How To Win the War on Bugs

When we first started our aquaponics system, I was utterly amazed by the fact there were simply no bugs! I had always heard about how hard it was for organic farmers to fight pests, and I was excited to find out that it was easier than I thought. In fact, I went so far as to mention this to a good friend, Donna Mitts, who had been an organic gardener her whole life, and even teaches it at a local school. She threw her head back and laughed out loud, then said, "Your farm is so new they just haven't found you yet!" Did she ever turn out to be right!

Here in Hawaii we jokingly talk about something called the "coconut wireless", which refers to how quickly news spreads. Turns out the pests have their own coconut wireless, because first just a few showed up, and they sent out the word to all their friends and family. About a week later, all of a sudden we were absolutely overrun with bugs, thousands and thousands, and I had almost no clue what to do. The thousands of aphids I could identify, and hundreds of caterpillars, but I had no idea where they had all come from. And I did not even know what a lot of them were! There are five or six kinds of bugs I had never before seen, so I called Donna again, and she came over to check out my new bug zoo.

In those early days, I remember seeing what I thought were cute little light green butterflies flying happily around our plants, landing gently on the leaves now and again. I learned from Donna that these pretty flying insects were in fact cabbage moths, and every time they landed, they were laying their eggs. Aha! That's where all the caterpillars had come from! Donna also identified solanaceous leafhoppers that were sucking the life out of my tomatoes, coating every stem, and that looked just like rose thorns. She showed me leaf miners, which were leaving little trails through the leaf. She pointed out tiny little white flies that were leaving behind a terrible, sticky mess.

She told me about some organic solutions, but she had no clue whether or not most of those solutions could be safely used with our fish. So, I began my research, and decided to start by learning to understand insects better.

General Insect Information

Insects have lived on the planet Earth for about 350 million years, and have adapted to live just about everywhere, from the very hot to the ultra-cold. Insects have also found ways to turn just about everything into their home, including plants, animals, other insects, soil, water, snow, deserts, buildings, stored products, and people, and they've been just as creative in turning almost everything into food. And believe me, if we consider something edible, there are insects that do as well! Most insects are not pests, and are completely harmless, but some are a real problem when trying to grow food, as I was learning.

Characteristics of Insects

Insects are invertebrates, which means they have no backbone or internal skeleton, but they do have an exoskeleton (internal skeleton), in the form of an outer hard shell. Their bodies are segmented with three major body regions: the head, thorax, and abdomen. Adults have two antennae, two compound eyes, six legs, and - if they have wings - they'll have either two or four wings. They come in a huge variety of shapes, sizes, and functions. Insects are cold-blooded; unlike us mammals, their body temperature closely follows the temperature of their environment. Insects are different from mites, ticks, and spiders, all of which have only two major body sections, and four pairs of legs, and do not have antennae or compound eyes. Centipedes (ouch!) are also different than insects, with one pair of legs on each body segment, and millipedes have two pairs of legs on each body segment. Sow bugs are actually crustaceans, like crabs, shrimp, and lobster (yum!), and usually have seven pairs of legs...perhaps we should try sow bugs cooked with butter?

Insect Development

All insects develop from eggs. Most hatch after the egg is laid, but some, like the aphids, hatch within the female, and live young are produced. Aphids almost always female, and are effectively hatched already gravid (pregnant), and each one begins hatching tiny aphids very shortly after her own hatching, which is why they can multiply and take over so quickly in your aquaponics system – their population grows exponentially! There are three basic kinds of insect development from the egg to the mature adult insect:

- Simple, Gradual Metamorphosis-Metamorphosis is the change from the egg to adult stage. Eggs hatch and there is a gradual change as the immature forms, called nymphs, mature to the adult stage. Nymphs have compound eyes and antennae and resemble the adults but are smaller, without fully developed wings, and cannot reproduce. Wings of the adult develop externally, and there is no resting stage, as there is with a pupa. Nymphs usually live in the same habitat as the adults. Grasshoppers, cockroaches, and aphids have a gradual metamorphosis, which is why you see small ones that look just like the larger individuals.

- **Incomplete and Complete Metamorphosis -** Some insect have a metamorphosis that does not include a resting stage, but is not simple and gradual; it is referred to as "incomplete." Dragonflies are an example of an incomplete metamorphosis: their nymphs live in water, have gills, and differ dramatically in appearance from the adults; they emerge from the water and molt into the adult form with wings, without a resting stage. Occasionally, you'll find a dried out, light beige, ghost-like shell of what is about an inch and a half long fierce-looking insect, near the edge of your troughs or on a plant. It's the left-behind shell of a dragonfly nymph, after it has crawled out of the water to molt into the adult dragonfly that we all easily recognize.

- **Complete Metamorphosis -** Immature stages are normally worm-like and are called larvae, and they feed a lot at this stage. The last larval stage is a resting stage called the pupa, which does not feed, usually is not active, and often is covered by a silken cocoon. Wings are developed internally, and when emerging, the adult expands the wings and flies off after they dry. Immature and adult stages are often quite different in form and live in very different habitats. Insects with complete metamorphosis include butterflies, flies, wasps, and beetles.

