July 6, l994

Dear Folks,

    We enjoyed hearing from each of you and will from time to time share with you anything we think we know, and/or anything, we think someone else knows about raising fish and plants, or aquaculture and vegetable culture, in a greenhouse using a symbiotic relationship where the operator feeds the fish and the fish feed the plants and the plants clean the water for the fish.

    We are not eager to start a newsletter but if you have questions or comments, we will be happy to seek answers and send them out to those interested and any comments or experiences, good or bad, that we/you think might help others.  We will do this until it gets beyond us in time, money, and talent.

    Aquaculture--vegeculture is kind of a different way to farm and requires attention to balance.  The method is wide open to both experiment and to development and we believe has real possibilities and great potential.

    When I say we, I refer primarily to Tim Garrett--the coordinator for the five-county Mid-east Resource Conservation and Development Council and myself.  Tim shared the joy of building the structure and helped with operation where possible and necessary.  My wife Jean also helped a great deal.

    First let us expose our limits.  We do not claim any originality to the idea.   Mark McMurtry, while a graduate student at North Carolina State University had the stamina and tenacity, and an advisor with foresight in Dr. Doug Saunders, to push through the opportunity to do his doctoral dissertation on the subject.  The subject did not fit snugly into horticulture, for you do not do aquiculture in horticulture normally.  Nor did it conform narrowly to aquiculture for you do not do horticulture in aquaculture.  Try persuading one discipline or the other to take you on and the "other" looms big and out of sync.  Dr. McMurtry persisted and was successful however and is to be commended.  We consider him the international expert on the subject.

    Secondly we spent about l0 months building the greenhouse (no money for builders) and about 16 months operating it.  We felt the need for at least one more round of funding to put into practice the critical things we think we learned.  We hope you can be persuaded not to make some of the mistakes we made which is only one of the sides of the research coin.

    The following is a variety of disorganized "bits of information" that might be useful to you.  We will not spend much time trying to persuade you that aquaculture-vegeculture will be an economically profitable system.  That will depend a great deal on the individual and a variety of other things.

    Bits of information:

    Ratio of water to sand is about l:l volume i.e. a cubic foot of water (about 7 gallons) to a cubic foot of sand.  The sand needs to be very coarse.

    We used sand approximately a foot deep average i.e. level on top and graded on the bottom.  A network of perforated 4" corrugated  plastic drain tile lay on the bottom in the sand.  Water has to be pumped one way and can be drained the other.  We chose to pump from the fish tank to the sand bed and drain back to the fish tank.  The sand bed was lined with a single piece of 6 ml. plastic.  You can go with a tougher liner if you wish.

    We heard of one person who is using pea gravel instead of sand.  Article enclosed.

    One mistake we made.  We first used sand that incidentally had mollusk shell and phosphate nodules in it.  The calcium was no doubt good for the tomatoes but the pH of the water stayed between 8.3 and 8.5.  A little high.  To correct this we added walls to the sand beds, put down a new piece of 6 mil. plastic liner, new drain pipe network, and a new and different sand.  This solved the pH problem.  The bottom of the sand bed sloped toward the fish tanks, l.25 inches per l0 feet. This slope is arbitrary and a lesser slope might work just as well. The top of the sand bed was leveled by hand.  A good way to do this is to stop-up the drains, flood the bed with water up to the approximate level of the sand.  Then using a drag made of  2x4s, make the frame approximately 2'x 8' and attach a rope for pulling add a cross piece of plywood or something to set a plastic bucket on with sand in it for weight.  The high spots in the beds can be dragged into the low spots using the level water surface as a guide.  Walls around the sand should be at least a few inches (4-6) higher than the sand (more if you like).

    At the appropriate time the sand will need to be inoculated with the Nitrous bacteria, to convert ammonia to nitrites, and Nitric bacteria, to convert nitrites to nitrates which the plants then use as fertilizer.

