ECHO *Asia Notes*

A Regional Supplement to *ECHO Development Notes*

Edited by Abram Bicksler and Rebecca Garofano — March 2014 | Issue 20

Farm-Generated Feed: Fish Feed Production

by Keith Mikkelson, Executive Director, Aloha House, Puerto Princesa, Palawan, Philippines

[Editor's Note: Keith has been practicing sustainable farming at the Aloha House Orphanage in Puerto Princesa for many years in order to produce nutritionally dense, farm-derived food that is consumed both at the orphanage and by local consumers. I had the privilege of visiting Keith and his family last March at the Aloha House, where the ECHO Asia/Aloha House Sustainable Agriculture Workshop was held. I was impressed by what they are able to achieve with very few off-farm inputs in a small amount of land area. In this article, Keith will share some of the basics for creating farm-generated fish feed.]

Farm-generated fertility makes agriculture more sustainable. Crop residues and manures are part of the nutrient cycle and can lower input costs through the use of thermophilic composting, vermiculture, bokashi production, or green manures. Farm-generated feeds can also reduce expenses, if farmers manage and utilize the resources already available to them. For, example, farmers might develop pasture using planned grazing for cattle; make hog feed from crop residue and by-products (such as whey and skim milk); cultivate legume shrubs for cut-and-carry operations for goats; and grow floating ferns and other water crops for fish and poultry.

As densities of livestock increase, the industrious farmer finds ways and means to increase his farm nutrient stream for the benefit of his system. **This article will examine the methods and techniques necessary for the smallholder farmer to succeed with farm-derived fish feeds.** A farmer should first fully exploit his extensive (and more passive) existing systems, and then consider intensifying his overall operation (Figure 1).

Important: Note that many journals, papers, and guides caution against the tendency to abandon established methods of feed production for a more intensive system without first assessing and then establishing new technologies with a transition period that is well-planned, capitalized and realistic.

Overview of the Aloha System

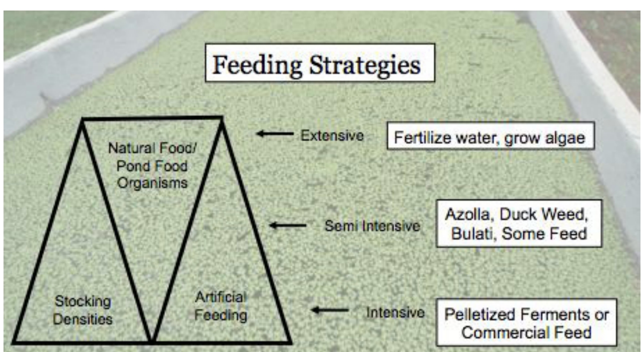
Planning includes securing both on-farm and off-farm feed sources, in case of contingencies. "Most farmers do not maintain all the ingredients needed to prepare a complete feed on-site or the equipment to blend and pellet it. They must, therefore, have guaranteed primary and alternative market sources at all times, which is not a simple management activity," (Skillicorn *et al.,* 1993). Our experience is with the tilapia GIFT variety, Improved Excel variety, and red tilapia from the Bureau of Fisheries and Aquatic Resources in the Philippines, as well as with Japanese koi obtained from commercial breeders in the Philippines (Figure 2). In our closed-loop recirculating aquaponic systems, we also keep catfish and snakehead fish outside the tilapia net culture. These bottom-feeders eat the residual feeds, minimizing waste and keeping settled solids moving toward the sump (the area of the system that retains water before the pump re-circulates it), through the pump and up into gravel beds or solids-removal filters. They also help control fry populations by preying on wandering hatchlings.

Feed Sources

Algae Bloom

For tilapia pond culture, where fish roam free or are in cages, algae should be the first feed considered. Ponds with a carrying capacity of 3 kg of fish/ square meter can benefit greatly from the addition of fertilizers, which can increase algal bloom and reduce the cost of inputs. Natural fertilizers are used in our system, but commercial fertilizers or purchased worm castings and composts can also be used. However, do plan to utilize farm-generated fertility before considering purchased inputs.

Fish that benefit from algae production (such as tilapia) have a mucus membrane



(top to bottom) ***Figure 1.*** *Feeding strategies for fisn, ranging from extensive to intensive.* ***Figure 2.*** *Tilapia being held by Keith Mikkelson at Aloha House.*

Featured in this AN

The ECHO Asia Impact Center operates under ECHO, a non-profit Christian organization that helps you help the poor to produce food in the developing world.

ECHO Asia Impact Center
PO Box 64
Chiang Mai 50000 Thailand
echoasia@echonet.org
www.ECHOcommunity.org

on their gills that allows them to access the nutrients in phytoplankton as a food source. High in protein, unicellular algae grow in the upward column of the water profile, with access to sunlight. Fertility in the form of manures, compost, bokashi (a fermented anaerobic compost made of organic matter with beneficial microorganisms), or vermicasts will be sufficient to induce the algal bloom when sunlight is adequate in the tropical environment. We need less than 1 ton/hectare/production run of 120 days for tilapia if the amount of phosphorous is sufficient.

The Secchi disk (Figure 3) is a simple tool farmers can make to monitor the turbidity of their pond in order to determine the amount of algae growing and to better estimate how much fertilizer is required to optimize the algae production.

Keep track of your turbidity weekly, and adjust the amount of fertility inputs based on the Secchi reading (Figure 4). To maximize food production, the goal is to stay close to the 30 cm (12 in.) zone of turbidity (when you place the Secchi disk in the water to 30 cm, you should just barely be able to see it). Turbidity (and subsequently, algae production) depends on the amount of fertility, sunshine, cloudiness and day length. Remember, this is a biological system and it will adjust slowly as inputs are added or removed.