Pest Insects and Their Relationship to Plants

- Grasshoppers, beetles, caterpillars, and slugs chew on leaves, stem, fruit
- Aphids, leafhoppers, thrips, mites, whiteflies, and scales suck plant sap
- Caterpillars, root and twig borers, weevils, and leafminers bore and make tunnels
- Fruit flies and katydids lay eggs on plant tissue
- Gall wasps and erinose mites create galls on plants
- Cockroaches, whiteflies, ants, aphids, caterpillars contaminate crops with their waste
- Bagworms, leaf-cutter ants and leaf-cutter bees remove parts of plants for their nests or shelter
- Ants carry or protect pests (aphids in particular), and eat fruit and vegetable tissue
- Aphids, leafhoppers and ants transmit plant disease

Beneficial Insects and What They Provide

- Bees pollinate flowers that produce fruits, seeds, nuts, vegetables and flowers

- Honey bees, silkworms, and mealybugs create useful products such as honey, beeswax, silk, and dye

- Ladybugs, praying mantises, some flies and wasps provide biological control as predators and parasites that destroy pest insects and weeds

- Beetles, grubs, and flies provide a food source to people, fish, birds, animals

- Maggots decompose carcasses

- Dung beetles decompose dung

- Beetles and springtails improve and aerate the soil through burrowing

- Bee and flies provide medicine (bee stings give medicine for arthritis, and fly maggots are used medically for cleaning out wounds)

- Butterflies and beetles are colorful: they give us beauty, and are collected as a hobby

So, how do we not only maximize beneficial insects while minimizing the insects that damage our crops, but also do it safely and with organic principles in mind, so that our fish are not harmed? There are a few excellent ways that we've tested and tried over the first five years of our wanton experimentation in aquaponics.

Integrated pest management (IPM) of insects is designed to use a combination of techniques to increase beneficial insects while using environmentally safe pesticides to keep insect pest populations below levels that harm your ability to grow food for yourself and your family, friends, and customers.

It is important to know that we're not talking about a single method of pest control, but a series of pest management evaluations and decisions that require **DAILY** observation. We've found that "the farmer's shadow" will dictate how successful your aquaponics system will be; your success at growing food will be directly proportional to the amount of time your shadow falls upon your system! Remember above, when I said just a few pests showed up, and then all of a sudden there were thousands? Now I realize that there was simply not enough of my shadow falling onto the troughs, and the pests (especially the aphids!) were reproducing madly. I did not know enough then to look for a problem when it was quite small, then to take steps to control the pest population while it was still very small.

The Difference Between IPM, Organic, and Aquaponics Pest Solutions

It is important to understand that standard IPM techniques (especially when you get to Step #4, below – the "Control" step) are NOT the same as organic techniques, and that even organic techniques are NOT the same as safe aquaponic techniques!

IPM methods include pest control from synthetic sources (chemical insecticides), while organic methods requires all pest control be sourced from natural, OMRI-approved methods (OMRI stands for Organic Materials Review Institute). But even some all-natural, organic methods will still kill fish in an aquaponics system! For instance, hot pepper wax and neem oil are two oils approved for organic use, but they will remain in your system and kill your fish!

The same goes for soaps – one of our students used an organically approved insecticidal soap in his system to combat spider mites in his commercial strawberry system, thinking he was safe because he was in a greenhouse. He was certain that no rain would fall onto his plants and wash the soap into his trough water. He eventually killed all of his fish – about 800 pounds worth! IPM incorporates some non-natural solutions, while organic techniques require all natural methods at Step 4, the "Control Step", but both include many solutions that will kill your fish. **Chemical insecticides, oils, and soaps, whether conventional or organically approved, SHOULD NEVER be used in an aquaponic system!**

WARNING: If in doubt; TEST! Take a few mosquito fish or, if you must a few of the "main" fish that power your system, and TEST whether or not what you're about to add to your system will kill them. **What we can tell you is that any SOAP is not to be added, nor any WAX, nor any OIL-BASED substance, because it WILL KILL YOUR FISH, even in a greenhouse!**

To test anything you are considering using in your system, take a five-gallon bucket, stick a small bubbler (air pump/airstone) in, and use a small amount of the crop input you want to add, in approximately the same proportion that you will add when using this substance as for crop protection, put your fish in, and wait 72 hours. This is the method we used for every single substance listed in Step 4, below.

Some terms that we should define: "Approved for organic use" means the substance has been approved for organic production by the **National Organic Program (NOP)**, a marketing program housed within the United States Department of Agriculture (USDA) Agricultural Marketing Service, the agency that sets marketing standards. The NOP mission is to develop and implement national standards that govern the marketing of agricultural products as organically produced, to facilitate commerce in fresh and processed food that is organically produced, and to assure consumers that such products meet consistent standards.

Another common term you will see on listed on labels is the term **"OMRI Listed"**. That means the product is OMRI Listed, and has been determined by the Organic Materials Review Institute (OMRI), an independent reviewing agency, to be suitable for use in certified organic production. This process costs the manufacturer around $600,000 for each product they review, so expect products that carry this on their label to be expensive.

But keep in mind, just because a product is "approved for organic use", or carries the "OMRI Listed" label, it does not mean it's safe to use in an aquaponics system!

Integrated Pest Management

First off, you need to know that there is NO magical cure! There is no legal, ethical, and safe way to rid all of the pests from your aquaponics system! There is simply NO WAY to achieve 100% control of your pests. Limited numbers of the pest will continue to survive in your crop, regardless of the method you choose for control. The proper use of beneficial garden insects is safer, has far less labor cost, and almost always results in better crop production than any of the other methods. **Use IPM FIRST!**

IPM consists of a four-step approach:

1. **Determine Action Thresholds**: How many pests it requires to trigger a control step is an important question. Finding one aphid, for example, may not mean you need to spray your entire aquaponics system. Address this question: "At what point will the pests affect the overall health of my system?"

2. **Monitor and Identify Pests**: Yellow sticky traps are the most inexpensive and common method to determine what pests are present, and in what numbers. You can order them online or find them in your local garden center.

