Restoring microbial diversity

Food security is a primary concern of nations around the globe. **Dr Mary Lucero** believes this can only be achieved by driving social change that increases the microbial diversity of our agroecosystems

From what context did your business End-O-Fite Enterprises LLC evolve? Could you outline the company's main objectives?

Contemporary agricultural and food processing practices tend to deplete beneficial plant-associated microbes (including endophytes) from our soil and food systems. These microbes contribute to both soil health and herbivore diets. Research has demonstrated that microbial communities carry out all the metabolic functions necessary to support plant growth and human nutrition. Disturbance – whether through tillage or application of synthetic chemicals – drastically alters the structure and function of microbial communities.

End-O-Fite Enterprises LLC was founded to restore microbial complexity to food systems. We work along the entire chain of production and consumption, from aiding growers to restore soil microbiomes, to providing consumers with information and access to products that increase biocomplexity in their diets. We also promote development of small businesses that diversify local and regional food systems.

How can the restoration of microbial diversity lead to sustainable agriculture and safeguard human nutritional health?

Increasing microbial diversity in agroecosystems can eliminate the need for synthetic amendments that pollute the environment and increase production costs. A properly structured microbial community is vital to maintaining nitrogen levels, retaining soil moisture, aerating soils and correcting imbalances that support the growth of weeds and pests.

Microbial communities in and on crop plants interact with hosts to regulate gene expression, and synthesise nutrients and biomolecules which improve yield, quality and nutritional value. Thus, they are fundamental components of human nutrition, representing the single most significant factor missing from modern diets.

In your opinion, what are the major issues impeding the development of sustainable solutions to restore food security?

Broad policies standardising agricultural and food service practices promote and/or enforce use of technologies that deplete the microbial complexity fundamental to sustainable, healthy, productive food systems. Synthetic fertilisers, herbicides and pesticides are widely permitted worldwide, with little regard for either their capacity to alter microbial communities in plants and soil, or for the impact such alterations of natural systems have on human nutritional health.

Agriculture has infinitely complex dimensions that are critical to the sustainability of both the economy and environment. Problems arise when broad management decisions are made by a few policy specialists that focus on a finite handful of targeted goals, like yield or profit, rather than considering the complex local variations critical to sustaining any agricultural system. When the decisions are made by multidisciplinary teams with intimate knowledge of local economies and environments, they are more likely to implement the diverse range of practices necessary to achieve sustainable food systems.

What social dynamics influence human management decisions and actions?

The most pervasive influences include broad policies that restrict individual management decisions and define the manner in which we interact within food systems. When regulations become too complex or restrictive, local leaders lack flexibility to adapt management strategies to suit local cultures and environments. Policies that force non-selective sterilisation of food-associated microbes fail to acknowledge the possibility that many food-derived microbes may be critical for human health. Policies guiding testing of agrochemicals evaluate the persistence of chemical residues in the environment, but fail to assess changes in the microbial community that result from chemical applications.

How do you propose to enhance information transfer across socioeconomic scales?

There is limited information transfer between large governments and the general public. Decisions impacting the public often fail to serve their interest. By empowering the public with local decision-making authority we can transcend this. Governments need to relax controls and reduce taxation that limits local control of education, capital, natural resources and food policies. We foster leadership within diverse communities by implementing small business tools that empower individuals to take control of nutritional and financial resources.

Collaboration is vital to working towards global food security. In what ways are you attempting to instigate key partnerships that will help you reach the goals of End-O-Fite Enterprises LLC?

We have partnered with growers to restore microbiomes to crop lands, and with business organisations to build connected international networks that train leaders who value good nutrition, financial independence and community interactions that support healthy food systems. We have also partnered with research institutions that explore microbiome interactions in agriculture and nutrition.

Could you add some final thoughts regarding the genetic engineering of plants within the context of this research?

The discovery of cryptic endophyte communities in aseptically cultured plants raises an important question about environmental containment of engineered genes. Accepted genetic engineering techniques were designed under the assumption that recipient plants, which are typically grown *in vitro*, are axenic. Conclusively demonstrating that a plant is axenic (free of contaminating organisms) when many cryptic endophytes can escape even molecular detection now seems a hopeless task. Knowing this, how can we assess the extent to which engineered genes have already been inserted into endophyte genomes which, under certain environmental conditions, may escape into the environment to colonise other plants, soils or herbivores?

Food security for the future

Avoiding agricultural disaster requires existing technologies to restore microbiomes to food systems while empowering growers and consumers to engage in sustainable food production, distribution and consumption

DESPITE THE INCALCULABLE importance of food to health – not only of our own bodies, but that of the ecosystems within which they are fostered – it's alarming just how little thought consumers can give to where food comes from and how it has been produced before reaching for their plates.

