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Reuse of inland low-salinity shrimp farm effluent for melon irrigation

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ABSTRACT

Environmental impacts associated with inland shrimp farming may be attenuated by using its effluent for crop irrigation. The objective of this study was to evaluate melon (*Cucumis melo* L.) yield and changes in soil chemical characteristics, in response to irrigation with low-salinity shrimp farm effluent, and to compare the results with freshwater irrigation. The following treatments were applied: two sources of water for melon drip irrigation (shrimp effluent and river water) as main factors and two nitrogen doses applied through fertigation (120 and 90 kg N ha^{-1}) as sub-factors. There were no significant differences among treatments regarding melon yield and fruit quality. Compared to river water, effluent irrigation decreased pH, calcium, and magnesium levels in the soil, increasing the exchangeable sodium ratio (ESR).
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1. Introduction

In recent years inland shrimp farming has grown rapidly in the Brazilian northeastern region, because of the development of technology for culturing *Litopenaeus vannamei* in low salinity water. In the Low Jaguaribe region the area occupied by inland shrimp farms reached more than 400 ha in 2004. Most of these farms discharge their effluents to lagoons, and to the Jaguaribe River, without any treatment (Figueiredo et al., 2005). That fact has raised concerns regarding potential environmental impacts, and the sustainability of shrimp farming in that region.

In semi-intensive and intensive pond systems, it is not uncommon to have up to 30–40% pond water volume exchange a day to supply oxygen, and to improve water quality (Samocha and Lawrence, 1997). According to Figueiredo et al. (2006), at the Low Jaguaribe Valley, the water exchange rate on inland shrimp farms usually ranges from 2 to 7% a day. Shrimp ponds often have higher concentrations of nutrients, plankton, suspended solids, and oxygen demand than the water bodies into which they discharge. Thus, pond effluents are potential sources of pollution in receiving waters (Boyd, 2003). Nitrogen and phosphorus pollution from feeds in shrimp farm effluents are considered a major concern to receiving water bodies and frequently contribute to their eutrophication (Dierberg and Kiattisimkul, 1996; Paez-Osuna et al., 1998).

Inland shrimp farming specific environmental impacts of concern include soil salinization, water quality degradation as a result of effluent disposal, and water use conflicts with competing activities such as agriculture (Flaherty et al., 2000; Pongnak, 1999). Those negative impacts may assume even greater importance in the semi-arid Brazilian northeastern region, which historically have suffered from water scarcity.

McIntosh and Fitzsimmons (2003) pointed out that in arid regions, integrating aquaculture production into traditional agriculture could be one solution to achieve a more efficient water use, by maximizing farm production without increasing water consumption. Besides that, the potential benefit of having nutrient enriched wastewater to irrigate field crops could be substantial, reducing the reliance on chemical fertilizers. They estimated that the amount of nitrogen in low salinity shrimp effluent could supply between 20 and 31% of the necessary fertilizer for wheat production.

Some possible negative impacts of using low salinity shrimp effluent for irrigation include soil salinization, and nitrate leaching. Also if the amount of nutrients added to soil by the effluent exceeds crop absorption capacity, it could build up to toxic levels. The present study aimed to quantify the effects of irrigating with low-salinity shrimp farm effluent on melon yield and soil chemical characteristics.

2. Materials and methods

The field study was carried out at Poço da Onça Farm in Russas, Northeastern Brazil, from June to September 2006. The farm uses water from the Jaguaribe River to grow marine shrimp (*L. vannamei*), in two ponds of 3 ha each. The estimated average daily water exchange rate was approximately 1%, with all effluents, including those generated during shrimp harvests, being collected in a drainage ditch, and used to irrigate forage (*Panicum maximum*) or discharged into the river.

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The soil on the experimental site was classified as a Fluvial Neosoil (loam soil, according to the United States Department of Agriculture textural classification), containing 18% clay, 36% silt, and 46% sand. The experimental design chosen to quantify the effect of low-salinity shrimp farm effluent on melon was a randomized block design factorial with five replications. Treatments included: two sources of water for crop irrigation (shrimp effluent and river) as main factors, and two nitrogen doses applied through fertigation (100 and 75% of the recommended N for melon) as sub-factors. The nitrogen doses were chosen to test the hypothesis that shrimp effluent could supply about one fourth of the necessary N fertilizer to the crop.

Plot dimensions were 9.0 m $\times$ 6.0 m. Soil preparation included a moldboard plowing followed by manual preparation of raised beds, which were 0.8-m wide, 0.1-m high, and spaced 2.0 m between centers of adjacent beds. A pre-plant fertilization was done 14 days before transplanting, by incorporating to the soil beds 375 kg ha^{-1} of triple superphosphate (41% of P_2O_5 and 12% of Ca), and 50 kg ha^{-1} of fritted trace elements. Then the beds were covered with plastic mulch.

Melon (*Cucumis melo* L. hybrid AF646) 10-day-old seedlings were transplanted to the beds at a spacing of 2.0 m between rows by 0.5 m between plants in a row. After the transplanting, the beds were covered with a white non-woven fabric to protect plants against insects. The non-woven cover was removed 24 days after the transplanting to allow flower pollination by honeybees.

Nitrogen and potassium were applied through fertigation, in every irrigation event, using urea (44% of N), and potassium chloride (58% of K_2O) as fertilizer sources. A total amount of 230 kg ha^{-1} of K_2O was applied to the plots. The amounts of nitrogen applied were 120 and 90 kg ha^{-1} for treatments with 100 and 75% of the recommended N dose, respectively. Insects and diseases were controlled when necessary.

