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Aquaculture Practices in Acidic Pond Bottom Soils in NE Region of India

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Abstract

The North-Eastern region of India has about 46 % of total national surface water resources. Most of the areas holding acidic water which has pH and alkalinity < 6.5 and < 50 mgl^{-1} respectively. Leaching of basic cations such as Ca^{++}, Mg^{++}, K^{+} and Na^{+} from the soil due to heavy rainfall left acidic cations like Al^{+++} and Fe^{+++} to remain in the soil. In such water, fish secrete more slime, become hypersensitive to bacterial and fungal infection and sometimes show the decolouration of gill tissue. The methods of rectification of acidic nature of both soil and water of the aquaculture ponds by controlling causative factors are discussed that can mitigate acidic problems in turn to enhance aquatic productivity in seed rearing as well as in grow out ponds. The possible fish yield can be achieved @3000-4000 Kg ha^{-1} y^{-1}.

Keywords: *Aquaculture, Acidic pond, North – East India*

Introduction

Soil is an important consideration while constructing pond for aquaculture (Hickling, 1962). The characteristics of pond bottom soil are also equally important in pond management. The exchange of substances between the soil and water affects various water parameters in turn its quality, ultimately influencing fish yield. Pond bottom soils are the store house for many substances that get accumulated in pond ecosystems through chemical and biological processes. The suitable aquacultural soils generally are loams with 20-30% clay which can provide a barrier against seepage. The most active fraction of the soils is clay particles because of their negative electrical charge, large surface area and the organic matter present for its biological availability and chemical reactivity.

India has about 91.0 mha (28% of total land area) of red and lateritic soils (Sehgal, 1993) spread over several states. Aquaculture productivity of such soils are usually of low order owing to light texture, poor organic matter, low water holding capacity, acidic pH, poor NPK status, low chemical and biological activities and also inadequate as well as toxic occurrence of some trace elements(Panda *et al.*, 1988). Acidic soils also contain high concentrations of iron and alumimium ions which are toxic to fish and other aquatic organisms and they precipitate phosphate, making the fertilizers unavailable to organisms in the aquatic environment (Egna and Boyd, 1996).

More than 80 percent of soils of North -Eastern states of India are acidic in nature (Prasad, *et al*, 1985). Majority of acid soil have pH below 5.6 and the remaining between 5.6 and 6.5 (Panda, 1987). North - East Indian region lies between 22^0 05' and 29^0 30'N latitudes and 87^0 55' and $97^0$24'E longitudes. On the other hand, Tripura placed between $22^0$56' and $24^0$32' N latitudes and $91^0$10' and $92^0$21' E longitudes. The region has an area of 26, 2,040 km^2, of which 72.6% is hilly, 16.6 % of land area is under crops, 50.6% is under forest, 5.3 % under non-agricultural use and 4.4% is barren and 5% fallow land. Most of the land area is covered by rugged and inaccessible terrain, steep hills, high mountain ranges, undulation topography, deep valleys, marshy and swampy lands.

The NE region is rich in water resources, both the surface and ground water, mainly due to its location in high rainfall area with an extensive river system. The region receives about 510 km^3 of water annually as rainfall (average rainfall 2500mm/year) that largely comes from south-west monsoon and surface water resources have been estimated as 1487.65 km^3 of water. Most of the ground water cannot be utilized due to the fact that most of the rivers flow through deep gorges and inaccessible terrain. The total riverine length, lakes, reservoirs and tanks area of this region are 19,468 km, 91,265,51,609 ha and 40,406 ha respectively (Sharma, 1997). The N-E region has about 46% of the Nation's valuable surface water resources.

Productivity of acidic water ponds in NE region

Most of the areas holding acidic water had pH <6.5, low total alkalinity (< 50 mg l^{-1}), medium dissolved oxygen (around 6.6 mg l^{-1}), low dissolved nitrogen (0.05- 0.17 mg l^{-1}), meager dissolved phosphate 0.01 mg l^{-1} and were mostly unproductive (Banerjea,1967). In acidic water, fish secrete more slime, become

hypersensitive to bacterial and fungal infections and sometimes show the decolouration of gill tissue.