Bat guano can be a good source of organic phosphorus, and we have found that our local bat guano (from fruit bat dung) has a higher level of phosphorous than our ruminant manures (Table 1). On our farm, fruit bat manure produced the lowest rating on the Secchi disk, meaning the highest turbidity and, therefore, the highest algae production. This is because of the high phosphorous in their guano. As an alternative, we have also found our vermicasts to be more effective than ruminant manures as a phosphorus additive.

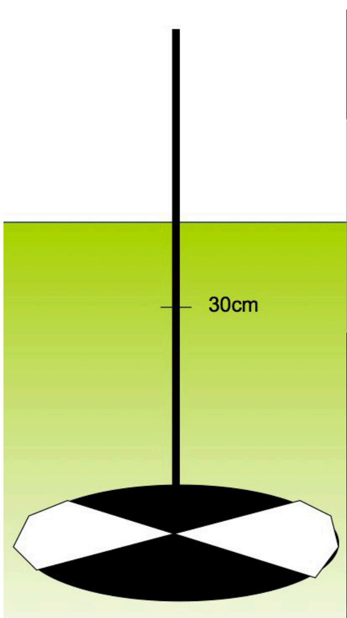
Commercial Fertilizer

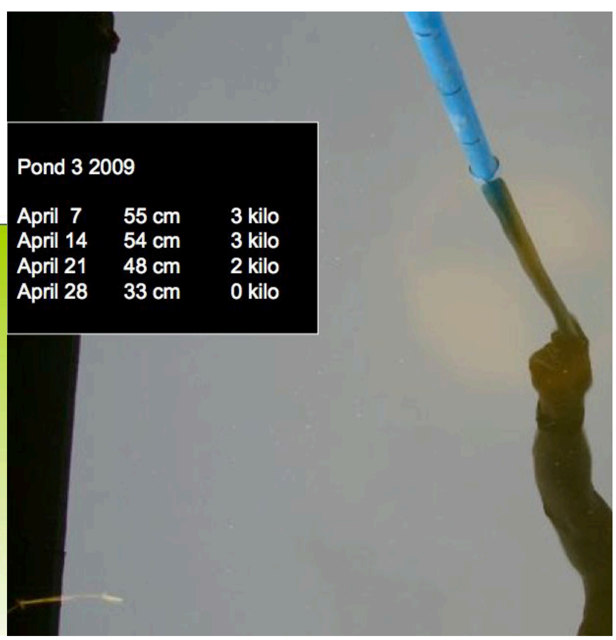
Recommendations for synthetic fertilizers vary based on water hardness and phosphorous source. That said, urea and a phosphate fertilizer are often recommended if composts or manures are not obtainable. Super phosphate fertilizer at 0.625 kg/100 m^2/week is recommended for algae feedstock for tilapia production (Bocek, NA). However, in our all-natural system, we find composts (if bat guano is not available) to be more than adequate at producing algae, thereby lowering costs and minimizing the impact on surrounding soil and water systems.

Floating ferns, such as azolla (*Azolla* sp.), duckweed (various genera and species) and even salvinia (*Salvinia* sp.), can be utilized if they are cultured separately from your fish. Omnivores like tilapia and koi readily eat large quantities of these greens as a feed source. Options for production include separate dedicated ponds,

Table 1. *Nutrient concentrations of Aloha House's 1) Bat Guano, 2) Vermicast, and 3) Bokashi for use in algae production.*

Sabang Bat Guano	ppm	%
Nitrogen (N)	2800	0.280
Phosphate (P_2O5)	18100	1.810
Potash (K_2O)	3800	0.380
Manganese	440	0.044
Iron	519	0.052
Copper	36	0.004
Zinc	206	0.021
Vermicast	ppm	%
Nitrogen (N)	5100	0.510
Phosphate (P_2O5)	8200	0.820
Potash (K_2O)	2500	0.250
Manganese	110	0.011
Iron	678	0.068
Copper	6.1	0.001
Zinc	206	0.021
Bokashi	ppm	%
Nitrogen	7600	0.760
Phosphate (P_2O5)	5000	0.500
Potash (K_2O)	8100	0.810
Manganese	50.99	0.005
Iron	175	0.018
Copper	3.37	0.000
Zinc	28.17	0.003
Calcium	1.41	0.000
Magnesium	0.16	0.000





(left to right) ***Figure 3.*** *Secchi disk diagram showing black and white quarters and optimum depth for turbidity.* ***Figure 4.*** *Secchi disk in action - note the ability to see the black and white quarters. Table shows growth in algae as a response to added amounts of natural fertilizer (in kg).*

containers or troughs, as well as net-protected rafts within the fish culture. Remember, any fodder crops grown within the fishpond must be protected or isolated from the fish, otherwise the fish will overgraze and deplete the crop! In addition, if the goal is algae production, plants growing on the surface will block sunlight and prevent growth of algae and other phytoplankton. It is difficult to produce both protein sources (i.e. algae and water plants) to their full potential in the same column of water.

