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PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 3 (12): 2171-2175, 2000

Relationships Between Biotic and Abiotic Components of Broiler Droppings Fertilized Pond Ecosystems

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Abstract: The limnological environment of the ponds was conducive for fish rearing under all the treatments except for 0.22 g N level and the control. Increasing the nitrogen level beyond 0.16 g N showed a significant rise in the potassium contents of water and hence zooplankton productivity was affected negatively under both 0.19 and 0.22 g N levels. The response of treatments towards the release of nutrients like nitrates and phosphates promoted both the phyto- and zooplankton productivities and hence exerted positively significant regression of phosphates in 0.10 g N level. Among the water quality variables, water temperature appears to be the most critical parameter influencing the productivities of both phyto- and zooplankton significantly.

Key words: Broiler droppings, major carps, phytoplankton, productivity, regression, zooplankton

Introduction

The growth of phytoplankton and aquatic macrophytes is the most critical aspect of fish reproduction in pond culture. The phytoplankton growth and its ecological factors in fish ponds have concerned fish farmers the world over. Many Chinese carp farmers judge the water quality of fish ponds by their colour - the degree of greenness reflects the abundance of phytoplankton (Lin, 1970). Plankton algae are food for fish as well as for zooplankton which, in turn, is food for major carps also (Jhingran, 1982). Unfortunately such an expertise seldom provides precise information on species combination and related water quality parameters influencing the fish growth under semi-intensive polyculture system in which excretory products are recycled. Chemical characteristics of ponds in relation to physical and biological properties are not well-documented in the literature. On the other hand, considerable information is available on toxic effects of heavy metals on fish and plankton (Cairns *et al.*, 1975; Katz, 1977; Javed and Hayat, 1995, 1996, 1998), including behavioural responses to pollutant (Larrick *et al.*, 1978; Morgan, 1979). Usually, these experiments have been under closely controlled conditions in laboratories and a few have been performed in actual ponds. Nazneen (1980) studied the influence of hydrological factors on the seasonal abundance of phytoplankton in the "Kinjhar" lake, Pakistan. The temporal distributions of phytoplankton were generally related to the variations of light and temperature. The effects of light and temperature were modified by the nutrients, particularly when nitrogen and phosphates were present in surprisingly low concentrations.

Materials and Methods

Factorial experiment, with two replications for each of the treatments, was conducted under ambient condition using earthen ponds. After preliminary preparations (Javed, 1988), all the ponds were initially fertilized, separately, with 40 kg broiler droppings (3333.33 kg ha^{-1}) as a starter dose to stimulate primary productivity. Fingerling major carps, 6-7 months old (induced bred, procured from Fish Seeds Hatchery, Faisalabad), average weight 21.32 ±1.99 g, were randomly stocked, from a selected population, in each of the ponds with stocking density of 25, 60 and 15% for *Catla catla*, *Labeo rohita* and *Cirrhina mrigala* respectively (64 fish in each of the ponds). Fertilization of ponds with broiler droppings (4.37% nitrogen) was started on the basis of nitrogen contents. Five levels, viz. 0.10, 0.13, 0.16, 0.19 and 0.22g nitrogen per 100 g of wet fish weight daily, were used as nitrogen treatments. However, sixth treatment served as control (without additives).

For the quantitative and qualitative study of plankton, from each of the five sub-stations at each pond, two samples were collected both from the surface and bottom. The method of microscopic examination as described in A.P.H.A. (1975) was employed following the sand filtration procedure for the enumeration of phytoplankton (Boyd, 1981). Zooplankton, were studied by taking 10 litres of each pond water from surface, column and bottom at each sub-station. These were pooled and filtered through a plankton net fitted with a glass bottle of 400 ml capacity (mesh size 56μ). The retenate containing different animals was preserved in Longyl acid and stored in refrigerator. A 5 ml portion of the above sample was taken for the quantitative study of zooplankton. Regression models were computed by using step-wise regression procedure (Steel and Torrie, 1986) for the regression of phytoplankton and zooplankton productivities (separately) on the physico-chemical variables to see the relationships / trends of planktonic productivity with water chemistry under different treatments.

Results

Regression of Phytoplankton Productivity of Fish Ponds on the Physico-chemical Variables:

0.10 g Level of Nitrogen: Phytoplankton productivity showed negatively significant regression on water temperature, light penetration, pH, total hardness, sodium and potassium while the same was negatively non-significant on nitrates. Electrical conductivity and phosphates were the two water quality variables which had positive and significant regression on phytoplankton productivity of ponds under this treatment. The high value of R^2 (0.9999) depicts high reliability of this regression model (Table 1).