Causes of soil acidity

Leaching of basic cations such as Ca^{++}, Mg^{++}, K^{+} and Na+ from the soil by heavy rainfall left acidic cations like Al^{+++} and Fe^{+++} to remain in the soil. This is the reason for the occurrence of acidic soils in humid regions and alkaline or neutral soils in arid zones. More over, due to hydrolysis, mineral particles lose their basic elements (Ca, Mg *etc*.) and these are replaced by hydrogen, iron or aluminium ions (Miller, 2004). The removal of bases from minerals renders them unstable in structure and when the process has gone far enough, the minerals disintegrate. The products of minerals decomposition may remain in part or entirely as substances containing replaceable hydrogen ions and hence be acidic or they may be recombining to form the clay minerals. Application of high doses of chemicals and organic fertilizers may eventually make the soil more acidic. Hydrogen is added in the form of ammonia-based fertilizers (NH_4^+), urea-based fertilizers [$CO(NH_2)_2$], and as proteins (amino acids) in organic fertilizers. Transformations of these sources of N into nitrate (NO_3^-) releases H^+ to create soil acidity.

Tripura and Fisheries

Tripura has a terrain comprising of tillas and lungas, *i.e.,* small hillocks and depressions. The hill run in north-south direction alternating with narrow valleys, rising from the plains of Sylhet in Bangladesh and goes south wards until the join the hills of Chittagong hill tract. Hills have higher elevation in the south. Jampai range is the highest having 914 m altitude. Soil pH range varies from 4.05 to 6.05. More than 90 percent of the soils of Tripura having pH below 5.6 and texture of high sand coupled with low silt and clay contents. On an average, 52.1 % of soils are low, 22.5% soils are medium and 25.4 % soils are high in organic carbon content. The available phosphorus index value varies from 1.34 to 1.82. The 60.5 % soils are deficient, 26.9 5 soils are medium and 12.6% are high in available phosphorus content. Low available phosphorus content is related to strongly acidic soil condition. In availability of potash content, 67.3 % soils are low, 24.7% soils medium and only 8% soils are high in potash content. Soils of Tripura are, unlike other places of the NE region, deficient in organic matter (Bhattacharyya *et al*., 1996). Laskar *et al.* (1983) found out that about 90 % of soils of Tripura were having pH below 5.6.

Tripura has 21,169.24 ha water area (Anonymous, 2004) out of which 37.2% is for capture and rest is for culture (ponds/tanks/minibarrages). Tripura contributes 7.21 % of fish production of NE region. The per capita availability of fish in Tripura is 14.120 kg where almost total population(95%) is fish eater with average productivity from culture ponds is 2799kg/ha and total fish yield is 49,231.32MT(2010-11) MT(Anonymous, 2012).

Mitigation of soil acidity

Lime is basically used for increasing the pH of the soil in ponds as well as reducing the aluminum or iron toxicity. The amount of lime needed to achieve a certain pH depends on:

(1) pH of the soil
(2) Buffering capacity of the soil
Lime reduces soil acidity by changing some of the hydrogen ions into water and carbon dioxide (CO_2). A Ca^{++} ion from the lime replaces two H^+ ions on the cation exchange complex. Liming increases the pH of bottom mud and thereby enhances the availability of phosphorus, added in fertilizer (Boyd, 1974). In highly acidic waters, liming will increase the pH of the water and improve survival, reproduction and growth of aquatic organisms.

Table 1: Common liming materials used and their application in acidic soils (Anon, 1985)

SN.	Material	Common name	Relative neutralizing value (%)	Rate of application based on pH of soil (9kg/ha)		
				4.5-5.5	5.5-6.5	6.5-7.5
1	Calcium carbonate	Lime stone	100	2000	1000	500
2	Calcium oxide	Burned / quick lime	150 - 175	1100	550	225
3	Calcium hydroxide	Hydrated/ slaked lime	120 - 135	1450	725	380

Alternative method

1. Application of organic manure is used for restoration of the pH from acidic to alkaline (Egna and Boyd, 1996 and Lin., 1986). The continuous deposition and active decomposition of the organic matter at pond bottom in this system create anaerobic conditions in superficial sediments and thus effectively prevent acidification in deeper soils.