    We purchased the concentrated preparation of bacteria and used about l/4 or less of the recommended amount.  They will multiply in the bed and do a good job.  They are aerobic and use oxygen just like fish use oxygen.  So do not get the idea that flooding the sand beds helps aerate the water.  The returned water from the sand beds has no oxygen left in it.  However as the water moves down through the sand it does pull air after it thereby helping provide air (oxygen) for the microrganisims and plants.

    After inoculating the beds with bacteria they should not be allowed to dry out again or the bacteria will die off.

    So now you have the sand beds.  Very coarse sand approximately l0 inches deep at the outer wall and l4 inches deep at the inner wall.  Plastic liner (one piece 6 mil. or tougher) under it.  Oh yes--the corrugated perforated plastic pipes for collecting and draining the water are placed every 8 feet so that they collect water from 4 feet on each side.  So put your first pipe 4 feet from the first wall and then 8 feet apart thereafter until you get within 4 feet of the last wall.  Cover the tile with a fine nylon cloth, used by drain contractors, to keep the sand out of the pipe.  Place your outlets, from the drain, so that they do not interfere with movement of carts, wheelbarrows, and persons between the fish tanks and sand beds.

    Parallel rows of ridges for planting and troughs for draining are made in the sand using a hoe.  Since sand will tend to erode back to level with water and time, the ridges and troughs are made new with each planting.

    A couple of home made "plumb bobs" made from old chains and a hook of some sort can be hung at each end from the wire overhead to serve as guides to make rows.  Or maybe you are better at free hand straight rows than I am.

    I know I have been unscientific in using the word "coarse" to describe the sand texture.  In our part of the country, (coastal North Carolina), most of the sand is a fine texture and we had to import builders sand the best we could but we never felt like it was as coarse as we would have liked.  My guess is that a good sand particle size would be about the same size as the letter "o" in this type.  Sand is only as coarse as the fine particles in the mixture because the fine particles will plug up the space between the large particles and retard water flow.

   There are ways of separating or partitioning sand into its sizes.  Some are more expensive than others.  If one of you know of good inexpensive methods for this, please get them to us and we will pass them to the others.

    Disease of tomatoes and cukes:

    The bacteria that causes southern tomato wilt seems to be most prevalent in deep soil.  So sand taken from deep pits might well contain that organism.  We never solved that problem but feel that it probably can be solved by sterilizing the sand (before inoculating with nitrifying bacteria) and maintaining a strict practice of good sanitation which includes showers and greenhouse clothes, boots, and foot baths before entering the sand beds.  Obviously one needs to remember that anything that goes into the fish tanks is going to be pumped into the sand beds.

    If one of you is ingenious enough perhaps you can find a mold, yeast, bacteria, phage (virus that kills bacteria) or other natural organisms that thrives at the prevailing greenhouse condition that will "set up house" in the beds and tanks and control the southern tomato wilt bacteria.  There is some indication that this happens naturally at times so someone just needs to figure out which one, and how to grow it in barrels or get it to thrive and multiple in sand beds and fish tanks.

    If any of you know of good ways to sterilize (disinfect) the sand and/or water, please let us know.

    I do not know the effectiveness nor legal status at this time of methylbromide.  I suspect that gaseous chlorine might do a good job on the sand and be reasonably inexpensive.  Of course the sand would have to be covered and sealed with plastic to hold the chlorine in for a while until it did the job.  As I think about it, well-water (deep or shallow) might be a source of the southern tomato wilt bacteria and by first chlorinating and then aerating or dechlorinating the water before or in the process of filling the fish tank might be a possibility that is within the economic and technological reach of a commercial system.

    Fish and fish tanks:

    Fish fry or fingerlings are added to the tank about once a month or so.  You can establish your own schedule.  Marketable size fish  (1.25-1.50 lbs.) are removed for sale at about 6-7 months after they are started.  This then gives fish of seven different size categories in the tank at one time and they are then harvested once a month per tank.

    Big fish are said to keep the little fish away from the food and even though Tilapia are vegetarians they will also eat the young.  Therefore the seven sizes are separated into seven different compartments within the tank.