Many floating ferns and aquatic plants are high in protein. In experimental trials comparing *Lemna minor* (common duckweed), *Ipomoea reptans* (kang kong or morning glory), *Trapa natans* (water caltrap) and *Salvinia cuculata* (often mistaken for Azolla) in India, both duckweed and morning glory had good feed conversion ratios and high protein: 28% and 32% respectively (Kalita *et al.*, 2007). These are great fodder crops when grown independently of the fish crop so as to ensure a regular harvest. Azolla (*Azolla caroliniana*), with a reported protein range of 19-30%, is another fast-growing floating fern that I wish had been included in the India study. A fish farmer must be careful not to overharvest these crops, however, so that sustainable production can be maintained. A general rule of thumb (under ideal conditions) is to harvest no more than half of the floating biomass per week (or 1/7 of the total biomass per day). The trick is to keep it in the rapid vegetative stage, so be sure to monitor which way is more productive in your system. Azolla tolerates moving water better than duckweed. Salvinia is the fastest growing, but can be very invasive.

In our floating feed pellets (described below), salvinia creates more buoyancy than azolla or duckweed, owing to its airy structure. Salvinia is fermented with the other higher protein ferns, rice bran, copra meal, fishmeal and molasses to create a high-quality floating feed. We find the air cavities in the salvinia are crucial to the buoyancy of our feeds. We will discuss the benefits of floating feeds later.

Pelletized Feeds

As farmers seek to intensify fish production, concentrated feeds are a method worth considering. However, the problem for many fish farmers is the cost of commercial feeds. The ECHO Technical Note "Fish Feed" (ETN, 2010) lists a variety of supplemental feeds that are commonly used: rice bran, mill sweepings, termites, table scraps, maize bran, and many green leaves (Murnyak, 2010). For feeding pelletized feeds, the Bureau of Fisheries and Aquatic Resources in the Philippines indicates that a progressive feeding schedule should be followed to optimize fish growth and profits (Table 2). It is best to match feeding to a specific age/weight of fish, and adjust the size of the feed pellets as the size of fish stocks increase. If fish are not graded, you must match pellet size to the smallest fish in the cage or pond, to ensure they can compete with the bigger fish during each feeding session. If you always stand in the same place and place feeds in the same area of the pond or tank, the fish will be trained to feed whenever you appear. This is helpful in monitoring the growth progress of your fish. Do not overfeed or feed off-schedule, as the fish will tend to eat your profits. Profits are lost because Tilapias have an ability to bypass their digestive tract while gorging on expensive feeds. This results in wasted feed and lower profit for the fish farmer. Farm-made

Table 2. *Philippines Bureau of Fisheries and Aquatic Resources feeding table designed to help growers optimize fish growth and profits.*

Bureau of Fisheries and Aquatic Resources (B.F.A.R.) Feeding Rate and Schedule				
Age of Fish (Days)	Type of feeds	Feeding Rate of Body Weight	Feeding Frequency	Ideal Weight of One Piece
1 - 15	fry mash	8.0%	4x day	6g
16 - 31	fry mash	7.0%	4x day	25g
32 - 46	starter	6.0%	4x day	36g
47 - 61	grower	5.0%	3x day	50g
62 - 76	grower	4.0%	3x day	72g
77 - 91	grower	3.0%	3x day	100g
92 - 105	finisher	2.5%	2x day	121g
106-120	finisher	2.0%	2x day	150g

Figure 5. *Making your own high-quality floating feed does not have to be difficult.*

feeds require proper drying and handling in order for the end products to perform well. A sustainable feed-drying system must be thought out in advance of any attempt at feed production.

On-Farm Production of Fish Feed

With experimentation and careful record-keeping, a fish farmer can produce his/her own high-quality feed (Figure 5). In many countries, readily available meat grinders and pelletizers have made it possible to create economic floating feeds for tilapia, koi or catfish. Our unit was obtained in Chinatown, Bangkok, Thailand. It is an un-branded stainless steel auger-driven meat mincer manufactured in China. We assembled it on a table at home and mounted it with a 1 hp motor (Figure 6). Before beginning, make sure you have a range of plate sizes to extrude your feed, so that feed and stock size can match. The sizes we use are in the 2-8 mm range for our 300-500 gram tilapia production. When we finish making the feed, we immediately dismantle and clean the auger, blade and plates. When done with a good auger-type grinder, very little effort is spent in the production of feeds (Figure 7). At Aloha House, two people can produce ten trays (approximately 45 kg) of moist feed in less than one hour. One operator feeds the mix into the auger from a tray and periodically tops off the tray to ensure a steady flow through the grinder. As the feed is extruded, a second operator uses a scoop to spread the wet pellets in a thin layer on a drying rack (Figure 8), then loads it in the solar dryer (Figure 9).

(top left & middle) ***Figure 6.*** *Meat grinder used for extruding fish feed. (top right)* ***Figure 7.*** *Extrusion of farm-derived fish feeds. (bottom right)* ***Figure 8.*** *Setting out pelletized feed on a drying rack made from bread boxes and window screen. (bottom middle & left)* ***Figure 9.*** *Solar dryer for pelletized fish feed at Aloha House.*

For drying racks, we use bread trays with a screen liner riveted to the bottom of each. Make sure airflow is adequate for rapid drying on sunny days. Box or wood frame dryers work well if wall thickness is minimized to save space. Our solar dryer is rooftop mounted and takes two or three days to dry our feeds, depending on pellet size and cloudiness. The general design of our dryer incorporates a sheet of UV-treated 0.2 mm (0.008 in.) greenhouse plastic clipped to a welded G.I. frame.

When dry, all feeds are sealed in 20-liter (5 gallon) pails with lids to ensure dryness and freshness. Eight percent (8%) moisture content can be achieved if conditions are ideal. Summer days with lots of sunshine are helpful, but during rainy cycles, producers may not be able to avoid cloudy days. Our solution is to take advantage of sunny periods and even create a surplus for rainier periods. The old adage "make hay while the sun shines" applies doubly in the tropics for feed production!

