RESEARCH REPORTS

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Acidification and Reclamation of Acid Sulfate Soil Fishponds in Thailand*

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Abstract

An experiment was conducted to examine the chemical characteristics of and the effects of fertilization on water quality and biological productivity in fishponds built in the acid sulfate soil region of Thailand. The acid soil acidified the overlying pond water rapidly to pH less than 4, but its acidification effect was reduced remarkably by repeated changing of the pond water with alkaline source water. Further improvement of the pond water was done by liming and enriching the ponds with inorganic and organic fertilizers. The pH in ponds receiving inorganic fertilizers ($N_{16}P_{20}K_0$) fluctuated widely necessitating repeated liming. Production of food organisms (phyto- and zooplankton) was relatively poor. Fish yield (*Oreochromis niloticus* and *Puntius gonionotus* stocked at a density of 3 fish/m^2) in five months was only 426 kg/ha. In comparison, the pH in ponds fertilized with chicken manure stabilized in the alkaline range and fluctuated little after initial liming. Relatively high plankton productions were achieved and fish yield was 1,528 kg/ha. Methods for reclaiming the acid soils for productive fishponds are recommended.

Introduction

Acid sulfate soils cause the acidification of large areas of surface water in the tropical ecosystems (Brinkman 1982). The worldwide extent of acid sulfate soils is estimated to be 13 x 10^6 ha of which 778,000 ha are located in Thailand's central plain (Pons 1969). Those soils contain large concentrations of sulfate and pyrites, creating extremely acid soils and surface waters in the region (Attanandana et al. 1982). In addition, the acid waters also contain free aluminum ions which are highly toxic to fish and form precipitates with phosphates making the fertilizer unavailable to organisms in the environment. Consequently, the surface waters affected by the acid soils are biologically unproductive. The application of lime and fertilizers greatly increased fish productivity in acid ponds in Malaysia (Hickling 1968).

Reclamation and utilization of acid sulfate soils for aquaculture are well documented for the coastal regions in the Philippines where the potential soil acidity could be leached and removed by tidal flush (Brinkman and Singh 1982; Singh 1985). However, in the flat terrain of freshwater regions, as in Thailand's central plain, such natural mechanism does not occur. To achieve this artificially is technically difficult and expensive, and the leached effluent may cause damage to adjacent surface waters.

This work reports the acidification of pond water caused by acid sulfate soils and the impact of inorganic fertilizers on plankton and fish production in those fishponds.

Materials and Methods

The experiment was conducted at the Nong-Sua Fisheries Station located in the lower part of Thailand's central plain where severe acid sulfate soils prevail. To examine the depth of some acid-related chemical features, soil samples taken in a 1-m core with a soil auger were sectioned in 20-cm intervals from surface to bottom. Each section was analyzed for pH, active iron, extractable aluminum, calcium, sulfur, phosphorus, and % base saturation. The effectiveness of leaching and washing processess for removing acidity from soil was determined in a small-scale experiment. Six enamel-coated containers (each 100 cm long, 40 cm wide and 50 cm deep) were filled with 20 cm of bottom soil taken from a new pond. Upon drying the soil, the containers were filled with alkaline water (pH 7.3) to 30 cm above the soil surface. The pH changes of the overlying water in the containers were recorded daily for four consecutive days, then water was drained and soil dried. Again, the tanks were filled with new source water and the pH was monitored for another five days.

A field experiment for determining the effect of inorganic and organic fertlizers was carried out in four 800-m^2 earthen ponds. Two received inorganic fertilizer ($N_{16}P_{20}K_0$) and the other two, organic fertilizer (chicken manure). The nutrient input from the inorganic and organic sources into each pond was calibrated at a rate of 8 kg P_2O_5/ha/month. Bottom soil analysis showed that the initial quantity of lime applied to the bottom ranged from 5,000 to 6,800 kg/ha.

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Two species of herbivorous fish, *Oreochromis niloticus* and *Puntius gonionotus*, were stocked in the experimental ponds at $2/m^2$ and $1/m^2$, respectively. During the five-month grow-out period we collected weekly data on pH, alkalinity, dissolved oxygen and chlorophyll *a* in the ponds. Fish growth was determined by monthly samples of 10% of the population, and zooplankton standing crop was sampled monthly.