0.13 g Level of Nitrogen: Nine physico-chemical variables, viz. water temperature, light penetration, pH, electrical conductivity, total hardness, sodium, potassium,

Table 1 : Regression of phytoplankton productivities of fish ponds on the physico-chemical variables, Dependent variable: Phytoplankton (Nos. per 2 ml of water)

Independent Variable	Regression Coefficient	Standard Partial Regression Coefficient	Standard Error of Partial Coefficient	Student T-value	Probability
0.10 g Nitrogen Level					
Water Temperature (°C)	-26.032	-0.839	0.121	-6.937	P<0.01
Light Penetration (cm)	-85.224	-1.639	0.194	-8.432	P<0.01
PH	-193.970	-0.279	0.035	-7.906	P<0.01
Electrical Conductivity (m. mhos/cm)	813.020	0.304	0.037	8.267	P<0.01
Total Hardness (mg^{-1})	-5.465	-0.455	0.057	-7.913	P<0.01
Sodium (mg^{-1})	-4.577	-0.745	0.072	-10.370	P<0.01
Potassium (mg^{-1})	-219.140	-1.563	0.174	-8.959	P<0.01
Phosphates (mg^{-1})	12310.000	0.514	0.035	14.810	P<0.01
Nitrates (mg^{-1})	-3.058	-0.049	0.092	-0.530	N.S
	Intercept =9007.18, R^2 = 0.9999, SE of estimate= 9.158				
0.13 g Nitrogen Level					
Water Temperature (°C)	-3.212	-0.109	2.215	-0.049	N.S
Light Penetration (cm)	-0.280	-0.006	2.378	-0.003	N.S
pH	-0.019	-0.339	0.052	-0.649	N.S
Electrical Conductivity (m. mhos/cm)	-0.019	-0.127	0.772	-0.165	N.S
Total Hardness (mg^{-1})	8.891	0.031	0.384	0.812	N.S
Sodium (mg^{-1})	-0.226	-0.044	1.407	-0.031	N.S
Potassium (mg^{-1})	-0.242	-0.171	1.089	-0.157	N.S
Phosphates (mg^{-1})	24989.000	1.408	1.365	1.032	N.S
Nitrates (mg^{-1})	-1.707	-0.032	1.165	-0.027	N.S
	Intercept =1094.14, R^2 =0.8840, SE of estimate=199.916				
0.16 g Nitrogen Level					
Water Temperature (°C)	0.623	1.773	0.999	1.773	N.S
Light Penetration (cm)	0.493	0.919	1.337	0.688	N.S
pH	-0.020	-0.220	0.028	-0.962	N.S
Electrical Conductivity (m. mhos/cm)	-0.057	-0.319	0.083	-0.386	N.S
Total Hardness (mg^{-1})	0.389	0.712	0.041	1.723	N.S
Sodium (mg^{-1})	-1.329	-0.261	0.041	-0.631	N.S
Potassium (mg^{-1})	122.320	1.464	1.041	1.407	N.S
Phosphates (mg^{-1})	10808.000	0.651	0.081	1.708	N.S
Nitrates (mg^{-1})	12.438	0.245	0.299	0.819	N.S
	Intercept = -7168.855, R^2 =0.9870, SE of estimate= 82.83				
0.19 g Nitrogen Level					
Water Temperature (°C)	-1.179	-0.032	0.772	-0.041	N.S
Light Penetration (cm)	-0.121	-0.710	1.702	-0.100	N.S
pH	0.080	0.664	0.517	1.285	N.S
Electrical Conductivity (m. mhos/cm)	1009.200	0.540	0.471	1.150	N.S
Total Hardness (mg^{-1})	-8.395	-0.550	0.414	-1.328	N.S
Sodium (mg^{-1})	2.055	0.489	0.521	0.938	N.S
Potassium (mg^{-1})	-0.684	-1.444	1.906	-0.758	N.S
Phosphates (mg^{-1})	24000.00	0.642	0.558	1.151	N.S
Nitrates (mg^{-1})	0.903	1.087	1.047	1.038	N.S
	Intercept = 5862.55, R^2 = 0.9490, SE of estimate= 176.551				
0.22 g Nitrogen Level					
Water Temperature (°C)	27.726	0.795	0.077	10.318	P<0.01
Light Penetration (cm)	-48.640	-0.725	0.106	-6.835	P<0.01
pH	-175.880	-0.161	0.040	-4.025	P<0.01
Electrical Conductivity (m. mhos/cm)	-1405.800	-0.768	0.132	-5.799	P<0.01
Total Hardness (mg^{-1})	3.945	0.297	0.047	6.351	P<0.01
Sodium (mg^{-1})	0.776	0.191	0.086	2.233	P<0.01
Potassium (mg^{-1})	0.140	0.367	0.112	3.261	P<0.01
Phosphates (mg^{-1})	10402.000	0.316	0.058	5.436	P<0.01
Nitrates (mg^{-1})	-17.047	-.273	0.077	-3.516	P<0.01
		Intercept =3610.69, R^2 = 0.9999, SE of estimate=25.147			
Control					
Water Temperature (°C)	0.023	0.027	2.020	0.013	N.S
Light Penetration (cm)	-0.470	-0.139	0.615	-0.227	N.S
pH	-7.691	-0.126	0.787	-0.160	N.S
Electrical Conductivity (m. mhos/cm)	-79.034	-0.396	1.032	-0.383	N.S
Total Hardness (mg^{-1})	0.261	0.162	0.774	0.209	N.S
Sodium (mg^{-1})	0.336	0.915	2.257	0.405	N.S
Potassium (mg^{-1})	4.974	0.471	0.858	0.549	N.S
Phosphates (mg^{-1})	-9740.500	-0.548	0.884	-0.620	N.S
Nitrates (mg^{-1})	1.784	0.171	0.752	0.228	N.S
		Intercept =-22.987, R^2 = 0.6870, SE of estimate=9.241			

