THE AQUA-VEGECULTURE SYSTEM

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The INTEGRATED AQUA-VEGECULTURE SYSTEM (IAVS), developed at NCSU by Dr. Mark McMurtry with the assistance of many collaborators, was reviewed during the 1988 annual meeting of the PVO/University Center at Cullowhee, NC. We all know that corporate memories tend to be short. That, plus the facts that we seem to be entering a new era in assistance projects coupled with our firm conviction that the technique is worthy of a more widespread field testing, prompts us to summarize the concept for you once more.

The IAVS system bears little resemblance to common aquaculture programs. It is a tightly-coupled, virtually symbiotic, system of producing both fish and vegetables on a small area of land and which employs extremely conservative water-management practices. Our continuing research reveals that one can realize both fish and fresh vegetable produce sufficient to feed a family of four, year-long, on a plot merely big enough to park the typical family car. Further, under North Carolina conditions, one can reutilize each unit volume of available water at least 100 times. Moreover, the efficiency in resource utilization and the tremendous productivity achieved in IAVS operations appears to be scale-neutral, except for the direct cost of providing for circulating the water as the fish tank water volume is increased and one goes from a gourd or bucket to mechanical, electric or solar-powered pumping.

A wide range of vegetable crops may be grown in various combinations including tomatoes, cucumbers, melons, eggplant, peppers, beans, lettuce, other greens and herbs; even tree seedlings for reforestation projects. Yields from the research conducted in Raleigh NC indicate that over 50 kilograms of tilapia may be harvested per year for each cubic meter of water cultured (individual fish harvested periodically as they reach 250 grams), plus about 360 kilograms of tomatoes or other vegetable fruits. At these yield rates, a "parking space" sized unit with 3 cubic meters of water and 14 square meters of vegetable filter bed could yield 150 kg of fish and 1100 kg of vegetable fruits per year (an average of 3 kg (7 lb) fish and 21 kg (46 lb) vegetables each week). Including annualized losses for evapotranspiration and incorporation into biomass (food) at 85% of total input and a seepage loss of 6%, each liter of water utilized by the IAVS technique can produce 6 g FW of fish and 17 g DW of vegetables. Collectively, tilapia and tomato yields result in 0.7 g DW of protein and 7 Cal. (or 7,000 calories) per liter of water used.

The main constraints in conventional aquaculture systems are that, as fish numbers/size increase, the dissolved oxygen content in the water decreases, while ammonia concentrations build up over time, which causes the water to acidify and to ultimately become toxic to the fish. The IAVS technique removes the fish waste products (unconsumed feed, fish metabolites, and dead algae), which accumulate on the bottom of the fish-culture tank, and recirculates the purified water which stimulates rapid fish growth. The waste-ladened water is passed through a physical filter (the sand bed), and a 'living filter' (the vegetable crops and micro-flora resident in the sand bed), and finally across an aerating cascade (or other aeration device) as it is returned to the fish-culture tank. Aeration increases the amount of oxygen dissolved in the water which increases the carrying capacity of the tank as well as increasing the rate of fish growth. In the IAVS technique, the conventional constraints to aquaculture production are eliminated, plus an additional crop of vegetables is produced simultaneously, while the water is maximally conserved to be utilized again and again.

A simple INTEGRATED AQUA-VEGECULTURE SYSTEM is illustrated in the attached sketch. Essentially, it is a hole in the ground, lined or sealed to prevent leakage, for the fish, plus a sand filter bed along one side in which the vegetables crops are grown. Several times daily, a fraction of the fish tank water (together with accumulated bottom-residues) are scooped or pumped onto the filter/plant bed surface. The nutrient-loaded water percolates through the filter bed sand, as the largest waste particles are physically filtered from the water at the filter surface. The finer particles and dissolved nutrients are absorbed by the plant roots and the numerous micro-organisms which inhabit the filter bed. The cleaned water tumbles across the cascade aerator by gravity as it returns to the fish tank for another cycle. The filtration/ irrigation event is repeated at regular intervals during daylight hours for as many as eight times per day. The principle operational criterion is to incrementally and cumulatively circulate the equivalent of the total fish tank volume (at a minimum) through the filter bed every day. Once a IAVS operation is installed, the only inputs are fingerlings, seed or transplants, feed for the fish, and some form of energy by which to move the water. Many fish-feed mixes, using locally available resources, have been formulated by various technical assistance organizations. (Note that standard commercial feed formulations are generally not desirable because they may contain high levels of certain trace elements which can build to toxic levels in a tightly-coupled system such as this.) Suitable feed may be locally produced in virtually any rural community (irregardless of region) from readily available resources or it may be prepared to order by commercial feed merchants. In any case, neither the availability nor the cost of feed need be prohibitive since each kilogram of feed input to the system will result in the production of approximately 0.75 kg of fish and 6.70 kg of fresh vegetables.