Results and Discussion

The depth profile of soil chemical characteristics showed decreased values of pH, calcium, base saturation and phosphorus as depth increased in the top 1-m soils. The opposite trend existed for iron, aluminum and sulfur with increased concentrations in deeper soil strata (Table 1). Those data indicate that the potential acidity in the soil increases with depth in the acid sulfate soil, suggesting severer acid problems would be encountered with deeper excavation in pond construction.

The results of the small-scale experiment on acidification showed that the pH of alkaline water decreased rapidly from 7.3 to 3.5 in 3-4 days, but the acid exported from the acid soil diminished greatly upon repeated water changes (Fig.1). The potential acid in the top soil could be reclaimed by repeated leaching and washing. However, mechanical pumping and draining of the pond is costly. Furthermore, the effluent from the leached acid water would cause damage to the organisms in the adjacent recipient waters.

The effects of inorganic and organic fertilizers on water quality and biological productivity in the acid soil ponds were remarkably different. The pH and alkalinity in the ponds receiving chicken manure were considerably higher (Fig. 2). Fluctuations in pH and alkalinity were particularly pronounced in the rainy season during which the pH in the inorganic fertilized ponds dropped below 6 and additional limings were required to maintain the pH desired for fish growth. The application of organic fertilizer in the acid sulfate ponds may involve significant biochemical processes that stabilize the pH in the pond bottom. The continuous deposition and decomposition of organic matter at the pond bottom create low redox or anaerobic conditions in the surficial sediment and its interstitial waters. These biochemical processes can prevent oxidation and lock the reduced sulfur compounds in the sediments. Furthermore, the low redox conditions would enhance the nutrient release and recycle, as well as reduce sulfate to highly insoluble ferrous sulfides from the sediments. The aluminum toxicity to fish, while most potent in its inorganic forms, may be averted as the aluminum ions are complexed by the large amount of soluble organic compounds (Driscoll et al. 1980). The drastic pH decrease in pond water during the rainy period was primarily caused by the runoffs from the pond dikes (Simpson et al. 1983; Singh 1985). Prevention of acid leaching from dikes is difficult because its periodical episodes effectively oxidize pyride; limings are ineffective as lime is easily washed off by rains and a new layer of soil is exposed.

As measured by chlorophyll *a*, phytoplankton production in the chicken-manured ponds ranged from 20 to 120 mg/m^3 compared to 5-30 mg/m^3 in the inorganically fertilized ponds (Fig. 3). Pronounced differences in zooplankton (mainly protozoans and rotifers) also occurred between ponds receiving the two types of fertilizers (Fig. 4).

Fertilizer effects on the fish production are presented in Table 2. Although the two species of fish were stocked at similar sizes (0.26-0.37 g/fish), the survival rates were significantly higher for *Puntius* (97-100 %) than those for *O. niloticus* (60-82 %) in both types of ponds. While the *Puntius* encountered little mortality, its final yields were only 92 and 234 kg/ha in inorganically fertilized and chicken-manured ponds, respectively; *Tilapia* yields were 334 and 1,294 kg/ha, respectively. In the Philippines, maximum milkfish yield in reclaimed acid ponds was 550 kg/ha in a three-month growing period (Singh 1985).

Management Implications and Recommendations

Depth profiles of acid related chemical features in the acid soil such as pH, aluminum, iron and sulfur indicate that digging should be avoided in pond construction. Instead dikes should be built on top of the original terrain with the top soil saved from digging the drainage canals. To reduce the amount of dike runoffs relative to the pond water volume, one should reduce the size of the dikes, increase the pond size and maintain high pond water level. The top surface of the dikes should be built in "V" shape with a central depression to collect excess rain water and empty it into the drainage canal. The ponds should be fertilized with animal manure to enhance greatly the production of food organisms, as well as to improve water quality by stabilizing the pH.

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Table 1. Depth profile of soil chemical characteristics at Nong-Sua Fisheries Station, Thailand central plain.

Parameter	Depth (cm) 0-20	20-40	40-60	60-80	80-100
pH	4.0	3.7	3.5	3.4	3.2
Active Fe (%)	0.7	0.7	3.0	3.4	2.9
Extractable Al (meq/100 g)	6.7	16.7	16.1	14.6	14.6
Calcium (%)	0.27	0.11	0.09	0.09	0.03
Sulfur (%)	0.49	0.17	0.43	0.66	0.78
Phosphorus (ppm)	310	155	130	110	105
Base saturation (%)	46	32	28	29	28

Table 2. Stocking density, survival rate, weight gain and total production of two fish species cultured together for 180 days in ponds treated with organic and inorganic fertilizers.

