0.001				
Mg	0.3686 p= 0.119	-0.2376 p= 0.219	-0.2900 p= 0.180	0.5117 p= 0.045	-0.0015 p= 0.498	0.0565 p= 0.431	-0.0277 p= 0.466	0.6341 p= 0.013	0.1010 p= 0.377			
pH	0.1373 p= 0.335	-0.6088 p= 0.018	-0.0936 p= 0.386	0.4170 p= 0.089	0.0739 p= 0.410	0.1426 p= 0.329	0.0218 p= 0.473	0.0045 p= 0.494	-0.1021 p= 0.376	0.0675 p= 0.417		
TS	0.8339 p= 0.000	-0.1979 p= 0.269	-0.7897 p= 0.001	0.4802 p= 0.057	-0.0190 p= 0.477	0.2518 p= 0.215	-0.1382 p= 0.334	0.2441 p= 0.222	0.1621 p= 0.307	0.3426 p= 0.138	0.2219 p= 0.244	
TDS	-0.1723 p= 0.296	-0.6153 p= 0.017	0.0862 p= 0.395	0.5515 p= 0.032	-0.2281 p= 0.238	0.1289 p= 0.345	-0.3289 p= 0.148	-0.2444 p= 0.222	-0.1537 p= 0.317	-0.0005 p= 0.499	0.1681 p= 0.301	0.4000 p= 0.099

P= values of probability and other values in each cell are of "*r*". p>0.05 NS, p<0.05*, p<0.01** (NS= Non-significant, *= Significant at 0.05 probability level, **= Significant at 0.01 probability levels)

WT=Water Temperature; LP=Light penetration; DO=Dissolved Oxygen; TA=Total Alkalinity; CO_3 =Carbonates; HCO_3 =Bicarbonates; TH=Total Hardness; TS=Total Solids; TDS=Total Dissolved Solids; PB=Planktonic Biomass solids were estimated by a TDS meter and the evaporation method was applied for the measurement of total solids, and planktonic biomass in water was calculated by the Wet Labs WETStar fluorometer (HANNA-HI 98302).

Statistical analysis

At the end of the experiment, data obtained for the physico-chemical parameters of water quality was subjected to correlation analysis using the Minitab statistical software version 9.1.1.

Results and discussion

The data obtained during and at the end of the present experiment was subjected to an appropriate statistical analysis to find out correlation coefficients among planktonic biomass and different physicochemical parameters of selected three ponds. The correlation matrix of various physiochemical parameters of the three ponds showed different patterns of correlation due to presence of planktonic biomass in respective ponds (**Tables 1-3**).

The correlation between light penetration and planktonic biomass was found to be significantly negative in control, T_1 and T_2 ponds. The correlation between water temperature and planktonic biomass resulted in a non-significant relation in control, T_1 and T_2 ponds. The correlation between the dissolved oxygen and planktonic biomass showed positive, but non-significant values in the control and T_1 ponds, while it was positively significant in the T_2 pond. The correlation between total alkalinity and planktonic biomass was noted to be positively non-significant in the control and T_2 ponds, while the reverse was true in the T_1 pond. The correlation between carbonates and planktonic biomass was found to be positively non-significant in the control and T_2 ponds, whereas negatively non-significant in the T_1 pond. The correlation between bicarbonates and planktonic biomass was positively non-significant in the control and T_2 ponds, while negatively non-significant in the T_1 pond. The correlation between total hardness or calcium and planktonic biomass was positively non-significant in the control and T_2 ponds, while it was negatively non-significant in the T_1 pond. However, the correlation between magnesium or pH and planktonic biomass was positively significant in the control pond, negatively non-significant in the T_1 pond, and positively non-significant in the T_2 pond. The correlation between total solids and planktonic biomass was found to be positively highly significant in all ponds (control, T_1 and T_2). The correlation between total dissolved solids and planktonic biomass was found to be positively non-significant in the control and T_1 ponds, while it was negatively non-significant in the T_2 pond.

These findings are like those of Chowdhury and Mamun (2006), who also reported positive and negative correlations, while working with planktonic population and physicochemical parameters of two fishponds at Khulna, Bangladesh. Similar results were also reported elsewhere (Mumtazuddin et al., 1982; Chowdhury and Zaman, 2000; Bhatnagar and Devi 2013; Abdel-Wahed et al., 2018) during their work on limnological parameters of different rivers in Bangladesh.

Conclusion

It is highly likely that the climatic conditions of different regions may considerably influence the physico-chemical properties of pond waters and thus may in turn influence the fish productivity. The current scenario of considerable change in global climate may aggravate the effects of the limiting factors on fish culturing in ponds. Thus, to achieve maximal fish productivity in pond culture it is apt to appraise the suitability of various physico-chemical factors involved in fish culturing.

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