2. Moderate dose of lime and organic manure increase pH and reduce the aluminum and iron contents.

As the nature and properties of bottom soil play an important role influencing the dynamics and magnitude of transformation of applied nutrients (Mandal and Chattopadhyay, 1992), soil specific fertilization is found suitable methodology for obtaining higher fish yield from red acidic soil based water bodies (Mukherjee and Chattopadhyay,2002). Extensive study was conducted in the state of Tripura with series of upland ponds during the period 2007-2009 (Datta *et al*., 2010a, b, c) and found out suitable soil specific aquaculture technology conducive for the low productive red acidic soil based pond water through alternative low manure and fertilizer based technology.

Methodology developed

a) **Correction of red acidic soil**

- The soil should not be allowed to get fully dried under sunlight to avoid the oxidation process of the iron and aluminium as it may lead to acute acidity and phosphate binding.
- While excavating the ponds in red soil, it needs to be damp.
- The pond should not be totally dewatered and dried.
- Catchment rain water should not be allowed to get direct entry into the pond. This phenomenon controls the acidity by checking intense leaching and in turn removal of minerals.
- Minimizing free board area by water filling to reduce iron oxidation. The replacement of basic cations by acidic cations such as aluminum (Al^{3+}) and hydrogen (H^{+}) could be controlled even in high rain fall areas.
- High altitude ponds need to have polythene lining to control intensive seepage.
- The acidic nature of pond soil and water with low to medium pH could be corrected by using quick lime (CaO) @ 250-350 kg of kg ha^{-1} y^{-1} in splitted doses. Subsequently organic manure can be applied for long lasting amendment process.
- Either raw cow dung @ 10,000 kg ha^{-1} y^{-1} or poultry manure@ 5,000 kg ha^{-1} y^{-1} in splitted doses may be applied preferably fortnightly.
- The next alternate is the application of organic manure in medium doses along with molasses (50kg ha^{-1} y^{-1}).
- The above processes can elevate the soil and water pH to desirable alkaline level and in turn will enhance the productivity coupled with high productive C: N ratio (8-14).
- The amendments need continuity.

b) **Seed rearing in red soil base ponds**

- Physico-chemical parameters of the soil and water need to be analyzed initially for ascertaining the status and demand of nutrients required.
- Pond size may be of 100-500 m^2 maintaining the water level of 1-1.5 meter.
- The pond preparation like deweeding, removal of unwanted fishes and eradication of aquatic insects to be conducted as per standard package of practices for carp culture.
- Liming in 2-3 doses (40% as basal dose).
- Organic manuring in split doses (basal dose 50%) preferably in liquid form. Freshness of the cow dung exhibits better and quick response.
- No chemical fertilization.
- After 5 to 7 days of manuring, fish seed to be stocked. For spawn rearing, aquatic insects to be eradicated 12 hours prior to stocking.
- Spawn of major carps can be stocked @ 1-3 million ha^{-1} and that of fry can be @ 1-3 lakh ha^{-1} , little lower than the normal package of practices.
- Rice bran and mustard oil cake (1:1) @ 3-5 % of body weight may be broadcasted preferably in the morning.
- Dissolved oxygen, pH and alkalinity of the water to be monitored at weekly interval.
- If needed, water to be added to maintain required depth.
- Sampling to be conducted periodically.

- Harvesting of spawn to fry in 15-18 days (20-25 mm) and fry to fingerlings in 45 days period (40-70 mm).

- A survival of 50-70 % can be obtained with moderate to high growth.

- Most suited species in red soil base acidic ponds is common carp.

c) **Grow out practices of carps in red soil base ponds**

- Soil correction procedure is same as in nursery ponds.

- Size of ponds 150- 1500 m^2 with an average water depth of 1-2 meters.

- Physico-chemical proprieties of the soil and water need to be analyzed before the start of culture.

- Eradication of the unwanted fishes can be done by using bleaching powder @ 200-250 kg ha^{-1} or by repeated netting.

- Liming (CaO) in split doses preferably in liquid form.

- Organic manure in split monthly dose (40% basal dose) after 7 days of lime application.

- Seed (fingerlings) stocking, IMC @ 8,000-16,000 no ha^{-1} in 4 to 5 species combination after 7 days of manure application. In high altitude ponds, common carp may be stocked.

- The 5 species combination preferably is catla 20 %, silver carp 15%, rohu 30 %, common carp 20 % and mrigal 15%. In case of 4 species combination, silver carp can be omitted and in turn rohu and common carp number may be increased.

