Exerpted from the Gifford Arboretum Newsletter, Spring 2014, Volume 9 issue 2

Beneficial Uses of Microbes for Improved Food Supplies

By: Philippe Douillet, Ph.D.
University of Miami Adjunct Professor and President of Ecomicrobials LLC

Recent reports from the Human Biome Project have caused great impact by showing the magnitude of the relationship we have with microbes. We host ten times more microbes in our bodies than human cells (100 trillion microbes, but only 10 trillion human cells per individual)! More importantly, this Project has brought into perspective the massive number of interactions we have with those microbes. These range from easily conceived protection of our skin from pathogens, to the impacts of gut microflora in obesity, diabetes, and even neurological conditions such as autism.

Just as microbes developed close relationships with humans, they also did this with plants and animals, many of which have been on our planet much longer than us. Not a single living plant or animal has been found without bacteria associations, and when grown without bacteria (under axenic conditions) both plants and animals develop poorly and incompletely. Even for more complex and less obvious interactions, such as those developed by arbuscular mycorrhizae fungi with plants, it has been found that over 95% of plants form symbiosis with these fungi.

I have now been working for over 30 years with beneficial microbes as they relate to plants and animals. I studied marine biology during college and also earned advanced degrees in this area. I have a passion for aquaculture, and I received my Ph.D. from Oregon State University in Fisheries and Aquaculture. However, early on, I noticed that microbes were blamed for culture problems such as disease and mortality, poor growth, high costs, and inefficiencies in water quality maintenance, etc., and, in all cases, microbes were treated as some black box for which there was only limited control.

I then started working with whole microbial communities, which were able to regulate stability in crustacean cultures and provide nutrients to supplement nitrogen poor diets, such as grass clippings. These regimes yielded better growth than those obtained with expensive, protein-rich diets. I found that these microbial communities could be stabilized and their beneficial effects transferred to bacteria-free crustacean cultures. However, the species composition of these beneficial communities could change, and it was impossible to control them long term.

I continued working with defined, single strains of beneficial microbes. Even though consistent beneficial effects under laboratory conditions could be obtained with these single strains, their applications in the field were not always consistent. This was an observation that I had also made with commercial probiotic products based on single strains.

Bacillus bacteria used as probiotics in agriculture and aquaculture applications

My next step was to work with defined blends of synergistic microbes. These communities of known composition do provide consistent beneficial effects in different crops as well as environmental conditions. They are more stable as a community than single strains, in part because they can utilize diverse mechanisms to accomplish a specific goal. For example, in order to control a fungal pathogen, a blend of bacteria can produce and secrete needed enzymes that break down the cell wall of the pathogen;

produce a whole array of antibiotics; and absorb and sequester essential nutrients for the pathogen by means of siderophores.

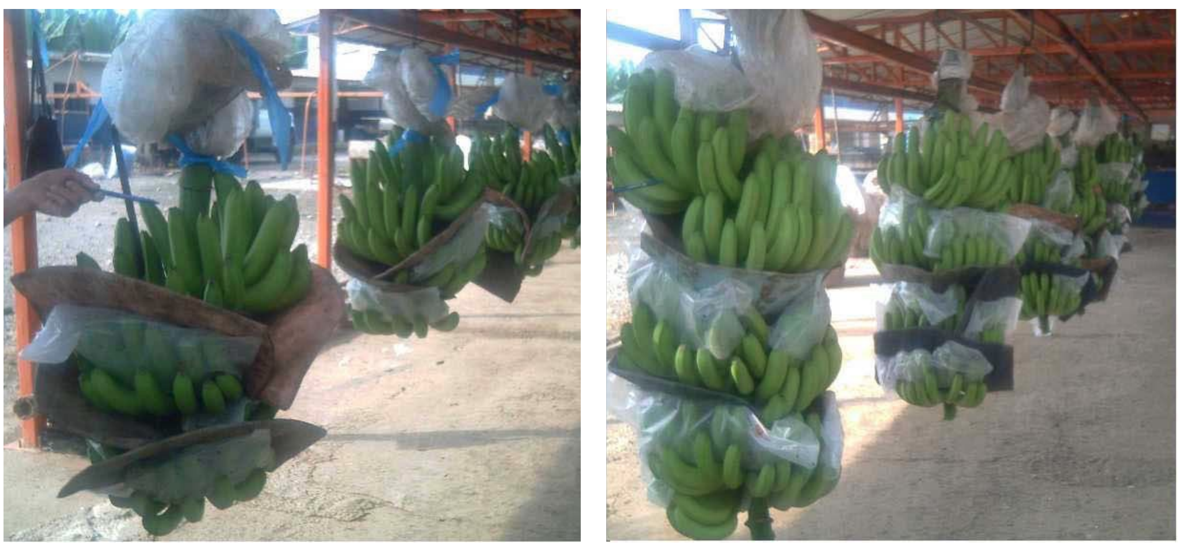
As a result of this research, I developed a blend of Bacillus that resulted in consistent control of the pathogen *Phytophthora* during two years of research on peppers and tomatoes, with no failures even in different geographical areas and crop varieties. This blend was patented in the U.S., and it has been found to control an array of fungal pathogens in plants. Part of the success was also due to the development of a balanced nutrient for the microbes, as they require building blocks to produce an array of complex beneficial molecules such as enzymes, vitamins, phytohormones and antibiotics.

