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Effect of fertilization on organic matter and pH of soil in ponds for *Litopenaeus vannamei* culture

ABSTRACT

Adequate management of the soil in shrimp ponds is one of the main resources in improving the stability of the culture and minimizing the occurrence of diseases. One strategy for improving soil quality is oxidizing organic matter and maintaining pH values near neutral. The present study tested the influence of different fertilization strategies on soil quality of ponds for *Litopenaeus vannamei* culture using two treatments: SN (enriched sodium nitrate) and SNS (urea, triple super phosphate and sodium silicate). Statistical analysIs were done using the Student "t" test (P < 0.05). The results were statistically different. The percentages of organic matter oxidation were 36.2% ± 4,0 and 20.0% ± 4.0 and pH values at the end of the study were 7.1 and 5.1 for the SN and SNS treatments, respectively.

Key words: shrimp culture, soil management, fertilization strategies

Efeito da fertilização sobre a matéria orgânica e o pH do solo de viveiros de *Litopenaeus vannamei*

RESUMO

O manejo adequado do solo de viveiros de camarão é uma das principais ferramentas para melhorar a estabilidade do ambiente de cultivo e reduzir o risco de doenças. Uma forma de melhorar a qualidade do solo é a oxidação da matéria orgânica e a manutenção dos valores de pH próximos da neutralidade. O presente estudo teve como objetivo testar a influência de diferentes estratégias de fertilização na qualidade do solo em viveiros de *Litopenaeus vannamei*. testaram-se dois tratamento: NS (nitrato de sódio enriquecido) e SNS (uréia, superfosfato triplo e silicato de sódio). Para análise a estatística utilizou-se o teste "t" (P < 0,05). Os resultados obtidos para os tratamentos NS e SNS, em relação à porcentagem de oxidação da matéria orgânica, foram de 36,2% ± 4,0 e 20,0% ± 4,0. O pH do solo no final do ciclo de cultivo foi de 7,1 e 5,1, respectivamente, estatisticamente diferentes.

Palavras-chave: carcinicultura, manejo do solo, estratégias de fertilização

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Introduction

In 2003, shrimp production in Brazil was about 90,190 t in a cultivated area of 14,824 ha, with a mean productivity of 6,084 kg ha^{-1} $cycle^{-1}$. However, with the occurrence of the infectious myonecrosis virus (IMNV) and the antidumping process, shrimp farming activities have decreased. In 2004, production was 75,904 t in an area of 16,598 ha, with a mean productivity of 4,573 kg ha^{-1} $cycle^{-1}$ (Rodrigues et al., 2005). Producers employ different management approaches in order to reduce loss and improve the quality of the culture environment, such as the application of hydrated lime in the pellets, syrup, probiotics, wheat flour and immuno stimulants. However, little has been done regarding soil management and fertilization (Brito et al., 2005).

Shrimp are benthonic organisms that live on and under the water/sediment interface, which is one of the main compartments in aquatic ecosystems, where many chemical transformations occur (Sipaúba – Tavares, 1994; Avnimelech & Ritvo, 2003). Poor soil and water quality in ponds can stress fish and shrimp, causing loss of appetite, slow growth, greater susceptibility to diseases and parasites as well as higher mortality rates (Boyd, 1997a). As shrimp health is directly related to soil and water quality, environmental improvements can be achieved through the use of appropriate management techniques (Pereira et al., 2004; William, 2002; McIntosh et al., 2001).

The term organic matter corresponds to scraps and detritus originating from vegetal matter and animals on the bottom of the aquatic ecosystem. Organic matter in the sediment is divided in two parts: unstable, which decomposes quickly; and refractory, which decomposes slowly. Organic matter decomposition occurs mainly in the aerobic layer 1.0 mm over the pond bottom (Boyd, 2004). It should be emphasized that accumulated organic matter can affect the health of the pond and, consequently, the farmed species due to decreased oxygen levels and the appearance of toxic substances (Hernádez & Nunes, 2001; Jamu & Piedraheta, 2002). Organic sediment accumulation after successive farming periods has a negative impact on benthonic fauna and water quality (Mukhi et al., 2001). Nunes (2001) demonstrated that an increase in organic matter in pond soil leads to a higher oxygen demand during the degradation process. The accumulation of organic matter is generally caused by high doses of fertilizers, large quantities of feed and dead plankton, leading to a higher Biochemical Oxygen Demand (BOD) (Nunes et al., 2004). A high BOD in pond water brings about a higher concentration of this variable in the effluent water, which could surpass the levels recommended by environmental agencies and the Global Aquaculture Alliance (< 30 mg L^{-1}) and lead to low concentrations of dissolved oxygen in the water column.

