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Research article

SOIL AND WATER QUALITIES INFLUENCING PRODUCTIVITY OF FISH PONDS OF DIFFERENT SOIL ZONES OF WEST BENGAL

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ABSTRACT: As potential areas for fish culture are being rapidly used up for various other purposes, high production targets are being fixed for the available water bodies for providing required amount of fish protein to the escalating population. Such high production targets can only be achieved by enhancing the productivity levels of available resources. This can be done by adoption of judicious management practices of various factors which govern productivity of the culture system. One of the most important factors to be taken into account in this respect is the availability of nutrients in the fish pond soil and waters. It is, therefore necessary to maintain the nutrient status of the pond to optimum ranges for obtaining maximum production of fishes from aquatic ecosystem. To reduce the possibility of indiscriminate application of nitrogenous fertilizers in any fish pond, an idea about the status of this nutrient element in the pond soils appears to be necessary. In the present study, therefore, occurrences of different forms of nitrogen in three different kinds of pond soils commonly observed in India viz. alluvial, red and lateritic and hilly, were studied with respect to their relationships with various other soil properties and, especially, the production of primary fish food organisms in water.
Key words: Soil and water qualities, fish ponds productivity

INTRODUCTION

The productivity of a fish pond is determined to a great extent by the nature and properties of the bottom soils which in the words of Hickling [1] is the "Chemical laboratory of a fish pond." Importance of bottom soils in determining the productivity of fish ponds is well documented [9,12, 2]. The significant role of bottom soils in influencing availability of different nutrient elements to primary fish food organisms has been discussed in details by [3]. However, the basic properties of a particular soil group being largely different than the other ones, the fish ponds situated under a particular soil zone are likely to exhibit some specific characters of the soil and water environment which may be reflected in their biological productivity levels also. Considering this fact, [3], while discussing different aspects of aquaculture pond bottom soil management, suggested that the soil deficiencies should be identified and treated while undertaking new fish culture programmes in any fish pond. In this study, an attempt has been made to identify the major soil factors associated with primary production in the fish ponds giving special emphasis to nitrogen in influencing productivity of fish ponds located under three major soil zones of West Bengal, India viz. red and lateritic, hilly and alluvial. It is hoped that the study will help to find out the major productivity limiting soil factors for fish ponds under these three soil zones and, thereby, to develop adequate soil system based productivity management programmes for these ponds.

MATERIALS AND METHODS

Bottom soil samples were collected from upper 15 cm layers of forty-five nos. of fish ponds situated under three different zones of West Bengal viz. red and latertic, hilly and alluvial, taking fifteen nos. of soil samples from each zone. The samples were air dried, ground and sieved to 80 mesh size and used for analyzing pH (1:2), organic carbon [22], easily mineralizable nitrogen, [21], mineralized nitrogen [11] available phosphorus (Bray's extractant no.1), available potassium [11], texture [20], and DTPA extractable micronutrients viz. Fe, Mn, Cu and Zn [14]. The soil samples required for estimation of parameters other than texture and organic carbon were incubated under submerged condition for 10 days using 1:10 soil: water ratio for developing a semi-aerobic condition in the soil simulating to fish pond situation and were then used for the estimations.

Water samples of respective fish ponds were analyzed for pH, total alkalinity, total dissolved solid (TDS), electrical conductivity and water soluble N, P and K. Gross (GPP) and net (NPP) primary productivity values were also estimated using light and dark bottle method [18] and estimating the dissolved oxygen by following the method described by [23]. Statistical analyses of the results were carried out through correlation coefficient studies of different soil and water properties with the dependent variable GPP.