Benefits of Fermentation

Digestibility and shelf-life of fish feed are enhanced through the activity of certain beneficial microorganisms during the production process. According to findings from one study, the use of microorganisms increased the crude protein in copra from 17.24% to 31.22%. The amino acid profile was also found to be greatly improved (Cruz, 1997). *[Note: In addition to fermenting fish feeds, at Aloha House we also ferment our feed for chickens, ducks, and hogs with the help of diverse probiotic groups of microbes. However, we do not use fermentation for our ruminant feeds. (Creating on-farm feeds for other animals will be covered in another EAN)].*

When fermenting your feed, it is important to use proven strains that are not cross-contaminated with wild pathogens. We use EM-1, a commercial product that undergoes laboratory testing and is approved for aquaculture by the Bureau of Fisheries and Aquatic Resources in the Philippines. EM-1 was formulated by Dr. Teruo Higa in Ryukyus University, Okinawa, Japan, and is readily available in over 100 countries. The product includes cultures of robust lactobacilli, photosynthetic bacteria, beneficial yeast and more. They will feed on sugars and other carbohydrates, while creating secondary metabolites that increase the nutrient range of the feed. My book, *A Natural Farming System for Sustainable Agriculture in the Tropics*, is a user's guide to EM technology. It is available online as a free PDF download or can be obtained through ECHO bookstores. Even CO_2 is produced during fermentation, helping to increase the floatation of our feeds! Cheese or yogurt whey, sourced from a local creamery, could be used to some effect if EM-1 is unavailable. Start small by substituting the whey at the same rate as EM1 and adjust upward if it does not have an effect. Good fermentation should create a sweet and sour smell after 2 weeks. If foul odors such as rotten eggs (sulfides) or rottenness occur do not feed to your fish. It still has value after you remediate. Just discard your SMALL failed experimental batch to the compost heap and use as fertilizer.

We pre-mix all our dry materials (rice bran, copra meal) and then add the greens (salvinia, azolla, duckweed), EM-1, and molasses diluted in water. After complete mixing of all ingredients to 30-50% moisture content, we allow it to stand in an open container for three to six hours before extruding it through the machine. Letting it stand will ensure more uniform moisture content of the materials and achieve a better end product. A simple field test for moisture content in the 30-50% range is the ball test. Take the feed in two hands and form a ball with mild pressure. If it does not stick it is too dry. If it is dripping wet it is over the moisture target. The pellets will continue to ferment while drying and even in storage, to a lesser degree, until all moisture is evaporated. As long as you have a dry pellet that can crumble under pressure and not stick to each other, you are in the 8-10% moisture range, which is ideal after drying. It is not necessary to go below 8% moisture.

Formulas for Tilapia

When creating your feed, be sure to measure and weigh each component accurately and record the performance of each trial mix. Keep some of your fish on the current feed system (control) so you have something to check against. Compare the weight of fish with your new feed and control after one month to see how it performs. We encourage you to use what is available in your area and learn to optimize your own blend based on regular testing. A spreadsheet is useful for adjusting inputs and formulating feeds that will be worth your while. After many months of record keeping, you will be able to evaluate the benefits of your farm-generated feeds. We find that if we formulate the mix based on crude protein, the rest takes care of itself. Earlier I discussed floating ferns as a fresh feed; for bio-diversity and a broader range of inputs you can use a combination of duckweed, azolla and salvinia added to your low cost, high quality pelletized feed. Learn to culture these ingredients. Purchasing them will eliminate your savings! Spirulina (a cyanobacterium, also known as blue-green algae) is another possible alternative or addition to floating ferns. Over 30% of worldwide spirulina production goes to non-human feed stuffs (Belay *et al.*, 1996). Other substitutions have been explored with mixed results, including water hyacinth in Nigeria (Igbinosun et al., 1988). I would not recommend experimenting with water hyacinth and have not been impressed to do so myself. But if you do please send us your results!

Rice bran should be D1 from the "Cono" mill. Other lesser grades (D2 to D4) should be avoided due to the high quantity of cellulose. See the Rice Mill Primer in the notes section of my book for more information (Mikkelson, 2005). Other brans (corn, wheat etc.) can be used, but beware of compromising crude protein levels. Most modern corn varieties contain half the crude protein of rice bran. Top quality rice bran is 12% to 14% crude protein! Copra meal contains up to 24% crude protein, but a caution is in order: copra meal (like Black Soldier Fly larvae) contains high-quality protein but is also high in fat and should not be used excessively. High fat will sacrifice weight gain due to lower carbohydrates and protein.

Vitamins and Minerals

Finely crushed rock powders from gravel mills will have a range of minerals to supplement any deficiencies in cut greens or floating ferns (Murnyak, 2010). We use our organically-grown moringa at 1% by weight of the mixture if we do not have rock powders. Finely ground livestock-grade limestone can also be added for bone growth support. When integrating fish and plants in an aquaponic system, the fertility for plants is derived both from the fish excrement and wasted feed (tilapia waste 10-20% of their feed, which is converted by bacteria into plant-usable nutrients). In Australia, 40-55 grams of carnivorous fish feed will fertilize 1 square meter for horticulture using the raft method, whereas 60-100 grams of tilapia feed (because tilapia are omnivores) will be needed for the same level of production (De Dezsery, 2010) (Figure 10).

To Float or To Sink?