3. **Prevention:** In our large systems, we have found that planting an entire area in the same crop invites more pests to that area, while interspersing cultivars gives us fewer pests. Companion planting, such as marigolds planted throughout the system are supposed to provide some pest deterrence, as does crop rotation - planting different plants in different areas of the system. We'll talk more about prevention below.

4. **Control:** When your monitoring, identifying, and action steps tell you that pest control is necessary, and your prevention methods are no longer sufficient to knock down the pests in your aquaponics system, then it's time to undertake control methods. What we're looking for is the solution that has the lowest impact, environmentally, economically, and on your system.

Below we list all the things that work in aquaponics systems, following the section on Prevention.

Prevention

Preventing the problem of pests is always preferable to trying to knock down a large population that is eating the food that you should be eating. There are many steps you can take that fall under the category of prevention. Here are some of the methods and controls you can safely use with aquaponics systems:

Diatomaceous Earth

Aphids are one of the main pests we combat in our systems. They show up quickly, and because they're almost all female clones, and they're already gravid (pregnant) when they hatch, they multiply VERY quickly. One of the easiest ways to prevent aphids from colonizing the plants in your system is to prevent ants from carrying them up onto your rafts, because aphids are transported and "milked" by ants. If you control ants in the ground, you prevent aphids from taking hold in your system. You can achieve this by spreading diatomaceous earth (DE) around the perimeter of your trough area.

DE is the fossilized remains of diatoms, tiny sea creatures that lived millions of years ago. It is almost pure silica, along with some beneficial trace minerals, and enlarged under a microscope, it looks like shards of glass. On any insect that has a hard external shell (carapace), such as ants, the DE works its way in under the hard shell and punctures the insect's body, which then causes death by dehydration. Understand that DE is not an attractant, so you have to take the DE to where the ants live, they won't come to it.

DE is totally non-toxic, with no increased tolerance over time such as insects develop when using poisons, because the method of killing is purely PHYSICAL, rather than chemical. DE is great for use in your house as well, because fleas and cockroaches are affected in the same manner as ants, as they also have a hard carapace. Use a turkey baster to spread it easily along the sides of your troughs, and buy a lot of it. It keeps well (it's already millions of years old!) and it's not at all expensive. Amazon sells food grade, OMRI-approved DE for $53, plus $3.99 shipping, and Earth Works Health sells a 50lb bag for $33, that's guaranteed to be less than 0.5% crystalline silica. Find it here, at their website: http://www.earthworkshealth.com/

Some important things to know about DE:

1. **If DE gets wet, you must re-apply.** If it gets wet, it loses its effectiveness. Even morning dew can be enough render the sharp shards ineffective.

2. **Make sure not to breathe it!** It's utterly non-toxic, but the rule remains – as with any substance – wear a dust mask to avoid getting these sharp shards in your lungs.

3. **Avoid DE that is made for pool filters.** The kind formulated for use in pool filters has far more crystalline silica (which is toxic) because being super-heated has crystallized it. This type of diatomaceous earth **is very poisonous if inhaled**. Avoid DE made for pool filters!

4. **Avoid DE that includes toxic chemicals** that causes the insect to become more active. These chemicals will speed up the process of killing the insect because the increased movement of the insect causes it to lose moisture and dehydrate more quickly, but it's toxic to your fish! A dead giveaway is a label that says "97% Diatomaceous Earth", with 3% some other chemical. You want 100% DE.

5. **Food grade DE** is completely non-toxic because it is less than half a percent of crystalline silica and was intended to be added to animal feed. This means it is safe enough to eat and not as toxic to your lungs if you happen to breathe some in. In spite of it being completely safe for people and animals, it is very dangerous to insects. The insecticidal DE described below is required for commercial growers but if you are not growing commercially, there is no need to purchase high-priced DE when food grade is just as effective, and less expensive.

6. **Insecticidal DE** is also food grade, 100% DE that has had no processing or any added chemicals whatsoever. The crystalline silica content is also very low in this kind of DE, it's absolutely the same as food grade, with the only difference being that it has an EPA label allowing it to be sold as an insecticide. The EPA charges a tremendous amount of money to register a product with them, and hence the resultant products are usually also very expensive. You can get the same results by purchasing the food grade version, but if you are selling any of your produce to anyone else, you must use crop additives that are EPA registered, according to federal law.

Boric Acid

Another similar method is to spread boric acid in the same way you'd spread DE. NOTE: "Borax" and "Boric acid" are not the same. Borax is $Na^2B^4O^7$-10H2O, or hydrated sodium borate, while boric acid is $B(OH)^3$. To kill ants, roaches, or fleas, you need boric acid. But on a cautionary note, boric acid is toxic to children and pets if eaten. If you're using it on the ground, you should know that you are adding boron to the soil, and excess boron renders the ground useless for growing anything. It takes only a very small amount to be excessive because boron is actually considered an herbicide. For both these reasons, DE is by far the preferable material to use, and we do not recommend the use of boric acid to kill ants unless you are very careful, and know it will not be eaten!

Boric acid is quite expensive from the pharmacy, but you can get far less expensive boric acid that is meant for killing roaches. It is available online if you can't find it in local stores, but Home Depot usually has it. "Victor" is one brand of boric acid that is made to combat roaches, and is commonly available at home and garden centers.

For killing ants outdoors, orange oil (d-limonene) kills on contact, as well as disrupting the chemical trails that ants follow (which is why they're always running along in a line, one after another). Mix 2 to 4 ounces of orange oil and a small squirt of soap in a gallon of water and drench the entire ant mound. You can find orange oil at some feed stores, or order it online (I get all my essential oils at Liberty Natural, www.libertynatural.com); it's quite inexpensive. Keep in mind this method is NOT for use on the rafts in your aquaponics system, but rather only on the ground where the ant colony lives; this is an oil that will stick to your fish's gills and kill them.