In aquaculture ponds, an increase in organic matter normally occurs during culture cycles, as new ponds generally have a small amount of organic matter and all additional material is quickly decomposed. However, if there is a lack of proper treatment, the concentration of organic matter increases after successive harvests and the decomposition rate is reduced (Nunes et al., 2004). Ritvo et al. (2002) pointed out that there is a correlation between the concentration of nutrients, such as potassium, nitrogen, carbon, boron, iron, zinc, and manganese, and the time period the shrimp ponds have been in use. Soil treatment by removing or oxidizing the excessive organic matter in the pond sediment is one of the recommended biosafety practices. In Brazil, 95% of shrimp producers treat pond soil with pH correction and metabolic elimination (Rocha et al., 2004).

A number of studies have shown that soil quality affects the productivity of aquatic organisms, especially in shrimp culture (Boyd & Munsiri, 1996; Boyd & Munsiri, 1997; Ritvo et al., 1998; Sonnenholzner & Boyd, 2000a; Sonnenholzner & Boyd, 2000b; Ritvo et al., 2000, Ritvo et al., 2002; Lemmonnier et al., 2002; Tepe & Boyd, 2002; Méndez et al., 2004; Brito et al., 2005). When there is a lack of oxygen, microorganisms utilize another electron receptors, following the sequence NO_3^-, Mn^{+4}, Fe^{+3}, SO_4^{-2} and HCO_3^-, as the redox potential reduce. According to Chien (1989), most aquatic culture environments have a small redox potential, resulting in thermal stratification of the water column and organic matter decomposition. To solve this problem, the sodium nitrate application has been suggested as an organic matter oxidant for use in pond soil (Boyd, 1997a). Thus, the present study sought to test the use of sodium nitrate enriched with phosphorus, sodium silicate, boron, magnesium, sulfur and potassium in marine shrimp ponds to improve organic matter oxidation and pH correction.

Material and methods

Experimental design

The experiment was conducted for a period of 130 days on a marine shrimp farm located in Goiana, Pernambuco, Brazil. A total of 40 ha were used, divided into four ponds of 8 ha and two of 4 ha. Two treatments considered were: SN (sodium nitrate enriched with 6.0% phosphorus (P_2O_5), 23.2% sodium (Na), 3.5% soluble silicate (SiO_2), 0.35% boron (B), 0.15% magnesium (Mg), 0.08% sulfur (S) and 0.37% potassium (K)); and SNS (urea, triple super phosphate and silicate). Both treatments had three repetitions, totaling six experimental units.

Sample collection and analyses

For the sediment collection, a 35 cm length of PVC pipe with a diameter of 50 mm was used. The pipe was marked externally every 5 cm from the base to orient soil penetration until the collection depth (Boyd, 2004). Only the sub-samples contained in the last 10 cm of the pipe were utilized for analysis.

Samples were collected at the beginning of the experiment before the ponds were filled. Further samples were collected at the end of the culture period, taking sub-samples with approximately ½ kg of sediment for each hectare of surface pond area. Each sub-sample was separated for the final sample composition by pond. All sub-samples from each pond were mixed in a plastic bucket and homogenized, from which a single sample with a mean weight of 1 kg was taken. The final sample was maintained protected from the sun at room temperature in a plastic bag labeled with the date, place and pond number. Sample preparation (Allen, 1989), pH of the soil (Vinatea et al., 2004) and organic matter analyses (APHA, 1995) were performed at the Limnology Laboratory of the Fisheries and Aquaculture Department/Pernambuco Federal Rural University.

Sodium nitrate application (SN treatment)

A quantity of 250 kg ha^{-1} sodium nitrate was directly applied to the soil without dilution in strips at 5m intervals from the slope of the pond. Twenty four hours after the application, the ponds were filled to 50% of the operation level (Castro, 2000). After shrimp stocking, doses of sodium nitrate were utilized, improving the water column for the required culture levels (Table 1).