RESULTS AND DISCUSSION

Ranges of different soil properties of the fish ponds under three different soil zones of West Bengal and their average values have been presented in table 1. As observed from the table, pH values of the pond soils of hilly zone appeared to be predominantly acidic ranging between 5.1-6.8 with an average value of 5.8 followed by the soil samples of red and lateritic zone ranging between 5.4-7.5 with an average value of 6.7. On the other hand, the soil samples of alluvial zone were found to be between neutral to alkaline in nature ranging from 6.3-8.4 with an average value of 7.5. Similar trend of pH was observed for pond water of these three zones also. Fish ponds of the hilly zones showed lowest range of pH in water ranging between 6.07-8.29 with an average value of 7.6 while the said range for the fish ponds of red and lateritic and alluvial soil zones were 6.68-8.34 and 7.3-8.11 respectively with corresponding average values of 7.6 and 7.68. The study showed that although there were considerable variations in pH values of the bottom sediments of the fish ponds under three different soil zones, yet the water pH values were comparatively higher for all the fish ponds and the mean values assumed almost similar values. This behaviour may be probably attributed to photosynthetic activities of the primary producers in these ponds which helped to maintain higher pH values in water [6] in all the fish ponds and tended to reduce their variations. Importance of neutral to slightly alkaline pH for bottom soils for good productivity of fish ponds has been emphasized by [2], and many others [6,16]. Organic carbon content of these pond soils varied between 0.03 and 1.2 % with an average value of 0.41% while said range and average values of the pond soils of hilly and alluvial zones were found to vary from 0.3-1.36 % and 0.6-1.45 % with respective mean values of 0.77% and 0.87% respectively. While discussing the nature and properties of fish pond soils, [4] suggested occurrence of less than 1.0% of organic carbon to be indicative of low organic matter content in pond soils. Considering his views, a large section of the studied pond soils of the three soil zones could be considered as low in organic carbon content. Production of fish food organisms contributes largely to accumulation of organic matter in bottom soils of fish ponds [8,2]. In the present study, low ranges of primary productivity levels of the studied fish ponds (table-2) probably tended to restrict accumulation of organic matter in the soils. In addition, long summer spells of the tropical countries also encouraged the oxidation of soil organic matter. This probably restricted formation of organic materials in the pond bottoms. This low occurrence of organic carbon may affect other soil properties like availability of different

Table 1: Properties of bottom soils in fish ponds under three different soil zones of West Bengal

Parameters	Range		
	R & L*	Hilly	Alluvial
pH -(1:2)	5.4-7.5(6.7)	5.1–6.8(5.8)	6.3–8.4(7.5)
Easily Mineralizable N (mg kg^{-1})	78.4 - 224.6(124.59)	55.2 – 375.2(211.87)	66 – 299.5(196.32)
Available P (mg kg^{-1})	4.5 - 31.25(17.27)	15 - 60(28.33)	25 - 80(55.75)
Available K (mg kg^{-1})	74.8 - 280.6(187.89)	105.3 – 289.4(189.44)	211.9 – 418.8(301.09)
EC (dSm^{-1})	0.12 - 1.18(0.46)	0.183 – 1.13(0.42)	0.104 – 1.32(0.66)
Org C (%)	0.03 - 1.2(0.41)	0.3 – 1.36(0.77)	0.6 – 1.45(0.87)
Mineralized N(mg kg^{-1})	47.6 - 184.6(120.37)	36 – 141.6(73.9)	72.66 – 216.4(152.32)
Avl Zn (mg kg^{-1})	0.05 - 0.288(0.13)	0.102 - 0.302(0.18)	0.102 – 0.376(0.22)
Avl Cu (mg kg^{-1})	0.102 – 0.376(0.22)	0.222–0.636(0.37)	0.152–0.936(0.39)
Avl Fe (mg kg^{-1})	44 – 103.6(71.15)	37.5 – 93.6(49.04)	15.2 – 69.4(29.36)
Avl Mn (mg kg^{-1})	8.4 – 28.8(17.45)	5.6 – 29.8(14.36)	15.6 – 59.2(35.7)
Texture			
Sand (%)	69 - 90(80.13)	50 - 68(60.0)	47 – 58(52.13)
Silt (%)	3-21(11.06)	21-36(28.47)	10-21(17.13)
Clay (%)	2-16(8.8)	3-20(11.53)	24-35(30.73)

* **– Red and lateritic zone**

Nutrients; CEC, water retentively etc. which are closely related with organic matter content of the pond soils.

Available N values (easily mineralizable form) of the soils of the three different zones viz. red and lateritic, hilly and alluvial showed ranges of 78.4 - 224.6, 55.2 - 375.2, 66.0 - 299.5 mg N kg^{-1} soil with average value 124.59, 211.87, 196.32 mg N kg^{-1} respectively (table-4.1.1.) Similarly, the water soluble N content of these three zones showed a range of 3.24 – 17.73, 2.13 – 22.8 and 13.75 – 33.69 mg l^{-1} and 23.3 mg l^{-1} respectively (table-2). [1] Opined that the bottom soils with less than 250 mg $kg^{-1}$of available N content might be considered to be low for fish ponds of India. Considering his views, the observed values of available N in all the fish pond soils of red and lateritic zones could be taken to be rather poor. Available N content of good numbers of fish ponds under alluvial and hilly zones could also considered to be inadequate. Mean values of easily mineralizable N in the bottom soils of the fish ponds under all these three zones indicated these ponds to be largely deficient in N. Since occurrence of N in any soil environment remains closely related with organic carbon content of that soil, such low availability of N in fish pond soils of these three major soil zones of West Bengal was quite expected.