How To Combat Nocturnal Foliar Feeders

There's an elegant solution to keep foliar feeders, such as Chinese rose beetles away from your aquaponics system if they prove to be a problem. And this mechanical answer makes your aquaponics system look wonderful at night! Depending on what ethnic group you belong to, we've heard these beetles called "Japanese beetles", "Chinese beetles", "Portuguese beetles", it goes on and on.

A taro leaf that has been skeletonized by Chinese Rose Beetles. These beetles also eat your baby sprouts out of the pots in the sprouting tables, and you can't tell it's them without a lot of detective work.

It's much easier just to string those small white Christmas LED lights over your sprouting tables and have a timer turn them on for the first two to three hours of darkness.

The bad news is that this insect control method just makes the beetles fly away to another location on your farm, or to your neighbor's place; it doesn't kill them or incapacitate them.

Chinese rose beetles did a lot of damage in our systems before we learned this simple trick, especially in our sprouting tables, where one or two cruise through and leave a wide swath of destruction, eating the tops off of hundreds of tiny sprouts. Chinese rose beetles leave behind what are called skeletonized leaves – they eat the soft tissue between the veins, and leave the veins behind, leaving the leaf looking like lace. It's very distinctive, and below is a photo of a taro leaf that's been attacked by Chinese rose beetles.

They eat the leaves of a lot of different plants, including rose, grapes, beans, eggplant, corn, cucumber, ginger, and ornamentals. Chinese rose beetles have a very distinctive life cycle that includes hatching out of the ground, where their larval stage lives, swarming around the plants above where they emerged, eating everything in site, mating, and then dropping back to the ground to lay eggs. And because they swarm, feed, and breed most actively in the two hours after dusk, the answer is to keep things lit up, at least for a couple of hours after the sun goes down. We strung a few strings of Christmas lights around the perimeter of our aquaponics systems, and over our sprouting tables, hooked them up to a timer so they were on during the first 2 to 3 hours of darkness, and have never since had a Chinese rose beetle cause a problem. And it looks wonderful at night!

Physical Barriers

Physical barriers include weed mat and floating row covers. Weed mat allows you to keep weeds away from the sides of your troughs. You should aim for a 3 to 4-foot open space with no weeds at all for the best results, as pests often move from weeds to crops. You can buy weed mat at your local garden center or construction supply center. We've found that laying down a layer of 6-mil black construction plastic under the weed mat works best. Here in Hawaii we have a 365-day growing season, and a lot of sunshine and rain, all of which combine to make fighting weeds an almost full-time job. Adding this plastic under the weed mat before you stake it down makes it virtually impossible for weeds to grow through the weed mat, whereas with weed mat alone, it's not hard for weeds to come through.

Floating row covers prevent pests from landing or crawling onto the leaves of your plants. It's really simple: if an insect pest can't touch the surface of a leaf, it can't eat it or lay eggs on it! Floating row covers are probably the best kept secret in all of organic food production. We got ours from a company called Dubois Agrinovation, out of Canada (http://www.duboisag.com, (800)463-9999). We bought their Agryl product, which is a light, non-woven fabric that is UV stabilized and has a life of 8-10 years. If you're in colder climates, Aqryl comes in different weights, with the heavier weights offering the advantage of creating a microclimate where both heat and humidity are conserved, which

translates to earlier and larger yields in cold weather.

Resistant Plant Cultivars

One main way of maintaining a healthy and vibrant aquaponics system is to use plant species and cultivars (varieties) that are well adapted to your local conditions and which show resistance to your local pests. To find out which cultivars to plant, talk to gardeners and farmers in your area. They'll tell you which varieties are best, as well as a wealth of other valuable information. They are almost always willing to "talk story" about their passion.

What you're looking for comes under the technical term of "host plant resistance," which means plant cultivars that exhibit less insect damage when compared to other cultivars under similar growing and pest population conditions. Host plant resistance is often taken to mean immunity to pest damage, but there's really no such thing as immunity. There are three main kinds of host plant resistance: **tolerance, non-preference, and anti-biosis**.

Tolerance is when a plant survives or produces better than a standard variety with the same number of pests, or when a large insect population can be supported on a plant without the plant suffering a lot of damage.

Non-preference occurs when a cultivar is attacked less frequently than other cultivars, even though pests could choose to eat either variety. For whatever reason, some cultivars seem to be less "tasty" to insect pests, or may possess certain physical or chemical properties that discourage insect feeding or egg-laying.

Anti-biosis is when a plant has physical or chemical characteristics that protect the plant from pests. For example, plants with tough stems or chemicals such as aromatic essential oils that repel insects are examples of anti-biosis in plants.

These factors may be outside your conscious awareness, but the outcome will be that you notice that a plant just generally grows or produces better than another cultivar. We've planted dozens of different kinds of tomatoes, for example, and two of them showed dramatically fewer pests than all the others. Those two have shown up all over our property as "volunteers", growing here and there, doing very well on their own.

When selecting seeds to purchase, read the description in the catalogs for information on resistant cultivars that will grow well in your area. Check with your county extension agent, local nurseries, as well as other gardeners and farmers for best cultivars to grow. Over time, your experience with different cultivars will show you very clearly which ones are best suited for your aquaponics system. If you're growing heirloom varieties, which we strongly recommend, you can save the seeds from the cultivars that do best in your system and won't need to purchase seeds (this is why we have tomato "volunteers" on our property!)