- The pH, alkalinity, dissolved oxygen, plankton and primary productivity of pond water are to be monitored regularly including fish growth parameters.

- Supplementary feeding: mustard oil cake and rice bran (1:1) @ 3 -5% of body weight daily.

- Culture period is 3-9 months.

- Possible yield with RCD @ 2500- 4000 kg ha^{-1} and poultry manure @ 3000- 4000 kg ha^{-1}.

- Average growth of fish- 150-600 g.

Conclusion

The method of rectification of acidic nature of both soil and water of the pond by controlling the causative factors through application of lime and organic manures in moderate and splitted doses is simple and easily applicable by the farmers with minimum efforts and cost. Adoption of suitable management practices and species for this type of water bodies especially for NE region would be useful in aquaculture practices.

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Table 2: Physico-chemical properties of pond water with red pond bottom soil of Tripura*

Sl No:	Parameter	Minimum	Maximum	Means
1.	Turbidity (NTU)	7.16	57.00	18.44±1.96
2.	Transparency (cm)	11.00	29.00	17.11±0.77
3.	pH	5.62	7.80	6.62±0.07
4.	Electrical conductivity (Scm^{-1})	10.00	100.00	47.61±3.77
5.	Redox potential (mv)	-27.00	66.00	3.29±3.17
6.	Carbon dioxide (mgl^{-1})	1.00	12.00	4.61±0.56
7.	Dissolved oxygen (mgl^{-1})	3.20	10.80	5.21±0.27
8.	Total alkalinity (mgl^{-1})	28.00	186.00	76.19±6.63
9.	Total hardness (mgl^{-1})	32.00	90.00	52.77±2.36
10.	PO_4-P (mgl^{-1})	0.01	0.69	0.25±0.04
11.	NH^+_4- N (mgl^{-1})	0.002	0.118	0.04±0.01
12.	NO_3-N:(mgl^{-1})	0.01	0.14	0.03±0.01
13.	Fe (mgl^{-1})	0.08	1.93	1.03±0.07
14.	Al (mgl^{-1})	0.31	9.65	2.66±0.43
15.	Ca (mgl^{-1})	0.38	10.09	2.90±0.53

* Results of the experiments conducted at Tripura, 2007-2009

Table 3: Physico-chemical properties of pond bottom red soils of Tripura*

Sl No:	Parameter	Minimum	Maximum	Means
1	Turbidity (NTU)	69	91	80.86±1.108
2	Transparency (cm)	3	10	5.72±0.36
3	pH	6	22	13.31±0.86
4	Electrical conductivity (Scm^{-1})	26	128	53.55±4.62
5	Redox potential (mv)	7	20	10.10±0.43
6	Carbon dioxide (mgl^{-1})	4.3	6.4	5.77±0.11
7	Dissolved oxygen (mgl^{-1})	0.03	0.85	0.37±0.04
8	Total alkalinity (mgl^{-1})	0.01	0.05	.02±0.002
9	Total hardness (mgl^{-1})	3.80	50.80	20.49±2.27
10	PO_4-P (mgl^{-1})	0.41	27.13	7.39±0.97
11	NH^+_4- N (mgl^{-1})	1.06	14.94	4.09±0.55
12	NO_3-N:(mgl^{-1})	1.08	3.84	3.43±0.27
13	Fe (mgl^{-1})	1.87	39.04	14.52±1.71
14	Al (mgl^{-1})	1.19	8.23	2.75±0.32

15	Ca (mgl^{-1})	0.34	12.67	5.92±0.58

* Results of the experiments conducted at Tripura, 2007-09

Table 4: Gross Primary Productivity and Net Primary Productivity of earthen ponds of Tripura*

Type of water body	Parameter	Minimum	Maximum	Mean±SE	Std. deviation	CV
Earthen pond	Gross primary productivity ($GmCm^{-3}day^{-1}$)	0.113	0.638	0.243±0.029	0.152	62.25
	Net primary productivity ($GmCm^{-3}day^{-1}$)	0.028	0.600	0.178±0.033	0.169	94.61