Table 1. Application protocol of sodium nitrate enriched with phosphorus, silicate, boron, magnesium, sulfur and potassium in *Litopenaeus vannamei* farming ponds

Tabela. *Doses de nitrato de sódio enrequecido com fósforo, silicato, boro, magnésio enxofre e potássio aplicados nos viveiros de* Litopenaeus vannamei

Sodium Nitrate			Dosage (kg/ha)	Observations
	Application in the soil	250	without dilution	one dose
Application in the water column	Week (stocking)	30	Dilution	two doses
	1	20	Without dilution	one dose
	2	20	Dilution	two doses
	3	20	Without dilution	one dose
	4	15	Without dilution	one dose
	5	10	Without dilution	one dose
	6	15	Without dilution	one dose
	7	10	Without dilution	one dose
	8	10	Without dilution	one dose
	9	10	Without dilution	one dose
	10	10	Without dilution	one dose
	11	10	Without dilution	one dose
	12	5	Without dilution	one dose
	13	5	Without dilution	one dose
	14	5	Without dilution	one dose
	15 [a]	5	Without dilution	one dose
	Total kg/cycle	450		

[a]After the fifteenth week of culture, the sodium nitrate enriched with phosphorus, sodium silicate, boron, magnesium, sulfur and potassium was applied weekly at 5kg ha^{-1} without dilution in a single dose until the end of the culture cycle.

Specific program of urea, triple super phosphate and silicate application (SNS treatment)

Before filling the ponds, soil correction was performed through calcareous application, adjusting each pond according to the pH of the soil (Boyd, 1997a). In this treatment, commonly used inorganic fertilizers (urea, triple super phosphate and sodium silicate) in marine shrimp farms of Northeast of Brazil were utilized. Fertilizers were applied weekly in a diluted form at proportions of 40 to 10 kg ha^{-1} of urea, 10 to 4 kg ha^{-1} of triple super phosphate and 10 to 4 kg ha^{-1} of sodium silicate. The amount of fertilizer was chosen according to the pond water transparency.

Shrimp density and feeding

The density utilized was 35 shrimps m^{-2}. Shrimps were fed with a commercial ration of 30% CP (crude protein) distributed in trays and the quantity offered was adjusted daily according to the ration consumption observed in the trays.

Statistical analysis

Data analysis utilized the descriptive method expressed in confidence intervals and subsequently applied experimental statistics considering the Student "t" test ($P<0.05$).

RESULTS AND DISCUSSION

Soil organic matter

The analysis of the soil organic matter for the SN and SNS treatments revealed an initial average concentration of 1.930 ± 0.952% and 2.0167 ± 0.001%, with a final concentration of 1.231 ± 0.075% and 1.612 ± 0.063%, indicating a 36.2 ± 4.0% and 20.0 ± 3.1% oxidation of the organic matter, respectively. Thus, there was a significant difference between treatments regarding oxidation of the final organic matter (Table 2).

Table 2. Percentage of organic matter and pH at the beginning and final culture cycle (average, n = 3 ± standard deviation)

Table 2. *Percentagem de matéria orgânica e pH no início e no final do ciclo (média n = 3 ± desvio padrão)*

Treatments	SN	SNS
Initial organic matter (%)	1.930 ^{a} ± 0.952	2.016 ^{a} ± 0.001
Final organic matter (%)	1.231 ^{a} ± 0.075	1.612 ^{b} ± 0.063
Organic matter oxidation (%)	36.2 ^{a} ± 4.0	20.0 ^{a} ± 3.1
Initial pH	5.3 ^{a} ± 0.5	5.8 ^{a} ± 1.5
Final pH	7.1 ^{a} ± 0.6	5.1 ^{b} ± 0.3

SN = Sodium nitrate enriched with phosphorus, sodium, silicate, boron, magnesium, sulfur and potassium. SNS = Urea, triple super phosphate and sodium silicate.
Letters (a, b) indicate differences between treatments according to the Student "t" test ($P<0.05$).