Do not be overly concerned with whether or not your feed floats or sinks; studies are finding protein to be more important than buoyancy! The high-energy cereals used in commercial feeds sacrifice the Feed Conversion Ratio (FCR). FCR is calculated by the ratio of weight gain/weight of feed consumed. Younger fish may gain almost 1 gram for every gram consumed (FCR 1.0), while older fish will need to eat 2 grams of feed to gain 1 gram in weight (FCR 2.0). The digestible, convertible nutrition in the feed is most important. We have studied the feeding habits of tilapia and koi in our glass observation tanks, and we find that they recover all of the feed if detritus levels are not excessive. In fact, Cruz *et al.* (2001), found in one study that floating feed did not perform as well as sinking feed. They concluded, "Sinking pellets promoted significantly higher growth rate, bigger fish and gave better FCR in Nile tilapia juveniles than those fed with floating pellets. The better performance of fish fed with sinking pellets may be attributed to the higher crude protein content (42.05%). Similar results were obtained by Gur (1997), who reported that the average daily gain and FCR at a crude protein level of 40% were significantly higher and better than at 30%. He concluded that the crude protein levels for optimum growth and FCR were from 40 to 45% for Nile tilapia with initial mean weight of 13 g." (Cruz et al., 2001). Higher protein can be obtained for carnivorous fish by increasing the fishmeal in the mixture, but be sure that your source is mercury-free. Black Soldier Fly larvae, with a protein content of 45%, can also be used as a high-protein additive (De Dezsery, 2010), but must be dried before mixing into your fermented feed.

Starting Formula

Here is a good starting point for creating your own feed (Table 3). Be sure to keep notes and adjust the ingredients based on your available feedstock and the performance of your farm-made feeds! Costs listed are relevant for your location but might differ elsewhere.

Figure 10. *Tilapia next to aquaponic plant grow-bed at Aloha House.*

Table 3. *Basic Tilapia feed using on-farm inputs. Note, 1 USD = approximately 45 Pesos.*

Tilapia Feed with Fish Meal & High Crude Protein Greens							
	Crude Protein	Cost P / 50 kg Sack				Cost	
Commercial Feed	32.00%	1,300.00				26.00	P / kg
Fermented EM Feed	32.31%	512.34				10.25	P / kg
Ingredient	Crude Protein	Weight (kg)	%	Cost P/kg	Crude Protein Units	COST	
Rice Bran(D1)	14%	28.00	32.2%	14.00	3.92	392.00	P
Copra Meal	22%	8.00	9.2%	9.00	1.76	72.00	P
Fish Meal	72%	17.00	19.5%	25.00	12.24	425.00	P
Duck Weed	44%	3.00	3.4%	0.00	1.32	0.00	P
Az olla	44%	10.00	11.5%	0.00	4.40	0.00	P
Salvania	22%	20.00	23.0%	0.00	4.40	0.00	P
Moringa	18%	0.30	0.3%	1.00	0.00	0.26	P
Livestock Lime	0%	0.10	0.1%	8.00	0.00	0.80	P
Rock Dust Minerals	0%	0.26	0.3%	1.00	0.00	0.26	P
Charcoal - Fine	0%	0.26	0.3%	1.00	0.00	0.26	P
Molasses	3%	0.10	0.1%	8.00	--	0.80	P
EM	1%	0.10	0.1%	8.00	00	0.80	P
	Wet Weight	86.96 kg	100.0%		28.09	10.25	P / kg
	Dry Weight	60.87 kg				14.64	P / kg

Conclusion

Small scale fish feed production can be managed by the careful use of locally grown and farm generated inputs. The more high quality inputs you supply yourself with, through efficient production and harvesting, will give you more profits through less capital input by producing your own feeds.

References Cited

Ako, H., and A. Baker. 2009. Small-scale lettuce production with hydroponics or aquaponics. Sustainable Agriculture 2.

Belay, A., T. Kato, and Y. Ota. 1996. Spirulina (Arthrospira): potential application as an animal feed supplement. Journal of Applied Phycology 8: 303-311.

Bocek, Alex (Ed.) No Year. *Water Harvesting and Aquaculture for Rural Development*. International Center for Aquaculture and Aquatic Environment, Auburn University. *Available*: http://www.ag.auburn.edu/fish/documents/International_Pubs/Water%20Harvesting/English/Introduction%20to%20water%20harvesting.pdf

Cruz, E.M., and M.T. Ridha. 2001. Growth and survival rates of Nile tilapia Oreaochromis niloticus L. juveniles reared in a recirculating system fed with floating and sinking pellets. Asian Fisheries Science 14: 9-16

Cruz, P. 1997. Aquaculture feed and fertilizer resource atlas of the Philippines. FAO Fisheries Technical Paper 366, Rome, FAO. *Available*: http://www.fao.org/docrep/003/W6928E/W6928E00.HTM

De Dezsery, A. 2010. Commercial Integrated Farming of Aquaculture and Horticulture. International Specialised Skills Institute. *Available*: http://www.backyardaquaponics.com/Travis/ISSI%20-%20REPORT.pdf

Igbinosun, J., O. Roberts, and D. Amako. 1988. Investigations into the probable use of water hyacinth (Eichornia crassipes) in tilapia feed formation. *Nigerian Institute for Oceanography and Marine Research Technical Paper 39*.

Iqbal, S. 1999. *Duckweed Aquaculture*. SANDEC Report No. 6/99. *Available*: http://www.protilemna.com/docs/Duckweed%20Aquaculture%20Potential%20Possibilities%20and%20Limitations%20SANDEC.PDF

Kalita, P., P. Mukhopadhyay, and A. Mukherjee. 2007. Evaluation of the nutritional quality of four unexplored aquatic weeds from northeast India for the formulation of cost-effective fish feeds. Food Chemistry 103: 204-209.