    Stocking rate will be approximately 0.25 pounds of fish per gallon of water.  However much higher rates have been used and maybe after experience you can ease the rate up to a higher stocking density.

    Moving the fish monthly:

    Since number of fish are held constant and weight per gallon is constant then the size of each compartment must vary with size of fish.  When you harvest the fish from the final compartment then the next size must be moved forward and the next and the next, etc. and then new fry or fingerlings put in the first compartment.

    Using a hand dip net to move 6, 12, or 18 thousand pounds of fish each month is a laborious task, very stressful on the fish, and should be avoided.  To avoid this, a continuous net, beginning with a fine mesh, can be laid in the tank and brought up and over a pole or a plastic pipe, or a plastic pipe with a pole through it at each dividing point.  Weights to hold the nets down and in place can be made with plastic pipe filled with sand.  Make them small enough for one person to handle.  Then to harvest the mature fish simply move the cross pipe forward making the compartment smaller and crowding the fish in the end for dipping.  After emptying the compartment remove the pipe and move the next pipe forward to the original location of the first pipe that you removed.  The fish that were in compartment 6 are now in compartment 7 and ready for their final growth period, then move each pipe and fish forward accordingly until you reach compartment l where you now put in the cross pipe that was removed from compartment 7.  After harvesting and adjusting the pipes, put your new baby fish in compartment l and you are set for another month.  See how easy that was!  Nothing left to do for another month.  HA.

    If someone has a better way to separate and move fish please let me know.

    These fish, Tilapia, will graze algae from everything and will therefore taste like algae unless purged for 2-3 days to get rid of that off taste.  After purging, they have an excellent mild neutral flavor and good texture.

    One of the faster growing fish (Tilapia) is the hybrid of the Aureus and Nilotica strains of Tilapia.  It is best to stock all males or sex reversed or sex neutered or sex separated.  Females do not grow fast because their energy goes into producing young instead of muscle. To "sex reverse" tilapia, newly hatched fry are exposed to testosterone for a short time and that changes their ability to form eggs.  We bought fry already reversed.

    Tanks:

    Tanks were dug with excavators.  Our tanks were l0 feet wide and approximately 90 feet long and went straight down for 3 feet and then sloped to the middle where the water was about 5 feet deep.  The tank walls extended about 6 inches above the water.  I do not recommend this shape of tank.  It is difficult to dig and the sides cave in when water in the tank is low or empty.  Perhaps it would be well to slope the sides about 20-25 degrees instead of going straight down.

    The tank was lined with styrofoam 2' x 4' x 2" thick and a 20 mil. thick piece of permalon laid in place.  The permalon we bought was 20 layers laminated and it delaminated after about 2 years.  I understand it is no longer laminated but is one solid piece--probably better.  To prevent water build up under the tank agricultural drain tile was installed and drained to an outfall.  Where there is no outfall, a basin and sump pump with float switch might be wise.

    When feeding the fish, to keep the food from floating through the net, floating feeding rings made of p.v.c. were placed on top of the water.

    Keeping the tanks somewhat dark helps reduce stress for the fish.  Black plastic over a center pole above and parallel with the sides of the tank and with poles on the sides for weight can be swung from the top and allowed to "tent" over the tanks.  Fixed in about 15 foot sections it can be raised as needed.  Sections can be separated enough to allow feeding of the fish, observation, and enough light for the fish to feed.  The cover also helps prevent fish from jumping out of the tank which they tend to do at night.

    Aeration of the tanks was done with air stones and an air pump.  This was sized by Aquatic Ecosystems.  I am told there are perhaps more efficient ways to aerate the water but the stones provided plenty of air for fish stocked at 0.25 pounds per gallon.  If the water gets too cloudy pumping water can be increased and/or food reduced.

    Tilapia do well in warm to hot water.  Below 60  F. they will start dying.  In the summer time no cooling is needed for the fish.  They can also take low oxygen concentration. Even so, it is wise to have a standby generator.  If the greenhouse is close  and someone will know when the power fails, an automatic switch-over is not necessary for even in the heat of the summer they do fairly well for an hour or so--without power--plenty of time to start up the tractor with PTO generator or a self-contained generator.