Nos. Numbers, NS= Non-significant, R^2= Coefficient of determination, SE= Standard error.

phosphates and nitrates were selected for the regression of phytoplankton productivity of pond water on these variables. All the variables except total hardness and phosphates showed negative regression on phytoplankton productivity. However, all the partial regression coefficients for the selected variables were non-significant. The R^2 value for this regression model was computed as 0.8840 (Table 1).

16 g Level of Nitrogen: Phytoplankton productivity of ponds under this treatment was positively affected by water temperature, light penetration, total hardness,

Table 2: Regression of zooplankton productivities of fish ponds on the physico-chemical variables, Dependent variable : Zooplankton (Nos. per 5 ml of water

Independent Variable	Regression Coefficient	Standard Partial Regression Coefficient	Standard Error of Partial Coefficient	Student T-value	Probability
0.10 g Nitrogen Level					
Water Temperature (°C)	-0.416	-0.149	1.163	-0.128	N.S
Light Penetration (cm)	-8.623	-1.842	1.390	-1.325	N.S
pH	-36.561	-0.584	0.441	-1.324	N.S
Electrical Conductivity (m. mhos/cm)	183.820	0.763	0.489	1.561	N.S
Dissolved Oxygen (mg^{-1})	-7.620	-0.472	0.312	-1.514	N.S
Total Hardness (mg^{-1})	0.206	0.191	0.458	0.417	N.S
Potassium (mg^{-1})	-25.643	-2.030	1.674	-1.213	N.S
Ammonia (mg^{-1})	-819.230	-0.111	0.268	-0.414	N.S
Intercept = 714.33, R^2 = 0.9330, SE of estimate = 11.389					
0.13 g Nitrogen Level					
Water Temperature (°C)	0.200	0.050	0.405	0.124	N.S
Light Penetration (cm)	-1.613	-0.278	0.465	-0.567	N.S
pH	2.675	0.036	0.137	0.261	N.S
Electrical Conductivity (m. mhos/cm)	164.380	0.833	0.553	1.506	N.S
Dissolved Oxygen (mg^{-1})	21.036	0.981	0.361	2.722	$P<0.05$
Total Hardness (mg^{-1})	1.181	0.307	0.159	1.931	N.S
Potassium (mg^{-1})	-24.946	-1.303	0.394	-3.306	$P<0.01$
Ammonia (mg^{-1})	-4426.000	-0.483	0.153	-3.159	$P<0.01$
Intercept = -58.04, R^2 = 0.9790, SE of estimate = 9.434					
0.16 g Nitrogen Level					
Water Temperature (°C)	3.211	0.593	1.058	0.560	N.S
Light Penetration (cm)	-2.371	-0.287	1.284	-0.223	N.S
pH	-10.626	-0.074	0.273	-0.271	N.S
Electrical Conductivity (m. mhos/cm)	194.830	0.703	1.827	0.385	N.S
Dissolved Oxygen (mg^{-1})	-1.929	-0.054	0.237	-0.228	N.S
Total Hardness (mg^{-1})	1.263	0.150	1.208	0.124	N.S
Potassium (mg^{-1})	-8.436	-0.655	1.583	-0.414	N.S
Ammonia (mg^{-1})	444.220	0.055	0.415	0.133	N.S
Intercept = -257.68, R^2 = 0.9440, SE of estimate = 21.820					
0.19 g Nitrogen Level					
Water Temperature (°C)	4.109	0.937	0.388	2.412	$P<0.05$
Light Penetration (cm)	-5.676	-0.677	0.659	-1.027	N.S
pH	-47.827	-0.336	0.351	-0.956	N.S
Electrical Conductivity (m. mhos/cm)	-134.430	-0.609	0.402	-1.514	N.S
Dissolved Oxygen (mg^{-1})	3.712	0.124	0.281	0.444	N.S
Total Hardness (mg^{-1})	1.626	0.902	0.399	2.261	$P<0.05$
Potassium (mg^{-1})	-4.179	-0.747	0.341	-2.166	$P<0.05$
Ammonia (mg^{-1})	-4575.700	-0.970	0.717	-1.352	N.S
Intercept = 364.16, R^2 = 0.9510, SE of estimate = 16.783					
0.22 g Nitrogen Level					
Water Temperature (°C)	5.257	1.365	0.573	2.381	$P<0.05$
Light Penetration (cm)	-5.885	-0.795	0.474	-1.677	N.S
pH	36.265	0.301	0.237	1.272	N.S
Electrical Conductivity (m. mhos/cm)	-124.830	-0.618	0.752	-0.821	N.S
Dissolved Oxygen (mg^{-1})	-9.067	-0.428	0.244	-1.753	N.S
Total Hardness (mg^{-1})	-0.458	-0.313	0.245	-1.278	N.S
Potassium (mg^{-1})	0.026	-1.006	0.486	2.009	$P<0.05$
Ammonia (mg^{-1})	-3570.500	-0.804	0.584	-1.376	N.S
Intercept = 162.30, R^2 = 0.9340, SE of estimate = 17.356					
Control					
Water Temperature (°C)	0.556	0.793	0.238	3.330	$P<0.01$
Light Penetration (cm)	0.826	0.300	0.341	0.882	N.S
pH	-9.924	-0.200	0.271	-0.738	N.S
Electrical Conductivity (m. mhos/cm)	-18.853	-0.116	0.324	-0.358	N.S
Dissolved Oxygen (mg^{-1})	-1.078	-0.229	0.401	-0.571	N.S
Total Hardness (mg^{-1})	0.059	0.045	0.318	0.143	N.S
Potassium (mg^{-1})	2.146	0.249	0.340	0.734	N.S
Ammonia (mg^{-1})	-865.000	-0.130	0.192	-0.679	N.S
Intercept = 55.52, R^2 = 0.9270, SE of estimate = 2.972					