Fertilizer and fish spp.	Stocking rate ($fish/m^2$)	Survival rate (%)	Wt. gain (g/fish)	Yield (kg/ha)
Inorganic				
Puntius gonionotus	1	97	9.5	92
O. niloticus	2	60	27.4	334
Chicken manure				
Puntius gonionotus	1	100	23.4	234
O. niloticus	2	82	78.0	1,294

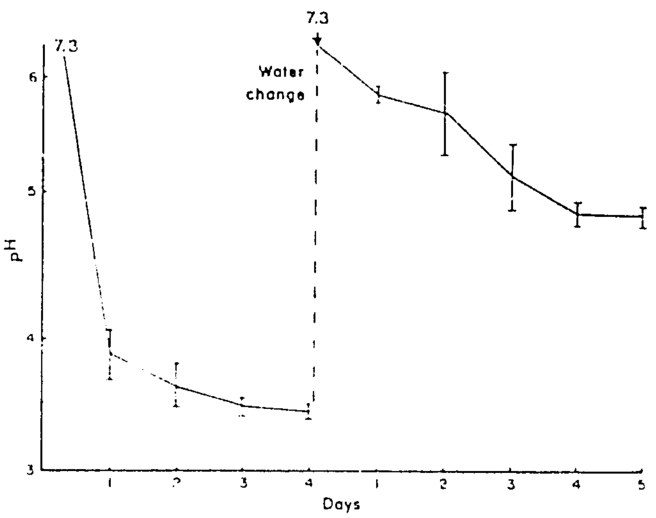

Fig. 1. Effects of acid sulfate soils on the alkaline pond water upon two successive water changes.

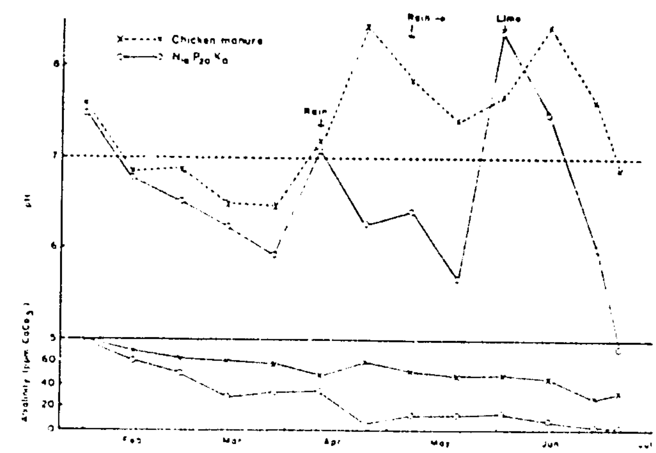

Fig. 2. Comparison of pH and alkalinity between inorganic and organic fertilized ponds.

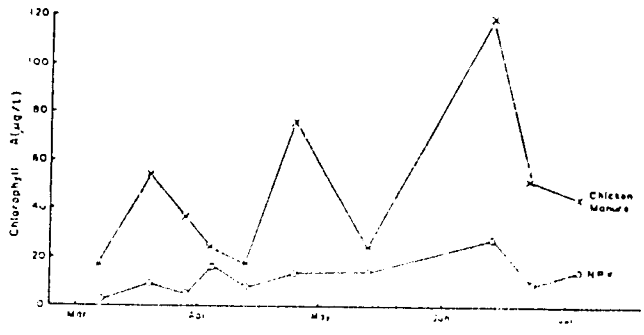

Fig. 3. Comparison of phytoplankton production (chlorophyll *a*) between inorganic and organic fertilized ponds.

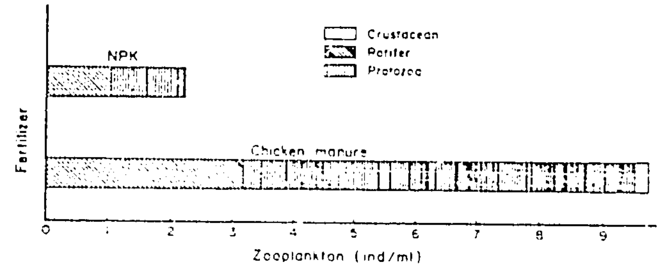

Fig. 4. Comparison of zooplankton standing crops and taxa composition between inorganic fertilized ponds.

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