The Green Revolution (GR) of the mid-20th Century may have temporarily alleviated the grasp of famine on the developing world thanks to the advent of innovative agriculture procedures, but it also had an unfortunate knock-on effect to the environment and the nutritional security of our food. Agriculture is an immensely complex and indisputably important part of global society; which invariably means that those with control over its machinations must have intimate knowledge of numerous local factors that interact to influence food security in any location.

Industrial advances in agriculture have tended to focus on uniform and narrow objectives such as crop yield or pest control, utilising synthetic fertilisers, herbicides and pesticides, with little thought for long-term impacts on microbial communities in plants and soil or on human nutrition. Indeed, these methods often fail to meet local-scale food demands or restore lost ecosystem services. Couple this with an ever-increasing human population, climate change and rising food/energy demands and a desperate need for improved crop production practices becomes apparent.

Though agricultural improvements have vastly increased the scale with which we can produce foods, it is a distressing fact that our global population includes almost 1 billion individuals who suffer from chronic hunger, as well as a far less accurately tabulated global percentage who suffer the broadest terms of malnutrition, including the nutritional deficiencies that lead to cancer, heart disease, obesity, and other chronic diseases. It is clear that without devising new ways to tackle the socioeconomic and ecological factors at play – not just monetary goals such as crop yield – global health will fall into steady decline.

MICROBIAL SYSTEMS ARE KEY

The research efforts of Dr Mary Lucero and her colleagues have focused on exploring the microbial interactions between: plants and their surroundings; epiphytes along plant surfaces, endophytes within plants, and rhizosphere and soil microbes on subsurface plant organs and soil interfaces. Many of these naturally occurring processes have direct parallels to agrochemical technologies aimed at enhancing crop production. For example, microbes can produce alkaloids that fend off insect pests (replacing the need for pesticides), fix atmospheric nitrogen, solubilise phosphorous and other minerals (effectively rendering synthetic fertiliser unnecessary) and vastly improve soil aeration and water holding capacity – two factors that may greatly reduce the need for intensive irrigation and deep ploughing.

In 2006, Lucero and the late Dr Jerry Barrow both employed by USDA-Agricultural Research Service at the time, filled US Patent US7901927 illustrating how the simple transference of microbial endophytes from a native plant to a crop plant can provide an incredible boost in the plants productivity and yield. At the time, they believed this simple process would one day make genetic modification obsolete.

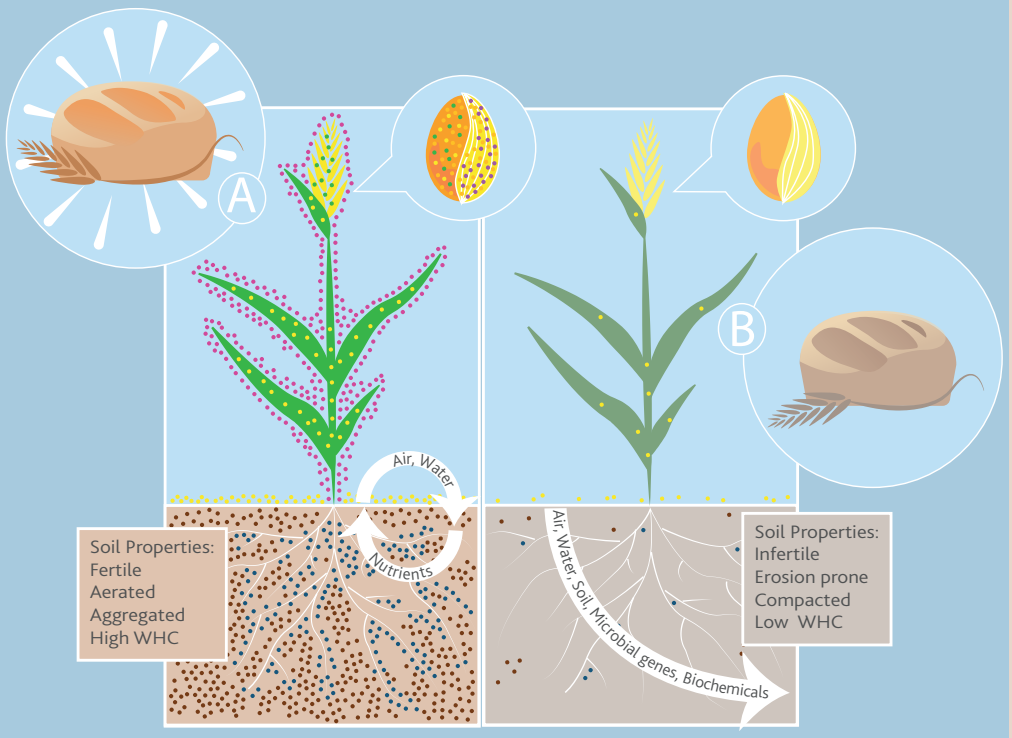
With the emergence of new metagenomic tools however, it was revealed that the consortium of microbes living inside a micropropagated plant was more complex than Lucero and Barrow had initially realised: "We originally believed our method promoted transfer of a single endophyte that persisted exclusively inside the plant," Lucero points out. "Over time, we found that we were transferring entire endophyte communities, and that persistence was not always ensured." This made results highly variable across different environmental conditions, prompting exploration of naturally occurring factors that regulate microbial community development.

