

Market Grade Fish with a Side of Basil



Jon Jordan

The UA aquaponic system links 250-gallon tanks of tilapia (foreground) with hydroponic beds of basil (background). The system conserves water and nutrients by circulating fish waste to the plants, which in turn filter the water that goes back to the fish.

Sustainable aquaculture and hydroponics

By Susan McGinley

It's no surprise that fish and herbs go together on a dinner plate, but at the University of Arizona's Environmental Research Laboratory they also *grow* together quite well. In a greenhouse "aquaponics" system that combines aquaculture with hydroponics, Nile tilapia swim in 250-gallon tanks (about 950 liters) linked to hydroponic growing beds planted with Genovese basil. The system conserves water and nutrients by circulating fish waste to the plants, which in turn filter the water that goes back to the fish.

While aquaponic methods have been studied before, the goal of this project was to find a minimal ratio of fish mass to plant mass that would produce commercial grade basil. Graduate student Jon Jordan and professor Joel Cuello, both from the Department of Agricultural and Biosystems Engineering, and professor Kevin Fitzsimmons, Department of Soil, Water and Environmental Science, wanted to develop a simple system that could be replicated by small or large growers anywhere in the world. Expanding urban populations and shrinking farmland worldwide have forced growers to develop intensive agriculture systems that yield more food on less land.

In 2005 the team set up nine separate aquaponic units, stocked them with fish, planted the basil, and began testing different fish densities and feeding rates. The amount of basil planted for each unit remained the same for all treatments, but the fish tanks were stocked with 3, 6, and 9 kilograms of tilapia. The fish were fed 60, 90 and 120 grams of feed per day, respectively in the first experiment. In a second experiment 4, 6 and 8 kilos of fish were fed 60, 90 and 120 grams of feed per day.

"We varied the biomass and feed rates of the fish in different replications of the trial while keeping the plant numbers the same," Jordan says. "We wanted acceptable market quality for the fish and the basil. There was a notable difference in quality and quantity of basil between treatments. The system was also very water efficient, with a water loss of only 0.7 percent of the total system volume per day due to evaporation. Additionally, no extra fertilizers aside from fish feed were added."

The system conserves water and nutrients by circulating fish waste to the plants, which in turn filter the water that goes back to the fish.

The researchers selected the Nile tilapia (*Oreochromis niloticus*), a native African fish, for its hardiness, preference for warm water, wide availability, and worldwide popularity as a food fish, according to Fitzsimmons.

"Tilapia is the second most common farmed fish in the world and now is the fifth most popular seafood item for US consumers," he says. "It's ideal for aquaponic systems because it's hardy and disease resistant. It thrives in warm water, and large schools of fish can be reared in small volumes of water."

Basil (*Ocimum basilicum*) was chosen as the complementary plant crop for its commercial value, the simplicity of its culture, and its preference for warm, high-light environments, according to the research team. The plants were germinated separately and

transplanted into each of the .9 square meter hydroponic modules at the rate of 34 plants per module.

“There were six treatments, with differing amounts of fish,” Cuello says. “Pairing aquaculture with hydroponics has been done before, but mainly as demonstrations. “We’ve actually established the minimal amount of fish for our 1400-liter system. If you want to increase production, you just increase the size of the project, keeping the same ratio of fish to plants.”

“Our minimum fish stocking density and feed rate to obtain commercially acceptable basil plants was found to be six kilograms of fish receiving 60 grams of feed per day for the 34 basil plants, spread over a 0.9 square-meter growing area,” Jordan explains. He notes that he would recommend a design ratio closer to 100 grams of feed per square meter of crop growing space, but that wasn’t strictly supported by the statistics.

The yield depends entirely on the scale of the system and the way it’s managed. “In my particular case I was yielding two to three kilograms of basil per square meter per 40-day growing cycle,” Jordan says. “Fish growth was a lot more variable between experiments and I can’t really generalize about what was yielded.”

Over the past hundred years, as the world’s population has expanded exponentially, modern agriculture has developed ways to keep up with the food



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The aquaponic system yields high quality basil.

demand by producing more food on less land. This major accomplishment has proved Malthus’ predictions of human demise wrong, according to Cuello. Malthus wrote that human populations increase geometrically (if unchecked), while food production can only increase arithmetically, leading eventually to mass starvation.

“Instead, agricultural science and agricultural engineering have helped realize large-scale food production and have increased the carrying capacity of the earth,” Cuello says. Yet some of these farming techniques have contributed

to air, water and soil pollution, and the depletion of fossil fuels.

“Our problem now is how do we keep up with the demand for agricultural production without depleting our natural resources and damaging our environment? Americans are currently the number one consumers in the world, consuming at least one-fourth of every natural resource while representing only 1/20th of the global population,” Cuello says. “But in the decades to come, hundreds of millions will be joining the middle class in China, India and other developing countries. Our challenge over the next hundred years is sustainability.”

The goal is to produce high quality food and make a profit while preserving the environment. By yielding market grade fish and basil, conserving water and using no pesticides or external fertilizer aside from the fish feed, the greenhouse aquaponics system tested at the UA is a step toward this goal.

“We’re using what we have, combined with new technology,” Cuello says. ☒



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Nile tilapia serve as an ideal fish in an aquaponic system that combines aquaculture and hydroponically-grown plants. Tilapia are hardy and disease-resistant, widely available and popular worldwide as a food fish.

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