Phosphorus is recognized to be the most critical single factor in the maintenance of pond productivity [12]. In the present study, available P values in the fish pond soils of red and lateritic, hilly and alluvial zones ranged between 4.5 – 31.25, 15.0 – 60.0 and 25.0 –80.0 mg kg^{-1} with average values of 17.27, 28.33 and 55.25 mg kg^{-1} respectively. On the other hand, the range and average values of water soluble phosphorus content of these three different soil zones were 0.06 - 0.875, 0.5 – 0.925 and 0.097 – 0.995 mg l^{-1} with average values of 0.385, 0.438 and 0.53 mg l^{-1} respectively. Below 13.0 mg kg^{-1} of available P in bottom soil and less than 0.05 mg l^{-1}in water phase have been suggested as the index of poor productivity of fish ponds in India by [1]. In the present investigation, although the mean availability of this nutrient element was marginally above this threshold value yet, in general, most of the pond soils of red and lateritic soil zones appeared to be below this level indicating considerable numbers of these fish ponds to be deficient in available P while hilly and alluvial zones showed moderate to good availability of P both in soil and water phase.

Table 2: Different water properties and gross primary productivity of water in fish ponds under three different soil zones of West Bengal.

Parameters	Range		
	R & L*	Hilly	Alluvial
pH	6.68 – 8.34 (7.62)	6.07 – 8.29 (7.60)	7.3 – 8.11 (7.68)
Available N (mg l^{-1})	3.24 – 17.73 (10.07)	2.13 – 22.8 (13.69)	13.75 – 33.69 (23.3)
Available P (mg l^{-1})	0.06 – 0.875 (0.385)	0.05 – 0.925 (0.438)	0.097 – 0.995 (0.53)
Available K (mg l^{-1})	3.8 – 36.8 (18.07)	1.4 – 34.6 (12.62)	16.5 – 49.8 (31.41)
EC (dSm^{-1})	0.101– 0.689 (0.301)	0.113 – 0.778 (0.357)	0.141 – 0.984 (0.434)
Total alkalinity (ppm of $CaCO_3$)	8 – 185 (86.4)	8 – 64 (27.4)	125 - 315 (192.73)
TDS (g l^{-1}))	0.006 – 0.353 (0.092)	0.033 – 2.31 (0.406)	0.028 – 0.29 (0.091)
GPP (mg C m^{-3} h^{-1})	83.33 – 291.66 (185.76)	125 – 333.33 (206.50)	187.66 – 625 (329.39)
NPP (mg C m^{-3} h^{-1})	41.66 – 166.66 (81.59)	62.5 – 291.66 (166.99)	137.86 – 458.33 (228.36)

* **– Red and lateritic zone**

In spite of being the third major nutrient element in pond nutrition, little work has so far been done on K dynamics of pond soils [16]. Wetland soils are considered to have good supplies of K because of their alluvial origin, clayey texture and large scale occurrence of K bearing minerals [5]. However, in the present study, the pond soils of red and lateritic and hilly zones exhibited, in general, comparatively lower values of available K ranging between 74.8 – 280.6 and 105.3 – 289.4 mg kg^{-1} with average values of 187.89 and 189.44 mg kg^{-1} respectively, than what were observed the fishponds located in alluvial zones. This behavior may be attributed to occurrence of poor organic carbon, lighter texture and consequently low cation exchange capacity in the pond soils of red and lateritic and hilly soil zones which properties govern the availability of K in soils to a great extent. The range and average values of mineralized N content were also presented in table 1.

Availability of Zn in the studied pond soils of thee zones showed a good variation ranging between 0.05 - 0.288 mg kg^{-1}, 0.102 – 0.302 mg kg^{-1} 0.102 – 0.376 mg kg^{-1} for red and lateritic, hilly and alluvial soils respectively with the average values of 0.13, 0.18, 0.22 mg kg^{-1} which may be considered to be of low order. Submerged soils generally tend to reduce the availability of Zn [16]. Values of available Cu also showed low availability in all the three zones. Available Mn status of the pond soils of red and lateritic zone were observed to range between 8.4 and 28.8 mg kg^{-1} with an average value of 17.45 mg kg^{-1} as compared to those in alluvial zone ranging between 15.6 and 59.2 mg kg^{-1} with an average value of 35.7 mg kg^{-1} and in hilly zones ranging from 5.6 to 29.8 mg kg^{-1} with an average of 14.36 mg kg^{-1}. Availability of Fe also showed high values in all the pond soils ranging between 44 – 103.6 mg kg^{-1}, 37.5 – 93.6 mg kg^{-1}, 15.2 – 69.4 mg kg^{-1} with average values of 71.45, 49.04 and 29.36 mg kg^{-1} for red and lateritic, hilly and alluvial soils respectively.