    Not everything has to be on the generator.  First on of course must be the air pumps or whatever means you are using to aerate.  Next perhaps the louvers to the greenhouse if they are powered.  Next the inflation fans that keep the plastic tight.  A snow storm with deflated plastic can do you in in the winter.  The heater fans will help and in the summer the exhaust fans.  In the summer, especially, you might want the dosing pumps connected occasionally so you are probably better off not to hard-wire them when building.  The hot water pump for circulating hot water to heat the tanks is low voltage and needs to be connected if outage is prolonged in cold weather.

    We heated the fish tanks with a simple closed circulation system of flexible polybutylene plastic pipe approximately 3/4 inch.  We ran two arms down and one back and used a small hot water pump.  The water heater was gas and needed no electric hookup.

    Polybutylene does not give-up or exchange heat very well but it was adequate to keep the water in the 70s in the winter.  After constructing the system we found a source for some stainless steel pipe that we could have used in sections.  It is a little expensive and still is not the best for heat exchange but better than polybutylene.  With fish you must avoid anything with copper in it, copper pipe and brass of any kind.

    The purging tank is very important.  It must be kept very clean and the water must be very clean and free of algae.  We never settled on a good purging tank but it should probably be built in hard wall adjacent to the last compartment of the raising tank.  This makes it convenient for dipping the fish from the tank into the purge tank.   With intensive vigorous aeration and some clean water exchange the fish can be purged in water at about 2 pounds of fish per gallon for 1-3 days.  The best way to tell if they are purged is to clean and cook a fish.  The meat next to the head is the last to lose the off taste.  When that is good, the rest is good.  Sometimes they purge in one day. Ultra clean purge tank and water is the trick--very important.

    Since the taste of the fish flesh is so sensitive to the water and what the fish eats, I wonder if we could turn this around and make fish taste like lobster or crab or whatever!!  I suppose if that could be done someone would already have done it.  Or would they?

    Plant nursery:

    Your seedlings are probably best raised in a separate facility that can easily be kept decontaminated and controlled for diseases.  This gives you a good plant to start with.  This is very important.

    I purchased seeds from DeRuter.  The tomato "Perfecto" was excellent and preferred by customers.  Tomatoes do not pollinate well in a greenhouse in the heat of summer.  There is at least one variety on the market--not used routinely for greenhouse, I think it is called "Heat wave."  Burpee makes claims of pollinating in the 90 degrees, I believe.  I have had no experience with it.

    To pollinate one can purchase bumblebees--very expensive--or pollinate by hand using a vibrator to vibrate the blossom stem.  I used an electric tooth brush--Water Pik--the old type that activated by pushing the shaft off center.  This worked well.  I am told that one can use a back pack air blower to do the job also.  If effective this would be much faster.

    We pollinated and suckered daily.  Probably every two days is adequate.

    Take all plant material, suckers, broken leaves, bad fruit--out of the greenhouse and off the premises.

    Pests:

    Like sanitation if you are not going to do the maximum to control plant pests then you might ought to forget it.  Aphids are bad on the plants directly and thrips and anything else bring in diseases.  So the best approach is to keep them out.  This means first of all eliminating plants outside the greenhouse with Round-Up or whatever, i.e. all plants within a 40-50 yard perimeter around the greenhouse.  Maybe even go a little extra on the side of the air intake.  Secondly use a fine mesh filter at all openings.  Thirdly subscribe regularly to a variety of predators.  Aphidolites, Lacy Wings, Lady Beatles, Encarcia formosa, etc.   We never had to contend with the various white flies or spider mites but because of poor screening and poor plant control outside, we did have problems with Aphids.  Localized control with insecticidal soaps and special light oils used sparingly can help kill off sites of infestation in the early stages.  Leaf spot, a fungus, can hurt the European cukes.  Excellent sanitation and good circulation of air is probably the most important controlling factor in this and other potential diseases.