Organic matter oxidation occurred in both treatments. Focken et al. (1998) reported an increase in organic matter from 3.7 to 7.8% over three months in *P. monodon* culture using a semi-intensive system in the Philippines. In *L. stylirostris* farming, Martinez-Cordova et al. (2002) found an increase in organic matter from 0.69 to 2.78% in ponds without fertilization, whereas this increase was from 0.77 to 3.63% in fertilized ponds. Ritvo et al. (1998) monitored soil quality after consecutive culture cycles on a Bowers Marine Shrimp Farm in Texas (USA) and found that organic matter went from 1.4 to 1.5% and nitrate concentration was reduced from 38.8 mg kg^{-1} to 30.9 mg kg^{-1} soil. Nitrate is the first element to be formed in organic matter decomposition following soil oxygen consumption through aerobiosis to anaerobiosis. Thus, the application of nitrate in soil and water is important, as the oxygen concentration in soil is most often very low.

The percentage of organic matter oxidation in the present study for the SNS and SN treatments was 20.0 ± 3.1% and 36.2 ± 4.0%, respectively. The explanation for this, may be that the quantities of fertilizers and rations used in the SNS treatment varied according to the culture environment and consumption by the shrimp, as indicated by water transparency and the trays. For the SN treatment, the organic matter oxidation was higher and the sodium nitrate acted as an environmental regulator.

Seo and Boyd (2001) found no difference in organic matter in soil ponds fertilized with and without sodium nitrate. Sodium nitrate is highly soluble and cannot be applied to waterlogged soil. It must be applied in dry ponds, stirring the soil to improve its oxidation power (Masuda & Boyd, 1994).

Méndez et al. (2004) studied the influence of organic matter on *L. stylirostris* post-larvae culture in four different areas in Mexico and found the best production results in areas where the initial concentration of organic matter was below 4.0%. Lemmonnier et al. (2002) state that soil degradation has a notable role in the reduction of survival rates and shrimp production in ponds.

In the present experiment, there was a significant difference in organic matter oxidation when sodium nitrate was used in the soil treatment and pond fertilization. The SN treatment provided a greater reduction in organic matter. Boyd (1995) states that when used in soil, sodium nitrate can be beneficial to oxidation. Similarly, Avnimelech & Ritvo (2003) recommend the use of sodium nitrate to improve soil quality, as nitrate is a reasonable oxidant and can reduce soil redox.

Nitrogen, phosphorus and organic matter tend to have higher concentrations in pond soil, having accumulated over time. The discharge of these compounds into effluents in natural environments can compromise the assimilation capacity of the receiving ecosystem (Boyd, 1997b). This discharge consequently causes eutrophication, thereby compromising water quality.

pH of the Soil

pH values of the soil in the SN and SNS treatments were 5.3 ± 0.5 and 5.8 ± 1.5 at the beginning of the farming, and 7.1 ± 0.6 and 5.1 ± 0.3 at the end of the farming, presenting a significant difference between treatments (Table 2).

Seo and Boyd (2001) found an increase from 6.5 to 7.1 in the pH of ponds fertilized with sodium nitrate when compared to ponds without sodium nitrate, when pH values varied from 6.7 to 6.9 from the beginning to the end of the culture. Ritvo et al. (1998) evaluated soil quality in two marine shrimp farms in Texas and found reductions from 7.6 to 7.1 and 8.6 to 8.2 after consecutive culture cycles. Ritvo et al. (2002) and Tepe & Boyd (2002) also found a reduction in the pH of the soil during consecutives cycles of production. Sonnenholzner & Boyd (2000) observed soil pH values varying from 4.8 to 8.2 in marine shrimp farms in Ecuador.

The pH of the soil influences the pH of the water. The acidic pH of the water makes the added phosphorus in this system precipitate with iron and aluminum. When the water is alkaline, phosphorus precipitates with calcium and is unavailable for use by phytoplankton (Vinatea, 1997). The SN treatment provided neutralization of the pH of the soil, favoring the decomposition of organic matter and minimizing the probability of phosphorus precipitation. One of the reasons for soil acidity is the oxidation of organic matter in anaerobic conditions, as such conditions produce a large number of organic acids (Ritvo et al., 1998). The acidic pH indicates the presence of sulfuric acid in the soil ponds (Johnston et al., 2002), which is a toxic substance that is highly inappropriate for benthic organisms. Moreover, when the pH of the soil is acidic, a greater quantity of calcareous is required for correction, thereby increasing the costs of production.

CONCLUSIONS

The strategy of SN fertilization improved soil quality in the marine shrimp ponds. It is advisable to apply sodium nitrate in accordance with the initial concentration of organic matter in the soil.

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