Nos. Numbers, NS = Non-significant, R^2 = Coefficient of determination, SE = Standard error.

potassium, phosphates and nitrates. However, the same had negative regression on pH, electrical conductivity and sodium. All the partial regression coefficients for this regression model were non-significant with the R^2 value of 0.9870 (Table 1).

0.19 g Level of Nitrogen : Regression of phytoplankton on electrical conductivity, sodium, phosphates and nitrates were positive while for water temperature, light penetration, total hardness and potassium were negative. However, partial regression coefficients for all the variables in the regression model were non-significant and the R^2 value for this regression model was 0.9490 (Table 1).

0.22 g Level of Nitrogen : Phytoplankton productivity was influenced positively and significantly by water temperature, total hardness, sodium, potassium and phosphates. However, the other variables, viz. light penetration, pH, electrical conductivity and nitrates had negatively significant partial regression coefficients. The R^2

value for this regression model was computed to be 0.9999 (Table 1).

Control Treatment: In control ponds the phytoplankton productivity had positive regression on all the selected physico-chemical variables except light penetration, pH, electrical conductivity and phosphates. However, all the regression coefficients were statistically non-significant. The R^2 value for this regression model was computed as 0.6870 (Table 1).

Regression of Zooplankton Productivity of Fish Ponds on Physico-chemical Variables: Table 2 shows the regression of zooplankton productivity of pond water on the selected physico-chemical variables, viz. water temperature, light penetration, pH, electrical conductivity, dissolved oxygen, total hardness, potassium and ammonia under all the six treatments.

0.10 g Level of Nitrogen: The partial regression coefficients for all the variables were negative except for electrical conductivity and total hardness. However, all the partial regression coefficients were statistically non-significant. The R^2 value for this regression model was computed as 0.9330 (Table 2).

0.13 g Level of Nitrogen: Under the influence of this treatment, zooplankton productivity showed positively significant regression on dissolved oxygen while negatively significant ($P<0.01$) regression on potassium and ammonia. The partial regression coefficients for the other variables were statistically non-significant. The coefficient of determination value for this regression model was computed as 0.9790 which depicts high reliability of this regression model (Table 2).