    Fruit:

    Cucumbers - The European cuke is a seedless--all female blossom vegetable that is still good quality for eating even at 3 pounds and 18-24 inches long.  It takes a lot out of the plant however to produce such a specimen.

    In working with the plant, all male blossoms (rare) should be removed and all fruit removed up to about 16-18 inches from the sand.  All other fruit should be harvested as soon as it is big enough to sell.  The reason for this is that the fruit is fed by the plant from the bottom up and the fruit lowest on the vine gets all the food and the next 6 or 8 up will simply die off.

    I played around with marketing baby cukes 6-8" long or any attractive size in your market, and this seems like a good possibility.  Five or 6 baby cukes in a clear package with an attractive label can command a nice price in a niche market and reduces stress on the plant.  In the end I believe each plant might produce more "value" this way than producing ll-13 inch cukes weighing a pound or so each.

    When the nutrients are not right the cukes will be pointed and curved.  These are of a lower value and used for restaurants.  Additional research needs to be done with this cuke in this setting to optimize production, work, and marketing.

    Tomatoes can be picked when they start to turn pink.  Preference for size of tomato varies greatly, so just about all sizes and shapes can be sold.  More than preferring a big tomato, customers prefer a tomato with juice and taste.  Once they find that, the rest is secondary.  They will wait for your tomatoes to arrive in the store.

    At times I had trouble with tomatoes splitting at the stem attachment.  Never figured out how to control that.

    Stringing plants:

    We purchased tomato twine and twine binders.  A non-slip knot or a twine binder was placed around the base of the plant; the twine then went over the wire overhead and back down to the sand level.  A non-slip loop was tied about chest high in the upward strand and the downward strand was run through this loop.  The slack was taken out of the twine and the downward strand was secured, in a slip knot, to the loop.  When the plant has grown and reaches the wire the plant can be leaned and lowered by releasing the slip knot and lowering the twine and plant after which the slip knot can be tied again.

    Fish:

    We have mentioned the hybrid Tilapia.  We have sold them in sizes from a quarter pound on up.  We sold them live to dealers that come 500 miles with tanks and oxygen to pick up 500-2,000 pounds; we sold them super chilled and packed in ice and sold them filleted.  Selling them live at the greenhouse in bulk is preferred for it is less work, less expense, and a higher price.

    Some persons prefer a pink variety but most prefer a gray hybrid.  Usually most prefer a fish l l/4  to l l/2 pounds.  Marketing is an art and unique to your area.

    Since there are a variety of colors of Tilapia and they are such a hearty fish that can live in both salt and fresh water, they might work well as a live bait.

    Fish food:

    Tilapia, unlike a trout or catfish, or bass has a very long gut.  It is a vegetarian.  Even so, only a small percentage of food that it eats is digested and used.  We used Purina Catfish Chow about 32% protein.  They have since been working on a fish food specifically for Tilapia. There are other companies that also produce fish food for commercial operation.

    Since much of the food comes back out as it went in, there is the possibility of polyculture with crawfish, prawns, koi, gold fish, and others.   Perhaps there is a worm somewhere that would work well in the sand and could be harvested and sold for a variety of things such as fish bait or fish food for aquaria held fish.

    Water dosing of plants:

    We desired to turn the water over at least once and maybe twice in 24 hours.  We would dose for l0-20 minutes and drain for 40-50 minutes.  But remember our sand was not as coarse as I think it should have been.  This will depend on the coarseness of the sand and the quality of the water.

    Back up air pump:

    Whatever system you use for aeration, you will want a back up in case of mechanical or electronic failure.  Some air pumps, after about three years, will not resume operating once it is turned off.

    Fish diseases:

    We had no significant problem with fish diseases.

    Other fish varieties:

    We tried popeye mullet but they did not survive more than a couple weeks.  We seined from the wild and they suffered considerable trauma and length of survival was directly proportional to their size.

    Carp is the most eaten fish in the world and there are some very good varieties available.