This same approach has been used to control mortality in a fish farm in Florida where mortality rates had been very high for over a decade while utilizing conventional treatments with antibiotics and vaccines. Isolation studies revealed that there were 5 different pathogens associated with the diseased fish. A blend of Bacillus was formulated using in vitro antagonism studies against the pathogens isolated from the fish. With this approach complete bio-control of the disease was achieved (Douillet & Robinson, Global Aquaculture Advocate, May-June 2008), and the fish mortality rates plummeted.

There is no single magic bullet to efficiently control pathogens and reduce the stresses that organisms are exposed to. Microbial management is required to provide the conditions for the microbes to develop and perform their diverse mechanisms of biocenosis, and this is where beneficial interaction with other scientists came into play. Several years ago, I started working with Dr. Daniel Benetti from RSMAS on a project to improve larval survival of the marine fish Cobia (*Rachycentron canadum*). The fish reproduced well in captivity; however, the survival of larvae to fingerlings was low (around 5%). An integrated management that included the use of Bacillus probiotics developed by the team lead by Dr. Benetti has resulted in survival rates of 30 to 35%. We continue to work to further improve these percentages.

Similarly, integrated management of systems with probiotic bacteria have been developed in Ecuador with German, Russian and Ecuadoran scientists. We have been able to consistently increase yields in banana crops by 30% for more than a decade while also controlling the deadly Sigatoka fungus disease without the use of pesticides. In other crops such as rice and shrimp, the increases in yield have been in some cases over 100% with similar integrated management approaches.

Microbes in the soil have many functions, and they are well known for recycling nutrients such as nitrogen and phosphorus. This recycling allows a whole array of microbes to proliferate in the soil. Bacteria are the organisms with the highest proportion of nitrogen in their tissues; their C/N ratio is 3. The immediate bacterial grazers such as protozoa or nematodes have a C/N of 30 to 50, so they need to excrete nitrogen after grazing on bacteria, and this nitrogen is in the form that plants assimilate best. The reason plants excrete through the roots up to 25% of the carbon they fix is to attract and feed bacteria and to create a food web close to their roots in order to get valuable nitrogen. This is the natural way of nitrogen fertilization in the soils. But the use of fertilizers and pesticides reduces the diversity and density of microbes in the soil, making them less productive. Under those conditions, plants become more dependent on fertilizers to get their nutrients. However, fertilizers are very simple in composition (mostly NPK formulations) and do not satisfy all plant nutritional requirements. Therefore plants become weak and release biochemical compounds into the environment that signal predators and pathogens that they are debilitated and easy targets. This can in turn be the beginning of an outbreak of disease, and the response by growers usually is to use more fertilizers and pesticides, thus compounding the cycle of soil degradation.



Banana bunches produced in a commercial farm in Ecuador under conventional methods using pesticides on the left, and under a 100% organic integrated management that includes the use of probiotic bacteria on the right

Lead by Dr. Elaine Ingham, a group of scientists at Oregon State University has worked extensively on the organisms that live in the soil. They were so successful in explaining poor growth performance in crops that they formed a company called Soil Food Webs that performs soil analysis of the diverse groups of soil organisms. After decades of work, we have now been able to corroborate the findings of Soil Food Webs in many countries and in diverse ecosystems from desert to forest soils. The use of microbial management that includes some organic and inorganic additives has increased soil organic matter in desert soils from a content of 0.03% to 0.8% in only a couple of years. Furthermore, it was demonstrated that when microbes in the soil retain nutrients and water, erosion is also reduced. With microbial management in many agricultural ecosystems, we were able to increase yields by 30 to 40% while also using 30 to 50% less fertilizer and 40% less water than conventional methods. Increasing food yields while decreasing adverse environmental impacts should be a global goal in agriculture.

Ecomicrobials LLC's most recent achievement has been in integrating fish farms with hydroponics in Florida. Tilapia are first grown under intensive conditions in bioreactors where they are cultured with floc technology enriched with our Bacillus blend. The result was that there was little to no accumulation of sludge as the probiotics and biofloc converted the waste into natural feed for the fish. This microbial-based feed allows the production of fish with feed conversion rates of 0.9 instead of 1.4 kg of feed per kilogram of fish produced. The water from the fish tanks is then used to feed hydroponic crops such as passion fruit and Chinese sour melon grown in coconut fiber with yields significantly in excess of those reached with conventional fertilizers. Other fish farms in the Homestead area that also use probiotics have been able to reduce their water consumption by 80%, their feed consumption by 28%, and their energy bills by 25%.

For many years the main criticism to biological control has been the inconsistency of results. But with these integrated management strategies, we can now get results that are as consistent as chemical managements, but with higher yields at similar or lower production costs. The benefits to the environment of not damaging our soil and water are a very important bonus.

****