Mikkelson, K. 2005. A Natural Farming System for Sustainable Agriculture in the Tropics. *Available:* http://www.echocommunity.org/?AsiaTech

Murnyak, D. 2010. Fish Farming: Basics of raising tilapia & implementing aquaculture products. ECHO Technical Note. *Available*: http://c.ymcdn.com/sites/www.echocommunity.org/resource/collection/D9D576A1-771A-4D95-A889-4FBD9E75D03D/Fish_Farming.pdf

Riche, M., and D. Garling. 2003. Feeding tilapia in intensive recirculating systems. North Central Regional Aquaculture Centre Fact Sheet Series 114.

Rakocy, J., M. Masser, and T. Losordo. 2006. Recirculating aquaculture tank production systems: aquaponics—integrating fish and plant culture. Southern Regional Aquaculture Center Publication 454.

Skillicorn, P., W. Spira, and W. Journey. 1993. Duckweed Aquaculture: A new aquatic farming system for developing countries. The World Bank. *Available:* http://infohouse.p2ric.org/ref/09/08875.htm

Producing the Biocontrol Fungi *Trichoderma* and *Beauveria*

by Brock Mashburn, Niemeet Chompoothong and Dr. Abram Bicksler

Introduction

In nature, dozens of species of harmful fungi can quickly kill a plant, including *Fusarium* spp., the causal agents of Fusarium wilt, and *Phakospora pachyrhizi*, the causal agent of soybean rust (Figure 1). Fungi are unable to produce nutrients on their own, so they must find another source; sometimes that source is old bread, orange peels, a rotting tree trunk, or a plant's translocation tissues. These pathogenic fungi thrive in conditions of poor air circulation, slow water drainage, over-irrigation or too much rainfall. Such poor conditions can often be prevented by spacing plants properly, following an irrigation schedule, and removing fungus-prone debris, such as old plant material and weeds. No matter what we do, though, there is a good chance that pathogenic fungi will infect our plants at one time or another.

Unfortunately, in our modern world, chemical fertilizers and pesticides have become the norm in agricultural production, causing severe and serious environmental pollution. Use of these agricultural methods can lead farmers to become dependent on more and more inputs, as environmental imbalance ensues.

Fortunately, Fungi Kingdom is not exclusively populated by pathogenic intruders, dwelling unpoliced in the murky corners of the invisible world. Two particular beneficials of the fungal world, *Trichoderma* spp. and *Beauveria bassiana*, have been widely studied for their beneficial properties in agricultural production. The potential of these fungi species is especially exciting because of their ability to improve agricultural productivity while decreasing the development of fungicide-resistant pathogens (Studholme, 2012).

Beauveria bassiana

Beauveria bassiana is a common soil-borne fungus occurring worldwide. It is an insect-pathogenic fungus. When spores of *B. bassiana* contact the shell of an insect, they penetrate the exoskeleton and begin producing a toxin called Beauvericin, which weakens the host's immune system until the insect dies (Caldwell, 2013). Eventually, the fungus will fill the entire body cavity. Under high humidity conditions, the fungus will grow through softer body parts, creating a characteristic "white bloom" appearance as the fungus covers the body (Figure 2). The whole process is slow, happening over three to seven days, so it takes time to suppress the insect population and a single application would not be sufficient. Also, note that *Beauveria* will only suppress and not eradicate an insect population, killing between 50 and 75 percent of the population on average. Spraying during times of higher humidity and at earlier insect life stages will increase effectiveness (Caldwell, 2013).

Beauveria is recommended mainly for the control of chewing pests, white fly and beetles. Since contact with the pest is required, it can be applied at any time without great risk to bee populations, as the hive is elsewhere. Even so, avoid spraying at times when bees are most active. In addition to controlling agricultural pests, certain strains of *Beauveria* are effective against bed bugs and termites. Before you purchase a commercial strain, do some research or read the label to find out what that strain is effective against. While most research has been done on its insecticidal activity, some studies have shown *Beauveria* to act against soil fungi such as *Rhizoctonia*, a pathogenic fungi that causes damping off, root rot and many other pathogenic conditions in a wide variety of plants (Ownley, 2004).

Trichoderma sp.

Trichoderma sp. is a genus of fungi also commonly occurring worldwide, with different species native to different areas; hence the 'sp.' designation above. The species are frequently found isolated from agricultural soils or are seen as green spots on tree bark and deteriorating wood (Figure 3). Several strains of *Trichoderma* have been developed as biocontrol agents. As a decomposer, *Trichoderma* fungi can be used to help speed up compost piles. *Trichoderma* sp. are most effective as a seed treatment, to prevent death from other fungi in emerging and young plants; in this role, *Trichoderma* can offer improvement over chemical seed treatments. Both encourage germination, yet *Trichoderma* subsists in the soil and the plant, promoting long-term benefits that a chemical treatment cannot (Harman, 1997). As a soluble spray, *Trichoderma* is also beneficial when applied to flowers, to prevent fungal growth that decreases fruit set.