    A nice 2-pound carp--purged well might be a good item in some areas, actually they are quite tasty, and if marketing can make cat fish popular in areas where they are known as "sewer trout" then any fish that has a mild taste and good texture can be made popular.  A carp or other non-tropical fish would remove the need to heat the water.

    The choice of fish or fishes that can be grown in this system are wide open and hopefully some of you will experiment with different varieties.  Large mouth bass are preferred by some markets and sell for a high price.  I understand there are some varieties that are trained to take pelleted food.

    A scenario that intrigues me is the possibility of a salt water system for redfish (channel bass) or other and clams and/or other shell fish and maybe shrimp.  For the horticulture part in the sand beds asparagus grows in salt water.  Redfish, clams, shrimp, and asparagus are all high priced items especially in areas far from coasts.  I believe this system is worth experimenting with.

    For marketing fish, retailing them live from portable tanks is attractive and fun for some people.  Orientals especially like to purchase live fish.

    Another interesting possibility for commercializing this system of symbiosis--aquaculture--vegeculture--is the development of a mini-system for the home (living room, den, or study) that is attractive, decorative and maybe useful.  Grow-lights would be needed for the plant phase.  These would also be useful for schools (as a demonstration of "balanced environmentalism,") waiting rooms and lobbies, nice restaurants--endlessly.  It is a wonderful conversation piece.

    Solar heat - where water must be heated for Tilapia and other tropical fish in the wintertime, there is the possibility of using solar heat to help a little.  Remember it takes one BTU to raise one pound of water one degree F .  The water of course serves also to store heat in the day time and release it for the plants during the colder nights.

    Greenhouse design:

    Unless you are working with grant money or have Research and Development funds, we suggest you start out small.  Small meaning that you could, if necessary, take the loss--whatever size that is for you.

    We used a 3-bay gutter connected quarter acre greenhouse.  We modified the plans for a 34 x 300 foot tobacco plant greenhouse by Williamson.  We made it into a l00' x 100' greenhouse.  We made steel trusses and installed them every l0 feet.  Except for the trusses, the remainder of the house is salt treated preserved wood and was assembled with screws.  Rim shanked nails would probably work as well and easier to use.  The bays were connected with gutters we made from salt-treated wood and rolled aluminum.  The inflated walls and roof were double layers of plastic which were anchored in an interlocking aluminum clip that came in 8-foot pieces.  Small inflation fans were installed as needed to keep the plastic inflated.

    We had the two fish tanks (26,000 gallons each) in the middle bay.

    Many other varieties of greenhouse design might work as well or better.  Perhaps of great importance is the need for the sides to be high enough for the plants to grow up to 7 feet tall or as high as you can reach.

    For a quonset type greenhouse, the legs could be anchored to posts that are 5-7 feet high giving a height of 8 feet or so at the side.  I would encourage you to use your own ingenuity for "arranging" things in the greenhouse and choosing building methods and designs and keep us informed of your successes, failures, questions, comments, and ideas that you are willing to share.

    I know we have not covered everything well nor with acute focus but it is a start.  Ask questions about particular interests, needs, etc. and we will write back.  We will probably write back anyhow.

    Oh yeah, Tilapia can be caught easily on hook and line with canned or frozen corn kernels as bait.  Nothing like roughing it in a greenhouse!

    Actually we left out perhaps an important item.  You will probably need two houses.  One for work and one for show.  Because once the word gets out every class within a hundred miles will want a tour--some several times.  You will get requests from far and wide--individuals and large groups. You will be novel, interesting, and exciting.  Resist this and stay humble.  At least keep them out of your "clean" greenhouse or you will never control diseases and pests again.

    There are only a couple dozen persons so far that have asked for information.  We would like to send this list to each of you so you can communicate directly with each other if you wish.

    Please send your questions and share your answers or suggestions with us and we will pass them on to others on the mailing list.  No doubt they will appreciate it and share their questions, suggestions, and solutions with you.

    Next, we will send a list of addresses and sources of things we purchased.

                                        Sincere best wishes,