Textural composition indicated the bottom soils of red and lateritic and hilly soil zones to be lighter in texture. Similar properties of red and lateritic soils have been reported by [17]. However, the pond soils of alluvial zones showed considerably heavier textures which behaviour might be attributed to alluviation of finer soil particles in this zone. Apart from influencing many chemical reactions and also retentivity of different nutrients in pond bottoms, textural composition may influence the water holding capacity of the studied pond soils also. In the present study, the observed average percentage of sand, silt and clay indicate that the soils of red and lateritic zones are lighter textured, mostly sandy and sandy-loam in nature. The hilly soils are predominantly sandy loam and alluvial soils are mostly observed sandy – clay - loam in nature.

Electrical conductivity (EC) indicates the total concentration of ionized constituents of a system. It is closely related to the sum of cations or anions, as determined chemically, and usually correlates with the amount of total soluble solids. Considering that changes in EC are associated with release or depletion of soluble ions in soil-water systems, EC might have an indirect role to play in pond productivity [15]. Range and average values of electrical conductivity of both soil and water were presented in table 1 and table 2 respectively which were observed to be considerably low.

The amount of acid required to titrate the bases in water is a measure of alkalinity. Numbers of bases like hydroxides, carbonates, bicarbonates, ammonia, silicate, phosphate etc may contribute to alkalinity of water. In the present study, the total alkalinities of the water samples of three different zones of West Bengal were presented in terms of mg kg^{-1} of $CaCO_3^-$. The range and average values are presented in table 2. The maximum value of average alkalinity was observed in alluvial pond water sample (192.73 mg kg^{-1} of $CaCO_3^-$) and the minimum value was observed in hilly water samples (27.4 mg kg^{-1} of $CaCO_3^-$).

Total solids of water sample represent different constituents. Different forms of solids e.g. total solids (TS), total dissolved solids (TDS), total suspended solids (TSS) and total volatile solids (TVS) are present in water. For the present study, total dissolved solids (TDS) of water samples of three different zones were measured and the range and average values have been presented in table 2. As observed from the table the fish ponds situated under hilly soil zones exhibited considerably higher TDS values in water than the ponds of other two soil zones. Higher rates of alluviation of fine soil particles in hilly zones probably resulted in such increased TDS values.

Table 3: Correlation coefficients between relevant soil parameters and gross primary productivity (GPP)

Parameters	Correlation co-efficient value with GPP	Level of significance
pH -(1:2)	0.6751	.01
Easily Mineralizable N (mg kg^{-1})	0.6052	.01
Available P (mg kg^{-1})	0.8131	.01
Available K (mg kg^{-1})	0.5091	.01

Table 4: Correlation coefficients between relevant water parameters and gross primary productivity (GPP)

Parameters	Correlation co-efficient value with GPP	Level of significance
pH -(1:2)	.4486	.05
Available N (mg l^{-1})	.8395	.01
Available P (mg l^{-1})	.5264	.01
Available K (mg l^{-1})	.5161	.01

Gross primary production (GPP) in fish ponds is well known to be closely related with the yield levels of fishes in various fish culture systems [13, 7]. To assess the significance of the studied soil properties to pond productivity, therefore, attempts were made to correlate these values with respective gross primary productivity levels of the ponds. The studies revealed that out of the different properties studied, only pH and available N, P and K values of the pond soils and waters were positively correlated with primary productivity of the ponds (Table 3 and 4). Since gross primary production is a major indicator of productivity levels of fish ponds [19], this study indicates that adequate management of the primary productivity limiting soil parameters viz. pH, easily mineralizable N, Available P and K would be helpful to increase productivity of a fish pond significantly.

CONCLUSION

The results of this study indicate that there is wide spread deficiency in availability of nitrogen in fish ponds under all the studied soil zones of West Bengal. This emphasizes the need of application of nitrogenous fertilizers in such ponds for increasing their productivity. The studies revealed that out of the different properties studied, only pH and available N, P and K values of the pond soils and waters were positively correlated with primary productivity of the ponds.

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