Until recently, the benefits of the *Trichoderma* fungus was thought to be from its ability to produce enzymes that target and degrade chitin, the structural component in the cell walls of fungi and insects. However, recent research has shown that the diverse benefits of *Trichoderma* are caused by different mechanisms (Contreras-Cornejo, 2009). It has been shown to enhance general plant biomass production and lateral root growth, through interactions that promote auxin production in the host

(left to right) ***Figure 1.*** *Fusarium wilt on a tomato plant. Fusarium oxysporum is a fungal pathogen that can affect hundreds of plant species. (Photo: Mercure, 1998)* ***Figure 2.*** *The 'white bloom' characteristic of Beauveria bassiana under more humid conditions. (Photo: Surendra, 2013)* ***Figure 3.*** *Trichoderma fungus occurring naturally on wood bark. (Photo: Samuels, 2014)*

plant. Auxins are a class of plant hormones integral in plant growth and development. *Trichoderma* is able to form a symbiotic relationship with some plants, even living inside the plant's vascular system and between cells (Hermosa, 2011), helping the plant resist foliar fungal pathogens (such as rice blast on rice plants) (Studholme, 2012). The fungus can also help plants better tolerate abiotic stress compared to non-inoculated plants (Hermosa, 2011). However, its anti-fungal ability can make *Trichoderma* harmful in the vicinity of mushroom production.

Producing *Beauveria* and *Trichoderma*

Strands of both *Beauveria* and *Trichoderma* fungi have been studied in lab conditions. Strains with the most effective beneficial properties have been isolated and reproduced, and are commercially available in Southeast Asia. Enzymes produced by these fungi differ depending on the strain, making their impact potentially unpredictable (Contreras-Cornejo, 2009). For this reason, we do not recommend that you attempt to find and reproduce your own 'local' variety. We do recommend, however, that you work to create soil conditions that will promote the growth of these beneficial fungi in your soil. You can do this by using minimal tillage or no-till techniques, by mulching, and by not spraying chemical fungicides.

Fortunately, producing your own *Beauveria* or *Trichoderma* spray at home is possible and quite easy. First, purchase a commercial strain, usually available as a dry powder. Be sure to keep this as your starter source for growing more batches of the fungus. Fungi can evolve easily over many generations; if you continually inoculate your substrate with spores from your previous batch, after only a few generations you may have something quite different (and much less effective) than the original. It is worth the cost to use the commercial strain each time you create a new batch.

Supplies

Be careful to avoid getting any fungus, no matter how beneficial, into your lungs or eyes. We recommend wearing goggles, a dust mask and gloves when inoculating the growing media. *Beauveria*, in particular, can affect humans, but only in extraordinary circumstances. All four reported cases have occurred when the host's immune system is already severely compromised.

Other supplies that you will need include: clean rice or sorghum, water, a rice cooker and spoon, large clear plastic bags, rubber bands, a needle, and your *Trichoderma* or *Beauveria* powder (Figure 4).

Procedure

1. Mix three parts rice to two parts water (3:2) in the rice cooker. Sorghum can be used in place of the rice, if it is cheaper or more readily available. Make enough to fill your rice cooker, and turn the rice cooker on.
2. When the rice has finished cooking, place two to three large spoonfuls (serving spoons) of cooked rice into a new plastic bag. Pack rice down, then flatten the bag and fold the bag over itself to prevent air (containing foreign spores) from getting in while the rice cools. Let the rice cool until it is comfortable to hold against skin.
3. Open the bag and sprinkle ½ teaspoon of *Trichoderma* or *Beauveria* powder on the rice (Figure 5). Close the bag and seal tightly with a rubber band at the top of the bag (Figure 6). Don't try to force all the air out of the bag. Mix the rice around to spread the spores among the rice, then pack the rice down again.
4. With a needle, poke 10-15 holes in the upper part of the bag where there is no rice. The holes will allow for air exchange. Alternatively, a few changes can be made to the procedure to reduce the likelihood of contamination. Instead of sealing the bag with a rubber band and poking holes in the bag with a needle, you can thread the bag through a 3 cm section of thin PVC pipe and use cotton balls or shreds of cloth to fill the hole. The cotton balls or shreds of cloth will allow for air exchange while preventing contamination, which is more likely with the holes in the rubber-banded bags (Figure 6).
5. Store the bags in a clean (preferably disinfected) indoor location at room temperature. Store in a an area with natural or artificial lighting.
6. After two days, mix the rice again inside the bag and pack it down.

(top to bottom) ***Figure 4.*** *Supplies for producing a fungal spray. The container pictured contains the fungus Beauveria.* ***Figure 5.*** *Not many spores are needed to populate the bag of rice.* ***Figure 6.*** *Two methods of storing. Above: The bags are closed with rubber bands, and then holes are poked around the top. Below: The bags are threaded through a pvc section, then banded down. Cloth or cotton is used to plug the holes.* ***Figure 7.*** *Niemeet Chomopoothong works under ECHO's homemade biohood. (All Above Photos: Brock Mashburn)* ***Figure 8.*** *Mass production of Trichoderma in Thailand. (Photo: IPM Thailand, 2013)*

7. After seven days, the fungi should have taken over the whole bag. It is now usable, but can live in the bag for three to four weeks longer. Healthy *Trichoderma* should have a sweet coconut odor and is most often dark green (Figure 8) but can be white or light yellow. *Beauveria* is scentless and should be white (Figure 6).

Your bags are contaminated by other fungi if you see different colors, especially black, and if the smell is putrid. Don't use any of the contaminated mixture, even if part of it looks pure. Discard the whole bag.

If problems persist, try completing the entire process under a biohood or a similar biosanitary machine. Directions for building a homemade biohood are available from ECHO on ECHOcommunity.org (Figure 7).

For a different method of inoculating corn with *Trichoderma*, see "PhilRice," under "Other Helpful Sources" below.