Removal of Crop Waste

Moving crop waste away from your system as well as disposing of weeds and other volunteer plants eliminates both food and shelter for many insect pests such as aphids, webworms, cutworms, white grubs, millipedes, centipedes, and spider mites. Turn crop waste into the soil with a shovel, or take it to your covered compost pile immediately to reduce pests in your growing area.

Companion Planting

Companion planting is the intentional mixing of different species of plants in an attempt to reduce insect populations. Many claims have been made about the ability of certain plants to protect certain other plants from insect damage, however, there's not good research to substantiate these claims. We plant marigolds here and there because I like marigolds, they're excellent in salads, and they make lovely leis, an important cultural practice here in Hawaii. I really haven't noticed any pest reduction near the marigolds, and there is no science to back it up.

Control

When your insect monitoring and identification indicate that pest control is required, and the preventive measures you've put in place are no longer working, the next step is to evaluate the proper control method both for effectiveness and safety. Mechanical controls, such as trapping or weeding, are always the first action step to take, however, if your system is large, or the insect population continues to grow, then additional pest control methods will be needed, such as targeted spraying of biopesticides. **Remember: organophosphate or other chemical pesticides CAN NEVER be used safely in an aquaponics system; nor can many "approved" organic pesticides such as oil, soap, pepper, or wax sprays!**

Mechanical Control

Mechanical control includes the use of physical methods or picking off insects by hand. Handpicking of insects and insect eggs provides fast and effective control, and works particularly well with larger foliage-feeding insects such as tomato hornworms, potato beetles, and squash bugs. Mechanical control methods obviously are more practical for a small aquaponics system than for a large commercial operation. Preventive devices and barriers are often easy to use, but their effectiveness varies.

Mechanical controls include using a stream of high-pressure water to knock insects off plant stems and leaves. Make sure to use this tactic only on sturdy plants to avoid plant damage. You can also physically remove the individual leaves that are harboring the pest, if there are not too many of them, or remove an entire plant from the system if necessary.

Mechanical traps such as colored sticky traps can be used to control or monitor insects. Many insects are attracted to yellow, while other colors used include blue, red, and white. Pheromone-baited traps attract a certain sex, usually males, of an insect species and can help reduce the mating population in the area. Food baits are also used in traps and usually attract both sexes.

There are other physical traps that are effective at mechanically containing certain pests, which you can place strategically around your aquaponics system:

- A small pan placed flush with the soil and filled with beer will attract and drown slugs and snails.
- A thin copper tape (1-mil to 4-mil) applied to the perimeter of your trough's 2X4 rim, will keep slugs and snails from crossing over into your rafts. Slugs and snails cannot stand to travel across copper. This tape is sometimes available with a sticky back from electronics industry sources that can be stuck directly onto painted wood surfaces with good results. It's expensive, but certain.
- A container, half-filled with a 10% solution of molasses in 90% water will attract and drown grasshoppers and some beetles. Adding a smashed banana or other fruit will improve the attraction properties.
- **Blacklight traps** are broad-spectrum insect attracting devices, but studies have shown that the electrocution devices kill more beneficial insects than pests, so these are **not** a good solution.

Temperature and Humidity Control

Spider mites in particular prefer hot, dry conditions. Over 85°F/29.4°C will cause explosive growth in spider mite populations. Using a stream of water as mentioned above would knock spider mites off, as well as increasing the humidity around the leaves, which also helps to bring spider mite infestations under control. However, spider mites merely knocked off can survive and colonize nearby plants, so you'll want to take more aggressive steps unless the initial population is very small. You can also mist your plants daily to increase humidity. If you see evidence of spider mites at all, take **immediate** action. I cannot stress enough how difficult they are to suppress once they've taken hold in your plants!

Control Using Beneficials

Beneficials can be either a predator (an insect that eats the pest) or a parasite, which is an insect that lives off the pest in some manner, weakening and killing it. An example of this would be a wasp that lays an egg in a caterpillar, and when the egg hatches inside the caterpillar, the larvae begins to eat it. You need to understand that if you purchase beneficials, it is the equivalent of ordering "seed stock" when you purchase good plants or seeds for your aquaponics system. The beneficials you purchase will be the foundation of your beneficial garden insect population, but they are only there as long as they have good food to eat (the pests you're trying to eradicate).

Once that good food is gone, they'll move on, to places where there is better food! When the pest population has significantly diminished or disappeared, so will your beneficials. When the pest population recurs, you'll have to order more beneficials. But over time, you will find that the more beneficials increase, the more your pests will decrease, because they'll come back "home" when you need them. The best place I have found to order beneficials is HydroGardens, out of Colorado, www.hydrogardens.com, (888)693-0578. Make sure you ask for their catalog, which is filled with good information. They'll also identify any insect that you are mystified by, and then send you the beneficials that you need to combat them.

A lady bug (lady beetle) eating an aphid, with two more aphids in the background left.

Ladybugs are one of the most pleasant and helpful of the "beneficials", and you can get them at HydroGardens (888-693-0578). These people will also identify your pest insects for you, and suggest beneficials that will control them.

Biopesticide Crop Treatments

Biopesticides are naturally occurring biochemical compounds that control pests, microorganisms that control pests (microbial pesticides), and pesticidal substances produced by plants containing added genetic material (plant-incorporated protectants).

There is an important legal requirement for biopesticides: if you are selling commercially**, you MUST**

use products that are registered with the EPA. To understand this more, realize that there are many good, "old-fashioned" organic crop treatments that work, but have hidden dangers. For example, spraying non-fat dry milk onto crops to combat downy and powdery mildew is an old time organic remedy. On the surface, this looks harmless enough; I've heard it really works, and it's very inexpensive. The problem is, imagine someone with severe lactose intolerance eating a large salad afterwards, never expecting to become ill because his or her salad was full of a hidden dairy product!