The crop was drip-irrigated using one lateral per row, and a drip spacing of 0.5 m along laterals. A dripline was used, with emitter nominal discharge of 3.0 L h^{-1}, at an operating pressure of 200 kPa. Water for the effluent treatments was pumped from the shrimp farm's drainage ditch. For the control treatments water was pumped from the Jaguaribe River.

Irrigation scheduling was based on crop evapotranspiration replenishment. Irrigation depths varied along the melon cycle, according to crop water requirements, being calculated based on monthly reference evapotranspiration (ETo), and crop coefficients (Kc) locally determined by Miranda et al. (1999). Water was applied every 2 days. Water meters were used to check the application of the predetermined water depth, and to assure that all treatments would receive the same amount of water.

The crop was harvested at 55 and 62 days after transplanting. Fruit yield, fruit weight, and total soluble solids (TSS) solids were evaluated. Data were submitted to variance analysis by Anova followed by *F*-test considering $p < 0.05$ aiming to detect significant differences among treatments.

Effluent and river water samples were collected every 2 weeks for macronutrient and salinity analysis. Samples were collected from the drippers, and analyzed for pH, EC_w, SAR, total N, nitrate-N, ammonium-N, CO_3, HCO_3, SO_4, P, K, Ca, Mg, Cl, and Na, according to the methodology described by (Richards, 1954). A *t*-test was applied to the irrigation water data, to detect differences between means.

Soil samples were collected at the beginning (before soil preparation), and at the end of the study (after harvest) to measure macronutrient concentrations, and soil salinity. Samples were taken using a 0.075-m soil corer, from the center of row beds, at two depths (0–0.2 and 0.2–0.4 m). Three individual cores were collected from each plot, and then mixed to form composite samples. Soil samples were analyzed for P, Ca, Mg, K, Na, S-SO_4, pH, EC_e, exchangeable sodium ratio (ESR), and organic matter content, according to the methodology described by (Embrapa, 1997). Data were analyzed using a paired sample *t*-test to investigate statistical differences between plots irrigated with the two water sources before and after treatments were applied.

3. Results

3.1. Irrigation water

Among irrigation water quality parameters monitored, statistically significant differences at the 10% level were found in pH, Ca, Na, and Cl (Table 1). The pH in the effluent was lower than in the Jaguaribe River water ($t = -2.38$, $p < 0.1$). Levels of Ca ($t = 1.96$, $p < 0.1$), Na ($t = 2.05$, $p < 0.1$), and Cl ($t = 2.80$, $p < 0.1$) were higher in the effluent as compared to river water.

Observed Ca high levels in the shrimp effluent as compared to river water may be attributed to the application of limestone ($CaCO_3$) to the bottom of the ponds prior to shrimp stocking. This is a common practice in the region, used for pond disinfection after shrimp harvest. The effluent higher levels of Na and Cl as compared to river water were probably due to water evaporation in the ponds during the shrimp growing cycle and to feeds residues.

With respect to salinity, the effluent EC_w ranged from 0.62 to 0.72 dS m^{-1} during the experiment, and was similar ($p = 0.142$) to the river water EC_w, which ranged from 0.57 to 0.67 dS m^{-1}. Even though the Na level in the effluent was higher than in the river water, Ca and Mg also increased. That maintained the effluent SAR similar ($p = 0.805$) to that observed in the Jaguaribe River water.

According to the Food and Agriculture Organization (FAO) water quality guidelines (Ayers and Westcot, 1985), both the river water and the shrimp effluent did not present any restriction for irrigation regarding to salinity ($EC_w < 0.7$ dS m^{-1}). However, both water sources presented slight to moderate restriction for irrigation regarding to reduction in soil-water infiltration, and toxicity of sodium and chloride for sensitive crops.

Although total nitrogen and ammonium-N levels were higher in the effluent than in the river water, by 49 and 27%, respectively, the differences were not statistically significant ($p > 0.10$). That probably occurred due to the reduced number of water samples analyzed during the experiment (four). Other studies have shown that shrimp farm effluent presented significantly higher levels of both total nitrogen and ammonium nitrogen as compared to

Table 1
Levels of selected water quality parameters measured from both river and effluent water during the experiment

Parameter	Effluent	River	Difference (E − R)
pH	8.02	8.64	-0.62^{*}
Ammonium-nitrogen (mg L^{-1})	2.13	1.68	0.45^{ns}
Nitrate-nitrogen (mg L^{-1})	1.25	1.23	0.02^{ns}
Total nitrogen (mg L^{-1})	4.48	3.00	1.48^{ns}
P (mg L^{-1})	0.49	0.42	0.07^{ns}
K (mg L^{-1})	10.92	9.72	1.20^{ns}
Ca (mg L^{-1})	30.95	22.84	8.11^{*}
Mg (mg L^{-1})	27.16	21.84	5.32^{ns}
Na (mg L^{-1})	90.21	82.20	8.01^{*}
Cl (mg L^{-1})	173.53	153.12	20.41^{*}
SO_4 (mmolc L^{-1})	0.07	0.07	0.00^{ns}
CO_3 (mmolc L^{-1})	0.13	0.41	-0.28^{ns}
HCO_3 (mmolc L^{-1})	2.77	2.52	0.25^{ns}
EC_w (dS m^{-1})	0.66	0.60	0.06^{ns}
SAR	2.93	3.03	-0.10^{ns}

Symbol (*) and ns denote statistical significance at the 10% level, and statistically non-significant, respectively.

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