Using *Beauveria* and *Trichoderma*

When your *Trichoderma* or *Beauveria* bags are finished, dilute 1 kg of inoculated rice into 200 liters of water* to make a sprayable solution. Make sure to rinse the bag and rice clean to get all the possible spores. Separate the rice from the liquid. Once the *Trichoderma* or *Beauveria* is mixed with water it must be used or discarded. Mixed solution will not remain effective long term.

Spray every three or four days while pests persist, especially on the underside of leaves. Sprays are especially effective when insects are young, during high humidity and when the spray is highly concentrated with spores. You can continue to spray once per week when the fungus or insect pest is under control. Do not mix with other sprays and avoid spraying other products for four days before or after spraying *Trichoderma* or *Beauveria* (Caldwell, 2013).

The *Trichoderma*-inoculated rice can also be added straight to compost piles, potting soils or planting stations (three days before planting).

Conclusion

"Natural Farming" methods encourage the use of nature's processes to replace potentially harmful chemical or inorganic pesticides, fungicides and fertilizer. Many of these methods are not yet widely recognized in Western agriculture or in the academic realm. However, the effects of the fungi *Trichoderma* and *Beauveria* as beneficial biocontrol agents are widely researched and are commercially available worldwide. Both fungi are easy to reproduce at a low cost, and their potential makes them deserving of the attention they are receiving in the academic world and among farmers in Asia.

**This is the rate used by Maejo University, Chiang Mai, TH: Boonsong Thansrithong, Agriculture Program Manager, ECHO Asia*

Works Cited

Caldwell, B., Sideman, E., Seaman, A., Shelton, A., Smart, C. 2013. Resource guide for organic insect and disease management, 2nd edition. Cornell University, Ithaca, NY: Arnold Printing Corp.

Contreras-Cornejo, H., Macias-Rodriguez, L., Cortes-Penagos, C., Lopez-Bucio, J. 2009. *Trichoderma virens*, a plant beneficial fungus, enhances biomass production and promotes lateral root growth through an auxin-dependent mechanism in arabidopsis. Plant Physiology, 3(149), 1579-1592. doi: PMC2649400

Harman, G. 1997. *Trichoderma* for biocontrol of plant pathogens: from basic research to commercialized products. Informally published manuscript, Departments of Horticultural Science and of Plant Pathology, Cornell University, Geneva, NY, Available: http://web.entomology.cornell.edu/shelton/cornell-biocontrol-conf/talks/harman.html

Hermosa, R. 2011. Plant-beneficial effects of *Trichoderma* and of its genes. Microbiology,158(1), 17-25. Available: http://mic.sgmjournals.org/content/158/1/17.long

IPM Thailand. 2013. *Trichoderma*. Available: http://thailand.ipm-info.org/natural_enemies/pathogens/trichoderma.htm

Langle, T. *Beauveria bassiana* (bals.-criv.) vuill. – a biocontrol agent with more than 100 years of history of safe use. Agriculture and Agrifood Canada, Pest Management Center. Available: http://www.rebeca-net.de/downloads/Beauveria bassiana.pdf

Mercure, P. 1998. Vascular wilts of tomato. Department of Extension, University of Connecticut, Storrs, CT, Available: http://ipm.uconn.edu/documents/raw2/Vascular Wilts of Tomato/Vascular Wilts of Tomato.php?aid=37

Ownley, B., Pereira, R., Klingeman, W., Quigley, N., Leckie, B. 2004. *Beauveria bassiana*, a dual purpose biocontrol organism, with activity against insect pests and plant pathogens. Emerging concepts in plant health management 2004 (pp. 255-269).

Studholme, D., Harris, B., Le Cocq, K., Winsbury, R., Perera, V., Ryder, L., Ward, J., Beale, M., Thornton, C., Grant, M. 2012. Investigating the beneficial traits of *Trichoderma hamatum* gd12 for sustainable agriculture—insights from genomics. Frontiers of Plant Science, 4(258), doi: PMC3726867

Surendra, D. 2013. An update on the bagrada bug. Unpublished raw data, Department of Agriculture and Natural Resources, University of California, Available: http://ucanr.edu/blogs/blogcore/postdetail.cfm?postnum=9531

Other Helpful Sources

Hayes, Dr. C. 1998. *Trichoderma harzianum*, strain T-22. Department of Entomology, University of Wisconsin, Madison, WI. Biological Control News. Available: http://www.entomology.wisc.edu/mbcn/kyf504.html

Kasetsart University Research and Development Institute. 2012. Useful of *Trichoderma*. Available: http://www.youtube.com/watch?v=jIwM9LpHI5I

Mahr, S. 1997. The entomopathogen *Beauveria bassiana*. Department of Entomology, University of Wisconsin, Madison, WI, Biological Control News. Available: http://www.entomology.wisc.edu/mbcn/kyf410.html

PhilRice. "*Trichoderma*: Biofungicide for vegetables." Rice Technology Bulletin No. 62: 18p., October 2009. Available, http://www.scribd.com/doc/61293557/TB62-Trichoderma-Biofungicide-for-vegetables

Samuels, G.J., Chaverri, P., Farr, D.F., & McCray, E.B. 2014. *Trichoderma*. Online, Systematic Mycology and Microbiology Laboratory, ARS, USDA. Retrieved January 7, 2014. Available: http://nt.ars-grin.gov/taxadescriptions/keys/TrichodermaIndex.cfm

Samuels, G.J. United States Department of Agriculture, Agriculture Research Service. 2000.*Trichoderma stromaticum* sp. nov., a parasite of the cacao witches broom pathogen. Available: http://www.ars.usda.gov/Research/docs.htm?docid=10933