The crop treatments listed below are products we've personally tested and know are safe in aquaponics systems. All are EPA registered for use on most crops, but read the label to make sure you're within the limits of federal law if you're selling commercially.

***Beauveriabassiana*, strain GHA**

BotaniGard® 22WP is a biological insecticide that controls primarily the nymphal and larval stages of whitefly, thrips, aphids, psyllids, mealybugs, scarab beetles, plant bugs, weevils, and many other insects. It's a mycoinsecticide, which means it's composed of a fungus, *Beauveria bassiana*, strain GHA, that controls even the most resistant strains of pests. It's species-specific, which means it only affects soft-bodied pests, while leaving hard-carapaced (shelled) beneficials such as ladybugs and preying mantises unharmed. Because BotaniGard has a higher spore concentration than other *Beauveria*-containing products, it's more effective, and it can equal or even exceed the effectiveness of chemical insecticides. BotaniGard is **not** OMRI-approved, so see the information for Mycotrol O, below, if you're going for organic certification. BotaniGard is sold in 1-lb containers, for around $80.

Mycotrol®O is the organic version *of BotaniGard,* **and is OMRI Listed** (Organic Materials Review Institute)**.** Mycotrol O is a biological insecticide that functions identically to Botanigard, it's just more expensive because it carries the OMRI seal of approval. It's sold in liquid form, in sizes: 1 pt. (~$65), 1 qt. (~$110) and 1 gal (~$290).

NOTE: Approved uses vary depending on region and regulatory authority; so check label for approved use in your area.

***Streptomyces lydicus* WYEC 108**

ActinovateSP is a 10% water-soluble powder that contains a patented beneficial microorganism called *Streptomyces lydicus WYEC 108.* This microbe grows on the plant's roots and leaves, living off the plant's by-products while at the same attacking harmful disease causing pathogens. It's a natural product that effectively controls a wide range of both foliar (leaf) and root diseases. It's sold in 20-gram, 2-ounce, and 18-ounce sizes. This product is relatively new, and somewhat expensive (over $100 per pound, but a pound lasts quite a while).

Actinovate SP controls many soil borne diseases including *Pythium, Phytophthora, Fusarium, Rhizoctonia, Verticillium*, late blight, and other root decay fungi, which can cause problems in aquaponics systems. We plant seedlings and spray Actinovate before the seedlings are transferred into the main system, drenching the top of the coir/vermiculite mix. We also apply Actinovate SP in a spray application to prevent the foliar diseases of powdery mildew, downy mildew, grey mold (*Botrytis*), Alternaria , fire blight (*Erwinia*), leaf spots and rusts, and black spot (*Diplocarponrosae*).

NOTE: Approved uses vary depending on region and regulatory authority; so check label for approved use in your area.

***Bacillus subtilis* QST713**

Serenade/Rhapsody is the brand name of a series of broad-spectrum fungicide and bactericide put out by a company out of Davis, California called AgraQuest. For simplicity's sake, we'll refer to them all as "Serenade".

Serenade is a highly effective fungicide and bactericide bundling several modes of action for a wide spectrum of control with little potential for the development of resistance in fungal and bacterial populations. Serenade is based on a proprietary active ingredient, *Bacillus subtilis* QST713; which is a naturally occurring strain, discovered after AgraQuest's team of scientists screened over 22,000 unique strains of bacteria. Each bag or jug contains chemical compounds produced by QST713 during fermentation, as well as spores that are unique in their production of both antifungal and antibacterial compounds. During production, AgraQuest controls fermentation parameters in order to optimize output of these compounds.
Serenade has four modes of action, two of which offer disease control, and two of which offer plant activation.

For disease control, Serenade has broad anti-fungal activity and strong anti-bacterial activity. To activate the plant, Serenade elicits plant defense mechanisms and promotes plant growth, to enhance yield and improve overall quality of produce. It triggers the plant's internal defenses and physiological responses, which begins upon contact with the plant. And the effect is systemic: these responses are triggered throughout the plant even when a small area is treated. These results have been proven with bioassay and RNA analysis, according to the company's website, http://www.agraquest.com/.

Serenade treats the diseases of: *Botrytis cinerea* (Botytis), sour rot, *Peronospora*spp. (downey mildew), *Erysiphe*spp. *Oidium*spp. *Podosphaera*spp. *Sphaerotheca*spp. (powdery mildew), *Sclerotina* (leaf drop), *Colletotrichum*spp. (anthracnose), *Alternaria* (early blight), *Erwiniaamylovora* (fire blight), *Xanthomonascampestrispvvesicatoria (*bacterial leaf spot *), Pseudomonas syringae* (bacterial speck), *Pseudomonas syringaepvsyringae (*Bacterial blight), *Xanthomonasarboricolapvpruni (*bacterial leaf spot), *Diplocarponrosea*(black spot), *Alternaria*spp. *Cercospora*spp. *Entomosporium*spp. *Helminthsporium*spp. *Myrotheciums*pp. *Septoria*spp. (leaf spots), *Xanthomon* (canker), *Phytophthora*spp. (rust), *Puccinia*spp. (scab), *Venturia*spp., *Septoria*spp.**, *Rhizoctonia*spp. *Pythium*spp. *Fusarium*spp. and*Phytophthora*spp.

****BACILLUS SUBTILIS IS NOT FOR USE IN CALIFORNIA**

NOTE: Approved uses vary depending on region and regulatory authority: so check label for approved use in your area.

