Aquaculture in Greenhouses:

Fish and Vegetables Grow Together

When the Indians tossed a few dead fish into the ground with their corn seeds, they were providing a great source of fertilizer. Since fish decay rapidly, their proteins and amino acids quickly turn into nitrogen which can be used by the plants. A 20th-century version of the plant/fish combination uses live fish to supply the protein. This not only smells a whole lot better, it makes a lot of sense. You get two high value crops from the same space and the same amount of water. Now being developed on a small scale in an experimental greenhouse, integrating aquaculture with vegetable production may turn out to be a good way to increase greenhouse profits in North Carolina and improve food supplies in developing nations.

When you walk into the greenhouse where graduate student Mark McMurtry has been running his experiments, you might at first wonder if you have happened upon a fish pond or a vegetable garden.

Under the floor are 16 fish tanks, each one holding 50 hybrid tilapia. On the floor to each side sit sandboxes filled with row after row of tomatoes. It is a system of total mutual dependence: The tomatoes get their nutrients from fish tank water circulating through the sandy soil, and the fish get their water cleaned of solid wastes and ammonia by the plants and soil bacteria.

A doctoral student in the Department of Horticultural Science, McMurtry has been experimenting with different numbers of plants per tank of fish. Small numbers of plants produce more fruit per plant, but larger numbers of plants produce more tomatoes per tank, he says. His yields are pretty good—25 pounds of tomatoes per square yard. He has tried growing cucumbers too, and their yields averaged 26 pounds per square yard.

When horticulture professor Dr. Doug Sanders extrapolates the potential yields of such a system to commercial-scale greenhouse production, it looks as if the combined vegetable-aquaculture operation might net about $25.00/square yard—in comparison with net revenues under $1.00/square yard for conventional one-crop greenhouse systems.

Hundreds of fish live under the 2 x 2 floor of this greenhouse. The tomatoes get their nutrients from circulation of the fish tank water, and the fish get their water cleaned by the plants and soil bacteria.

Fish flourish in the greenhouse, reaching 2 pounds in 7 months.

Yields are extraordinary—25 pounds per square yard.

And, because it is a system which can use the same water over and over, McMurtry believes that it could be adapted for food production in countries with scarce water resources. He has already found that water can be circulated through the system 200 times. The tanks are sloped so that fish wastes accumulate on the bottom. Several times a day, the water is pumped through an irrigation system to the tomato beds.

Nothing is wasted, and both the fish and the tomatoes are marketable. In seven months, with 25 cents worth of fish food, a tilapia grows from .5 ounce to 2 pounds. The system could also be used to grow other vegetables or seedlings or even tree transplants for reforestation.

Keeping a Balance

In this very productive system, bacteria help to maintain the delicate chemical balance. Without two kinds of soil bacteria, the ammonia in the water would be toxic to the fish and unavailable to the plants. The first species of bacteria turns the waste ammonia into a nitrite form which would be poisonous to the fish and useless to the plants. It takes a second species of bacteria to turn the nitrites into nitrates which the plants can use as a source of nitrogen fertilizer. Other species of bacteria recycle other nutrients.

Additional factors McMurtry tracks are the pH of the water and the concentrations of oxygen. To minimize the amount of ammonia produced before these bacteria build up in the closed environment system and the plant roots begin participating in the system, McMurtry says, he feeds the fish at a reduced rate during system startup.

McMurtry hopes that this system will be a useful way for people who live in arid parts of the world to produce the maximum amount of food from the available water. "I am trying to get this system into impoverished regions so that the people can feed themselves year-round," McMurtry says. ■

Mountain Aquaculture:

Mountain Trout

Three types of trout live in the mountain streams of western North Carolina: brown or european trout, brook trout, and rainbow trout, the most widely raised commercial species.

In North Carolina trout are grown in impoundments of surface waters which fluctuate in temperature, quantity, and quality, making trout production a challenging enterprise. However NCSU scientists are trying to lower some of the risks and costs of the fish business.

No Quick Profits

Producing fish is like producing any other animals in captivity—someone has to take constant responsibility for their welfare. Trout reach a marketable size of 12 to 14 ounces in about a year, and a large operation typically produces 100,000 pounds of trout per year. Fish held longer than a year weigh several pounds and bring higher prices, but are also more susceptible to disease and the stresses that come from hot weather, crowding, and sexual maturation.

Since trout are better at converting one animal protein into another than they are at synthesizing protein from plant sources, the best trout feed is already 38 percent protein. It takes 1.5 to 2 pounds of dry fish food to produce 1 pound of fish.

How much food the fish eat depends on water temperature. Milder winters and cooler summers are best for trout. At colder temperatures they don't eat as much as they do at the 55° to 62° that they prefer.

Water Factors

North Carolina mountain waters flow over a crystalline rock substrate which makes them neutral or slightly acidic. These waters have very little mineral content and low buffering capacity to absorb acids or bases without drastic changes in pH. North Carolina waters do, however, have some advantages.

Ammonia, excreted through the gills, is a primary waste product of protein metabolism in fish. In slightly acidic water, the un-ionized NH_3 quickly be-

To maintain oxygen for trout production, water is used serially by stair-stepping tanks one below another with a 4-foot drop between them. The aeration caused by the drop redissolves oxygen in the water for the next tank.