* Results of the experiments conducted at Tripura, 2007-09

Table 5: Descriptive statistics of the soil of treated ponds*

Parameter	Groups	Minimum	Maximum	Std. Deviation	Mean ±SE	CV
pH	1.00*	5.19	5.35	0.113	5.27±0.08	2.14
	2.00**	5.48	5.63	0.106	5.55±0.07	1.90
	Total	5.19	5.63	0.187	5.41±0.09	3.45
Rh (mv)	1.00	68.00	71.00	2.121	69.50±1.50	3.05
	2.00	44.00	54.00	7.071	49.00±5.00	14.43
	Total	44.00	71.00	12.579	59.25±6.28	21.23
Sand	1.00	8.00	10.00	1.414	9.00±1.00	1.75
	2.00	9.00	10.00	0.707	9.50±0.50	7.44
	Total	8.00	10.00	0.957	9.25±0.47	10.34
Sand (%)	1.00	80.00	82.00	1.414	81.00±1.00	1.74
	2.00	78.00	79.00	0.707	78.50±0.50	0.90
	Total	78.00	82.00	1.707	79.75±0.85	2.14
Silt (%)	1.00	4.00	5.00	0.707	4.50±0.50	15.71
	2.00	5.00	5.50	0.353	5.25±0.25	6.72
	Total	4.00	5.50	0.629	4.87±0.31	12.90
Clay (%)	1.00	14.00	15.00	0.707	14.50±0.50	4.87
	2.00	16.00	16.50	0.353	16.25±0.25	2.17
	Total	14.00	16.50	1.108	15.37±0.55	7.20
OC (%)	1.00	0.27	0.36	0.063	0.31±0.04	17.94
	2.00	0.36	0.57	0.148	0.46±0.10	31.82
	Total	0.27	0.57	0.127	0.39±0.06	32.56
Nitrogen (%)	1.00	0.01	0.01	0.001	0.01±0.00	7.69
	2.00	0.05	0.06	0.008	0.05±0.00	14.03
	Total	0.01	0.06	0.025	0.03±0.01	71.42
C:N ratio	1.00	22.50	27.10	3.252	24.80±2.30	13.11
	2.00	7.05	9.04	1.407	8.04±0.99	17.48
	Total	7.05	27.10	9.887	16.42±4.94	60.20
P (mg100g-1)	1.00	3.68	4.22	0.381	3.94±0.27	9.64
	2.00	2.74	2.88	0.093	2.80±0.06	3.31
	Total	2.74	4.22	0.696	3.37±0.34	20.59
K ($mg100g^{-1}$)	1.00	2.60	3.04	0.311	2.82±0.22	11.02
	2.00	2.57	3.76	0.841	3.16±0.59	26.57

	Total	2.57	3.76	0.554	2.99±0.27	18.51
Ca ($mg100g^{-1}$)	1.00	1.87	2.12	0.176	1.99±0.12	8.82
	2.00	5.67	6.04	0.261	5.85±0.18	4.45
	Total	1.87	6.04	2.236	3.92±1.11	56.63
CEC($meq100g^{-1}$)	1.00	2.48	2.65	0.120	2.56±0.08	4.67
	2.00	8.46	9.40	0.664	8.93±0.47	7.43
	Total	2.48	9.40	3.695	5.74±1.84	64.29
Fe ($mg100g^{-1}$)	1.00	3.32	3.70	0.272	3.51±0.19	7.74
	2.00	2.22	2.43	0.149	2.32±0.10	6.41
	Total	2.22	3.70	0.708	2.91±0.35	24.27
Al($mg100g^{-1}$)	1.00	4.45	4.48	0.020	4.46±0.01	0.44
	2.00	1.44	2.34	0.635	1.88±0.44	33.63
	Total	1.44	4.48	1.531	3.17±0.76	48.20