Bacillus thuringiensis*, subspecies *Kurstaki

Biological insecticides, or biolarvicides, based on a beneficial bacterium Bacillus thuringiensis (Bt) are the most proven, most widely used and most successful of the known biological pesticides. Each Bt cell produces a unique crystalline protein known as Cry toxins. These Cry toxins must be eaten by the larval stage (caterpillar) of the pest insect to be effective. Once eaten, very specific gut enzymes which only function in the alkaline conditions of soft-bodied insects and caterpillars guts dissolve the crystals to form the active ingredient that disrupts the pest's digestive tract.

Since Bt is most effective against small, newly hatched larvae, an early scouting program to determine early infestations is critical (just what I did NOT do back in the beginning of our aquaponics adventure!) After consuming a lethal dose of Bt, larvae stop eating within an hour, but may remain on the foliage until they die, usually within several days. Affected larvae move more slowly and tend to become shriveled and discolored before dying, so it's easy to see how effective Bt is, within 24 hours.

Bt was first isolated in 1901, and by 1920, farmers began using Bt to control worm pests. The first commercially produced Bt products appeared in 1938. Modern Bt products are based on the subspecies *Kurstaki*, (abbreviated as *BtK*) and exhibit increased efficiency as well as better persistence in the environment that makes them ideally suited as an excellent IPM, organic, and aquaponic

solution.

We use *BtK* because it works very well against crop-damaging Lepidoptera (the scientific name for the family of moths and butterflies) pests. It's environmentally friendly, not harmful to bees, birds, fish or other wildlife. Studies have shown that *BtK* does NOT harm beneficial insects that help keep secondary insects in check. *BtK* can be handled by workers without the use of costly protective gear normally associated with other pesticides. *BtK* plays an integral part in our IPM program, offering extraordinary relief when the evil cabbage moths are hard at work laying their eggs on our aquaponic crops.

Because of *BtK*'s specific mode of action, it's not harmful to humans or animals. The biological compounds put less stress on the environment than synthetic chemicals and have not been observed to be harmful to fish, wildlife or livestock. Workers are also able to handle *BtK* with considerably more ease than chemical-based compounds. The EPA has granted the minimum allowable safety requirements for use with *BtK*, both in terms of application and re-entry (the amount of time workers are supposed to leave the field after application).

As with any insecticide, workers are required to wear gloves, long sleeves and long trousers when handling *BtK*, are permitted to re-enter fields in as little as 4 hours after DiPel has been applied and crops can be harvested the same day they are treated. This is absolute overkill, as there is nothing whatsoever in *BtK* that is harmful to anything other than a caterpillar, but that's what the label instruction must say, according to Federal law.

Because of how *BtK* works, achieving good coverage during application is extremely important. Foliar application of *BtK* provides excellent caterpillar control as long as you take care to cover the part of the plant the pests will eat. We use backpack sprayers, making sure to thoroughly cover all plant surfaces, even the undersides of leaves as much as possible, positioning the nozzle at different angles and using enough pressure to penetrate the foliage thoroughly. To maximize coverage, we spray when the wind speeds are 10 mph or less.
We treat our crops when the larvae are young (early instars), before much crop damage occurs, and repeating the applications at an interval sufficient to maintain control, usually weekly, depending on plant growth rate, moth activity, rainfall after treating and other factors. We use an OMRI-approved wetting agent with both brands of BtK called "Safer-Gro" according to label directions, to spread the droplets of BtK out over the leaf surface as well as to improve weather fastness.

DiPel

DiPel is the brand name of BtK manufactured by Valent Biosciences, www.valentbiosciences.com, according to the manufacturer, DiPel contains a balanced blend of five bacterial protein toxins and a spore, which enhance efficiency and assist in resistance management, which refers to the pests ability to develop resistance to the product. DiPel is certified as organic by OMRI (Organic Material Review Institute) and is available in the following formulations:

- DiPel DF (Dry Flowable)
- DiPel ES (Emulsifiable Suspension)
- DiPel 10G (Corn Grit)
- DiPel SG Plus (Sand Granule)

We've used the DF formulation, and it worked very well. It costs about $20 per pound, but once on eBay I found a 5-pound bag for $20, plus $5.00 for shipping. That bag has lasted almost three years, and it's not completely gone yet!

Javelin

Javelin is a *BtK* product manufactured by Certis USA, in Columbia, MD. Javelin is also certified as

organic by OMRI. It would appear to be the same as DiPel, except on its label, the following words appear: "active Ingredient: *Bacillus thuringiensis,* subspecies *kurstaki* strain SA-11 solids, spores and Lepidopteran active toxins*…….85.0%", with other ingredients listed at 15%. The asterisk after the word "toxins" says "The percent active ingredient does not indicate product performance and potency and the measurements are not federally standardized."

The DiPel label has this exact same statement, after disclosing that DiPel DF is only 54% the "active ingredient *Bacillus thuringiensis,* subspecies *kurstaki* strain SA-11 solids, spores and Lepidopteran active toxins*".

Under normal circumstances, one would think that 85% active ingredients would be stronger and more effective than a product that contains only 54% active ingredients, however, that last statement seems to throw some doubt on that assumption. After four years of using DiPel, about six months ago I spotted some Javelin on sale at our local feed store for $8.00 per pound, and I bought all they had. I probably have a four-year supply, if not more, so watch for a report on our results and overall impressions in our weekly newsletter. So far, it looks at least as good as DiPel.