A minimum, single-family scaled IAVS facility would consist of a one cubic-meter fish tank, with the bottom sloped to a shaped “well” or sump pit, from which the fish waste products and water are bailed with a bucket or calabash. The hole created for the fish tank must be lined or sealed to minimize leakage (this is a water-conservative system) with whatever material is most appropriate at the specific site of application. This might be a sheet of plastic film, a layer of an expansive clay (a clay which expands when moistened and cracks apart when dried), or ‘gley’ (a clay-sealed layer of compacted organic matter and accompanying bacterial slime which naturally forms to seal many ponds and lakes). Adjacent to the fish tank, and connected to it by a drainage pathway, is the filter/ plant bed. At the scale indicated, the filter/plant bed would have a surface area of 4.5 square meters (1.5 meter wide by 3 meter long or equivalent) and have a sand/filter volume of 1.5 cubic meters (or approximately 30 cm. deep). The filter/plant bed is also lined or sealed (except for the drainage outlet) with the bottom of the bed sloped in the direction of the fish tank to facilitate recycling of the water. The fish tank and filter bed are configured (vertically orientated) with respect to each other such as there exists sufficient elevation change between the drainage outlet of the filter bed and the water surface level in the fish tank in which to construct a cascade aerator. The cascade (a series of small waterfalls) is purposefully designed to break the water flow into small droplets and thererfore mixing with the water with air (oxygen) as it falls back to the tank by gravity. The upper surface of the plant/filter bed is prepared to a level grade and is configured as appropriate to accommodate the specific vegetable crops/ species to be cultivated, with channels (irrigation furrows) placed between the rows of plants. These channels facilitate the uniform distribution of irrigation water across the surface (and through the volume) of the filter bed.

An IAVS facility can be built in the open air and the water circulated with only a bucket, or it may be enclosed within a protective structure of plastic film and/or mesh screening. Improved water movement may be accomplished by employing mechanical water pumps (human or animal powered) or with electric pumps operated by automated timers. Some sort of roof (protective enclosure) is often desirable because it reduces evaporation losses, can double as a plant support for vertically cultivated species, can screen out many potential insect pests, can form a barrier to rain-borne plant diseases and, in areas of torrential rains, prevents flooding of the fish tank and filter bed to eliminate the consequent loss of production.

Major inputs at installation are plastic film with which to line both the tank and the plant/ filter bed and the “right” type of sand. The plastic is not an absolute necessity, given availability of the proper type of clay with which to seal against seepage losses. Sourcing a supply of an appropriate grade of sand is a far more critical requirement. The key functional requirements of the sand are that the entire filter/ plant bed drain both completely and fairly rapidly. This is necessary such that the plants do not drown and to insure that a sufficient volume of fish tank water can be circulated each day by which to maintain adequate filtration of the fish wastes and to sufficiently oxygenate the returning water as it falls through the cascade aerator. Therefore, the sand should be fairly coarse, with virtually zero “fines” content (no particles below 200 microns in diameter). The ideal filter sand has a consistency approximately that of common table salt or of granulated sugar with no powdery fraction (larger particles can easily be screened out, if necessary). It is usually relatively easy to find a source of an appropriate grade of sand. From field experience in Africa, it has become clear that it is far better to haul sand from a relatively distant source than it is to wash out even a small percentage of silt/clay from a closer source.