* Results of the experiments conducted at Tripura, 2007-2009

Table 6: Physico-chemical parameters of water of treated ponds*

Parameter	**Av.old earthen pond**		**Av. newly created pond**		**Av. Initial**	**Av. Final**
	Initial	**Final**	**Initial**	**Final**		
Colour	light green	Green	pale gray	Green	-	-
Transparency(cm)	23.75	25.5	27.0	12.0	25.4	18.7
pH	6.7	7.3	5.9	7.2	6.3	7.26
Rh (mv)	4.0	-20	50.0	-6.0	27.0	-13.0
EC (Scm^{-1})	18.5	10.5	7.5	6.5	13.0	8.5
DO(mgl^{-1})	4.5	6.3	6.2	7.0	5.4	6.7
CO_2(mgl^{-1})	10.0	2.0	5	2.0	12.5	2.0
TA (mgl^{-1})	65.0	154.0	31.0	169.0	48.0	161.5
Turbidity (NTU)	51.5	26.1	44.7	19.5	48.1	22.8
Total hardness(mgl^{-1})	52.0	62.0	48.0	59.0	50.0	60.5
NH^{+}_4-N (mgl^{-1})	0.003	0.024	0.009	0.068	0.006	0.046
NO_3-N(mgl^{-1})	0.026	0.229	0.001	0.240	0.014	0.235
PO_4-P(mgl^{-1})	0.061	0.198	0.023	0.553	0.042	0.375
Al (mgl^{-1})	0.817	0.418	1.754	0.158	1.285	0.242
Fe (mgl^{-1})	1.566	0.410	1.787	0.067	1.677	0.239
Ca (mgl^{-1})	2.229	2.309	0.927	2.476	1.578	2.392

* Results of the experiments conducted at Tripura, 2007-2009

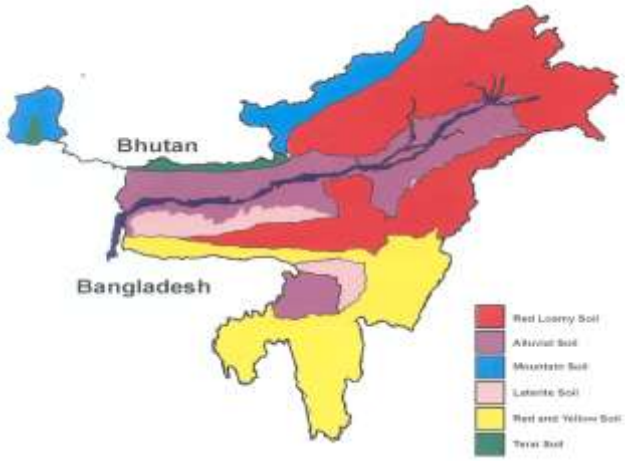

Plate No. 1 Soil types of North East India

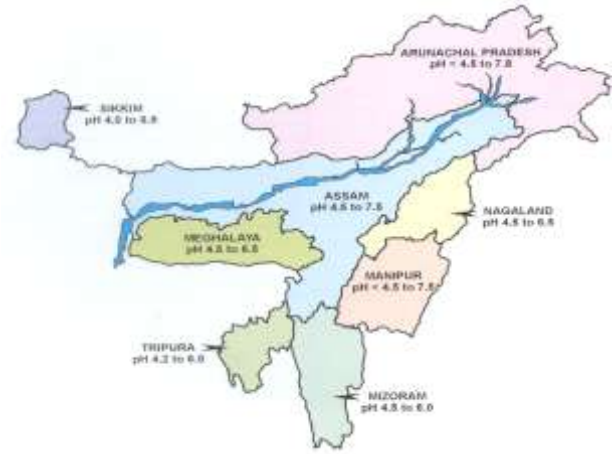

Plate No. 2 The N. E. States

Plate No. 3: Pond under construction in red acidic upland soil

Plate No. 4: Pond with red acidic bottom soil

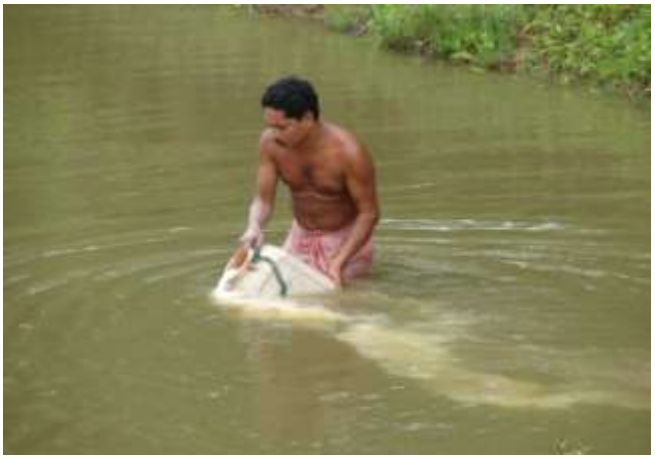

Plate No. 5: Management practices in acidic ponds

Plate No. 6: Fish harvested from rectified ponds