Both DiPel and Javelin are approved for use against the lepidopterous larvae listed below (from the label). I include the both the common names as well as the scientific names here. Most of these are not pests you will ever find in your aquaponics system. However, you might have trees or other crops planted in the ground, which might someday need this *BtK* product.

Common Name (Scientific Name) Of Pests Killed By Bt:
Alfalfa caterpillar *(Coliaseurytheme*), Almond Moth *(Cadracautella),* Armyworm *(Pseudaletiaunipuncta),* Artichoke plume moth *(Platyptillacarduidactyla),* Bagworm (*Thyridopteryxephemeraeformis),*Banana moth *(Opogonasacchari),* Banana skipper *(Erionotathrax),* Bertha armyworm *(Mamestraconfigurata),* Blueberry leafrollers (various species), Blueberry spanworm (*Itameargillacearia),*Bollworm *(Helicoverpazea),* California oak moth *(Phryganidiacalifornica),* Cherry fruitworm (*Grapholitapackardi),* Citrus cutworm *(Xylomygescurialis),* Codling moth *(Cydiapomonella),* Cotton leaf perforator (*Bucculatrixthurberiella),* Cotton leafworm *(Alabama argillacea),* Cutworm (various species in the family Noctuidae), Diamondback moth *(Plutellaxylostella),* Douglas-fir tussock moth *(Orgyiapseudotsugata),*Elm spanworm *(Ennomossubsignaria),* European corn borer *(Ostrinianubilalis),* European Grapevine moth *(Lobesiabotrana*),* Fall cankerworm *(Alsophilapometaria),* Fall webworm *(Hyphantriacunea),* Filbert webworm *(Melissopuslatiferreanus)*, Fruit tree leafroller *(Archipsargyrospila),* Grape leaf folder*(Desmiafunerali),* Grape leaf skeletonizer *(Harrisina Americana),* Green cloverworm (*Plathypenascabra),* Green fruitworm *(Lithophaneantennata),* Gypsy moth (*Lymantriadispar),* Helicoverpa spp. *(Helicoverpa spp.),* Heliothis spp. (*Heliothis spp.)*, Hornworms *(Manduca spp.)*, Imported cabbageworm *(Pierisrapae),* Jack pine budworm *(Choristoneurapinus),* Light brown apple moth *(Epiphyaspostvittana),* Loopers *(*various species), Mimosa webworm (*Homadaulaanisocentra),* Naval orangeworm (*Amyeloistransitella),* Oblique banded leafroller *(Choristoneurarosanceana*), Omnivorous leafroller *(Platynotastultana),* Omnivorous leaf tier *(Cnephasialongana*), Orange tortrix *(Argyrotaeniacitrana*), Orangedog *(Papiliocresphontes*), Oriental fruit moth *(Grapholitamolesta*), Pandemis leafroller *(Pandemispyrusana)*, Peach twig borer *(Anarsialineatella*), Pecan nut casebearer *(Acrobasisnuxvorella*), Redbanded leafroller *(Argyotaeniavelutinana*), Redhumped caterpillar *(Schizuraconcinna*), Rindworm complex *(*various), Roughskinned cutworm (*Athetismindara*), Saltmarsh caterpillar *(Estigmeneacrea*), Sod webworm *(Crambusmutabilis),* Southwestern corn borer *(Diatraeagrandiosella*), Spotted cutworm *(Xestia spp.),*Spring cankerworm *(Paleacritavernata*), Spruce budworm *(Choristoneurafumiferana*), Tent caterpillar (various, family Lasiocampidae), Tobacco budworm *(Helicoverpavirescens*), Tobacco hornworm *(Manducasexta*), Tomato pinworm *(Keiferialycopersicella*), Tropical sod webworm *(Herpetogrammaphaeopteralis),* Tufted apple bud moth *(Platynotaidaeusalis*), Variegated leafroller *(Platynotaflavedana*), Velvet bean caterpillar *(Anticarsiagemmatalis*), Western tussock moth *(Orgyiavetusta*).

Other Aquaponic System Pests:

- **Aquatic Snails:** Although they are not strictly a vegetable pest, we have seen aquatic snails show up time and again in our student's (and our) systems. These snails live underwater and do not survive

above water for any length of time. Fortunately, we haven't seen a variety yet that eats plant roots; the ones we've been infested with graze the algae off the sides of the troughs where the sun shines in at the edges of the rafts.

- In early 2012, we discovered that Chinese catfish eat aquatic snails. Our systems had become infested with these snails in 2011 because a farm intern had ignored biosecurity policies on the farm, by bringing some aquatic plants in to our systems from the local Petco; the snails came in with these plants. Chinese catfish apparently do **not** bother the roots of the plants in the rafts. Here's how we determined this: we ran two tests: we put four 5-inch long catfish into a small tank with 200 snails, and four more into a second small tank with a small raft with plants in it; we didn't feed the fish in either of these two tanks **anything** during the duration of the test.

- After ten days, there were only 20 snails left in the "snail tank" that originally had 200, and the catfish in this tank had all grown noticeably fat and larger. In the "raft tank", the plant roots were untouched, and (of course), the catfish were all the same size they had been when they went in. We are now testing this on a larger scale with 100 catfish in one of our systems to make sure there are no other problems, but the catfish appear to be a natural biological control for the snail problem.

  A further benefit here is that the catfish will be an additional edible product of the system, not requiring to be fed by us. We probably need to match the amount of catfish to the size of the troughs they go into so that the catfish's need for food is balanced by that trough's ability to supply food (snails). In other words, if we put the right amount of catfish into a trough, they will control the snail population and not require that we feed them purchased commercial fish food. And, we have a self-supporting new income stream for our commercial aquaponics farm.