Balancing the amount of fish to the number of plants (actually the rate of feed input to the rate of plant growth) is a crucial management consideration for attaining best results. Too few plants and the water would not be sufficiently purified for reapplication in the fish culture tank; too few fish and the plants would not receive sufficient nutrition. To that extent, operation of an IAVS requires some managerial skill (which can, obviously, only come with experience). However, the range of fish to plant balance is fairly broad, meaning the IAVS technique is relatively “user friendly” and well buffered against rapid changes in water chemistry which could lead to less than most desirable results or longer-term problems. Some previous gardening/husbandry experience on the part of the prospective operator is considered highly desirable. Minimal training in general aquaculture management, pest prevention and mitigation techniques, and simple water quality monitoring techniques is recommended for first-time operators. Even trained operators can sometimes make management “mistakes” in balancing the system’s biological components but these can be readily recognized with regular monitoring (or experienced observation) and “corrected” long before they adversely impair productivity.

Perhaps the most sensitive stage in the balancing process is during the startup phase (in the initialization process). However, once matured/stabilized, the INTEGRATED AQUA-VEGECULTURE SYSTEM is fairly easy to maintain at optimum production levels. Upon initial start-up, obviously there are either no plants at all or only very young transplants, yet there are also many young fish to nurture. How does one maintain a "balance" under these circumstances? For one thing, the initial batch of fingerlings are feed at a reduced rate which is gradually increased in direct proportion to plant growth and to several water quality factors. Water quality factors (concentrations of chemical constituents) will stabilize as populations of beneficial micro-organisms increase in the filter bed. During the initial irrigation event of the filter bed with the waste-ladened water, naturally occurring bacteria and algae are introduced (inoculated) to the filter and their populations will colonize the entire filter bed volume within two months. Until these microbial populations become fully established, feed inputs are minimized so as to result in proportionately reduced volume of waste-products to be processed by the filter bed organisms. Also, prior to the vegetable crops being established and growing rapidly, the filter surface will often turn completely green with algae. Collectively, the bacteria and the algae (micro-flora) are responsible for the chemical transformation of fish waste products into plant-available nutrients and, during the start-up phase, also function as a nutrient sink or buffer until the vegetable plants have attained growth rates sufficient to clean the water themselves. As the plants increase in size, they extract an ever-increasing percentage of the available nutrients from the water and they also begin to shade the surface of the plant bed. This causes a rapid decline in the algal populations and thereby releases the accumulated nutrients, which they represent for absorption by the vegetable crops. The longer an IAVS system (actually a miniature, managed, and complete ecosystem) is allowed to mature (continuously operated without interruption in, or an excess, in feed input rate), the more stable it will tend to become (biologically and chemically). Also over time, operator(s) gain experience in balancing inputs with outputs and refine (develop) management skills which further increase productivity. Typically, IAVS facilities develop into functionally mature ecosystems within three months from initialization and are considered to be fully mature following one-year of continuous management/operation.

"Two principle applications of this technology are readily apparent. One is as a small-holder activity using local inputs, providing food self-sufficiency plus a surplus for the cash market. A second application is large -scale, commercial enterprises sited near a population center. Either approach could be combined with ongoing water harvesting, gardening, or greenhouse projects, planned or already in place. This technology was expressly developed for and is eminently applicable to the requirements of regions where water and/or land resource availability are dominantly limiting to food production." McMurtry, 1986.

The INTEGRATED AQUA-VEGECULTURE SYSTEM holds substantial promise for providing limited-resource farmers an opportunity to augment both the family diet and their income. The prospect of producing meaningful quantities of nutritious food with a minimum adverse impact on the environment is significant. The additional characteristic of being able to do this with local inputs and unsophisticated managerial skills through a robust system capable of functioning well in harsh environments renders the IAVS technique doubly attractive.

The operating system and technical expertise of the INTEGRATED AQUA-VEGECULTURE SYSTEM's principle creator, Dr. Mark R. McMurtry, is essential (or at minimum, advantageous) for start-up and propagation of new installations. We can envision a number of arrangements under which Dr. McMurtry's services could be made available to first-time operators. We want to cooperate. We believe that the IAVS can make important contributions to health, nutrition and self-sufficiency in both rural and urban environments in developing countries.

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