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Evaluation of a Polyculture System Utilizing Several Plant Species to Enhance Phosphorus and Nitrogen Removal from Land-based Fish Farm Effluent

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Introduction

Most land-based fish farms in British Columbia release fish culture effluent to the environment on an ongoing basis. There have been major improvements in the capture and removal of solids from the effluent, but soluble minerals (such as nitrate and phosphate) are potentially being released into ground and surface water. The objective of this study was to examine the potential of *Wasabia japonica* (wasabi) and hybrid poplar (*Populus trichocarpa* x *Populus deltoids*) to remove soluble phosphorus and nitrogen from effluent water issuing from a land-based fish farm. In addition, the potential for wasabi grown in fish farm effluent to serve as a secondary commercial crop for land-based fish farms was explored.

Methods and Materials

In 2001, a preliminary trial using a small-scale aquaponic system was conducted to evaluate the potential of growing wasabi in the effluent water from the Brumar Consulting Ltd. freshwater salmon farm. The purpose of the initial usage of wasabi plants was to determine if they would survive aquaponic conditions using fish farm effluent water. At the end of the trial, wasabi plants were removed from the aquaponic bed and measured. All the plants survived and increased in biomass from the initial transplant. Based on the success of this preliminary trial, a research project was designed and submitted for funding under the Aquaculture Collaborative Research and Development Program (ACRDP) of Fisheries and Oceans Canada.

At the start of the experiment, 500 juvenile (<5 g) Atlantic salmon (*Salmo salar*) were placed in each of 100 tanks (~100 L). Fish were reared to ~5 g at which time 50 fish per tank were PIT tagged and then transferred into a 9-m^3 tank. The remaining fish were reared to ~20 g at which time they were heat branded and then pooled into another 9-m^3 tank. Surplus fish were transferred into a 12-m diameter tank until transfer (~20 to 30 g). All the effluent water in the rearing facility went through a drum filter (60 µm) before going to the wasabi or poplar beds.

In the experiment, wasabi was grown aquaponically in raised wooden boxes (beds) (Fig. 1). Each bed measured 6.0 x 1.5 x 0.3 m (L x W x H) and was filled to a depth of 25 cm with substrate. The beds were physically isolated from the ground with plastic. Beds were built with a slight downward slope, with feed solution (water or fish effluent) entering the beds at the higher end and being removed via a drain port at the opposite, lower end. A total of nine beds were arranged in three blocks, allowing for three treatments per block and a total of three replicates (beds) per treatment. Plants derived from side shoots taken from mature wasabi plants were transplanted July 3 and 4, 2002 into each of the following three treatments: pea gravel substrate with fresh well water, pea gravel substrate with fish effluent, and rock substrate (2 to 4 cm in diameter) with fish effluent. The plants were continuously trickle-irrigated with either fish-farm effluent or plain well water throughout the entire trial. Each bed held 90 plants arranged in five rows. Since wasabi requires shade, particularly in the summer months, the entire experimental area was periodically covered with shade cloth suspended above the beds. Over the course of the trial, air temperature (hourly), light intensity (periodically), water temperature (hourly), and flow rate (biweekly) measurements were collected. In addition, various mineral and ion (i.e. sodium, potassium, magnesium, calcium, chlorine, ammonia, nitrite, nitrate, phosphate, sulphate) concentrations and pH were measured biweekly in input and output solutions in the three wasabi treatments.

Three wasabi plants were destructively harvested from each bed of each treatment (total of nine plants per treatment) in November, 2002 and March, 2003. A final, more extensive, destructive harvest was conducted in October, 2003, consisting of 15 plants per block per treatment (total of 45 plants per treatment). A number of measurements were taken from each plant including: leaf number, leaf area, leaf fresh/dry weight, petiole fresh/dry weight, stem fresh/dry weight, stem length, stem width, root fresh/dry weight, side shoot number, side shoot leaf number, side shoot leaf area, side shoot leaf fresh/dry weight, side shoot petiole fresh weight, and total plant fresh/dry weight. In addition, various mineral (i.e. nitrogen, calcium, potassium, magnesium, phosphorus, sulphur, boron, copper, iron, manganese, molybdenum, sodium, zinc) concentrations in the plants were measured.

Hybrid poplar whips (64 plants per tank, planting density of 14 plants m^{-2}) were transplanted into three large circular tanks (4.5 m in diameter) filled with pea gravel. A continuous flow of fish effluent entered each of the tanks through a manifold at the top and drained from an outlet in the bottom. Unlike the wasabi trials, there was no water-only treatment. Destructive harvests were carried out in November, 2002 and October, 2003. On both dates, five trees were sampled from each of the three tanks. A number of measurements were taken from each tree including: leaf number, leaf fresh/dry weight, branch fresh/dry weight, trunk fresh/dry weight, trunk diameter, height, and root fresh/dry weight. In addition, various mineral (same as for wasabi plants) concentrations in the trees were measured.

Results

Wasabi

Very few significant differences in growth parameters were found when comparing the three treatments in the first harvest (November, 2002). This was likely due to the large initial variation in plant size which was observed during planting out, and which apparently followed to the first harvest. The only treatment differences noted were an increased area and fresh weight of side shoot leaves in the fish effluent in pea gravel treatment in comparison with the water only treatment. Again, few differences in various growth parameters were observed when comparing the water and effluent treatments in the second harvest in March, 2003 (side shoot leaf number and petiole fresh weight was higher in the fish effluent in gravel treatment). By the third harvest (October, 2003), however, it became clear that the plants grown in fish effluent were doing better than those in plain water, with significant differences in most growth parameters.

In order to compare nutrient environments in the two pea gravel treatments, we made periodic measurements of dissolved minerals in each feed solution using HPLC/ion chromatography. Due to the high measurement variability within each sampling location, no clear differences could be observed between water and effluent input concentrations. The data do show, however, that the concentrations of minerals in the effluent were very low, approaching that of ground water.

Total uptake of all minerals was higher in the effluent-grown plants compared to those grown in well water. The higher mineral content in effluent-grown plants was probably associated with their overall greater biomass.

Poplar

Trees appeared to be healthy throughout the trial (Fig. 2). Most of the tree biomass was concentrated in the main trunk, with lesser and approximately equal biomass found in the leaves and branches. The concentrations of most minerals were highest in the leaves compared to the branches and trunk. As a result, leaves were often the major contributors to total plant content of a particular mineral, such as nitrogen. In other cases, such as phosphorus, the trunk contributed as much to the total tree content as did the leaves.

Conclusions

This project proved that wasabi and hybrid poplar do have the potential for the removal of soluble nitrate and phosphorus from land-based salmon farm effluent water. More study is required to develop techniques that optimize nutrient removal from freshwater effluent water with wasabi, hybrid polar, and other plant species.

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Fig. 1 Wasabi growing in beds irrigated with fish effluent.

Fig. 2 Poplar stand growing in fish effluent.