0.16 g Level of Nitrogen: All the independent variables selected for this regression model showed non-significant regression on zooplankton productivity. The partial regression coefficients for water temperature, electrical conductivity, total hardness and ammonia were positive while for light penetration, pH, dissolved oxygen and potassium were negative. The R^2 value for this regression model was computed to be 0.9440 (Table 2).

0.19 g Level of Nitrogen: Under this treatment the zooplankton productivity showed positively significant ($P < 0.05$) regression on water temperature and total hardness but negatively significant on potassium while the partial regression coefficients for the remaining variables were statistically non-significant. However, zooplankton showed negative but non-significant regression on light penetration, pH, electrical conductivity and ammonia nitrogen. The R^2 value for this regression model was 0.9510 (Table 2).

0.22 g Level of Nitrogen: In this treatment zooplankton showed positive and significant regression on a single water quality variable, i.e. water temperature. The partial regression coefficients for light penetration, electrical conductivity, dissolved oxygen, total hardness and ammonia were negative but non-significant. The R^2 value for this regression model was computed as 0.9340 (Table 2).

Control Treatment: Multiple regression of zooplankton on water temperature, light penetration, total hardness and potassium was positive but non-significant except on water temperature which had significant regression coefficient. However, the same for pH, electrical conductivity, dissolved oxygen and ammonia-nitrogen were negative and non-significant. The R^2 value for this regression model was 0.9270 (Table 2).

Fish Yield and Survival: Fish yields and survival rates were also recorded under the five nitrogen levels (from broiler droppings) and the control (without additives). Net fish yields (from all the three fish species) were 3035.00, 3314.17, 3617.50, 3596.67, 2458.33 and 515.00 kg ha^{-1} while survival rates of fish were 93.75, 98.44, 98.44, 98.44, 73.44 and 84.37 % under 0.10, 0.13, 0.16, 0.19 and 0.22 g N levels and control respectively.

Discussion

Limnological parameters studied during this experiment were found in optimal range for major carps rearing under all the five fertilization treatments except 0.22 g N level. The percentage survival rates of fish under all the treatments were above 90 % except 0.22 g N level and control which had the survival percentages of 73.44 and 84.37 % respectively. The high survival rates indicated conducive limnological environment for major carps rearing under the existing experimental conditions. Nitrate and phosphate concentrations were significantly higher in 0.16 g N level which promoted the planktonic productivity measured in terms of phytoplankton and zooplankton counts per 5 ml of water. The positively significant partial regression coefficients of phytoplankton productivity on phosphate contents of water under 0.10 and 0.22 g N levels depict the importance of phosphorus in major carps farming system to act as a key metabolic nutrient and supply of this element regulates the productivity of pond ecosystem (Javed *et al.*, 1995). In fact, all the water bodies under study responded to the available varied phosphate concentrations in water with greater phyto- and zooplanktonic productivities. Potassium in water showed negatively significant regression on phytoplankton under 0.10 g N level while positively significant under 0.22 g N level. The regression of zooplankton on potassium was negatively significant under 0.13, 0.19 and 0.22 g N levels. Similar results have been reported by Javed (1988). He reported potassium as a factor responsible for reduction in zooplankton productivities in major carps farming systems. In 0.10 and 0.22 g N levels an important factor contributing towards phytoplankton productivity was the water temperature. However, the partial regression coefficient of water temperature under 0.10 g N level was negatively significant while the same for 0.22 g N level was positive and highly significant. Javed and Hayat (1996) reported variable responses of temperature towards phytoplankton productivity. Under 0.19 g N, 0.22 g N and control, the zooplankton productivities showed positively significant regression on water temperature also. Hammad *et al.* (1995) reported water temperature, pH and light penetration as the key factors influencing planktonic productivities in grass carp rearing ponds. Javed (1988) argued that high pH values during blooming period in fish ponds were the result of phytoplankton productivity.

Sladecek (1958) postulated relationship of grazing effect of zooplankton upon the phytoplankton. According to Hazelwood and Parker (1961) and actively grazing Diaptomus might reduce the standing crops of algae. Such an activity would produce a negative correlation between zoo- and phytoplankton in water. They also observed a significantly negative partial correlation between effective light extinction and the number of zooplankton. During this investigation it has been observed that under 0.10 and 0.22 g N levels light penetration showed significantly negative regression on phytoplankton productivity. These findings substantiated the results reported by Javed *et al.* (1995) who reported that in fish ponds temperature and intensity of light were the most important factors controlling the occurrence and abundance of phytoplankton.

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