In time, the group recognised that facilitating natural microbial community development in soils was more likely to produce stable, robust, and resilient crop systems than conventional agriculture, genetic modification or endophyte transfer techniques could offer. Managing to foster natural soil microbial community health would also reduce chemical usage, improve food quality, enhance soil, and make production safer and more economically feasible for growers.

SHIFTING SOCIAL PERCEPTIONS

Recognising that technologies for restoring microbial communities are readily available at large and small scales, and that continued disruption to the natural alignment of microbes and systems will inevitably lead to an agricultural collapse, Lucero co-founded End-O-Fite Enterprises LLC (EE) to engage in the mission of restoring natural microbial diversity to agricultural systems and human health. In collaboration with university partners, EE provides technical support to growers and non-profits who are converting to microbial-based production methods.

EE also works to address the social factors driving food production and diet selection. These efforts include educational approaches that highlight economic, environmental and nutritional health factors influenced by how and where food is grown; approaches that foster appreciation for microbially enhanced nutrition; and approaches that empower individuals to accept personal responsibility for broader aspects of food security. Home and community gardening are presented as critical avenues, not only for producing food, but also for enhancing multidimensional and experiential understanding of the factors that influence food quality.



Crop plants with healthy, diverse microbiomes (A) are nutritionally self sufficent, resistant to biotic and abiotic stress. Crop plants with fragmented microbial communities (B) that have been disrupted by chemical or mechanical methods are nutrient deficient, prone to pests and disease and therefore offer fruit with depleted microbial complexity and nutrition.

Collaboration is a vital component in the development of global food security. EE is working with growers, researchers, businesses, and non-profits to begin the process of restoring microbial diversity across food systems. They have also partnered with small businesses and multi-level marketing organisations, to train networks of leaders who value good nutrition, financial independence, multidimensional reasoning, and community relationships that support healthy food systems above the bottom line.

A major challenge is how best to spread the message for broad impact. There is a limited transfer of information between larger government bodies and the general public. These must be transcended to some degree. EE feels the best way for their organisation to tackle this issue is via the empowerment of individual producers and consumers. Individuals and communities need to maximise responsibility for developing food systems and localised economies in order to reduce dependence on remote governing agencies whose policies fail to accommodate varied local cultural, nutritional, environmental and economic needs.

VAST FUTURE POTENTIAL

EE was founded in December of 2012, so they have a long path ahead in the campaign to restore microbial biodiversity for increased food security… and when many of those methods involve fundamentally altering the way that agricultural business has been undertaken for the better part of 30 years, the path may be long and bumpy.

To some extent, it is their capacity as a small business that gives credence to their claims; after all, it is their belief that small businesses are integral components of a secure food system. Arguably, they find themselves at a critical time in the battle to alter public perceptions around the use of agrochemicals, antibiotics and preservatives that reduce food quality and impact upon the environment on the whole. Population growth, climate change and environmental decay are all extremely hot political topics that people are becoming increasingly aware of and engaged with. EE may have chosen the perfect moment to galvanise their message of a simpler and more naturalistic approach to agriculture, and present it to the world.

INTELLIGENCE

MICROBIAL RESTORATION TO INCREASE PLANT PRODUCTIVITY AND NUTRITIONAL HEALTH

OBJECTIVES

To restore microbial diversity to plant ecosystems for enhanced nutrient cycling, soil development and plant productivity, and to human diets for improved health.

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MARY LUCERO pioneered research in endophyte community ecology, highlighting characteristics of microbiomes that have been overlooked in plant biotechnology. At End-O-Fite Enterprises LLC, Lucero leads projects that advance food security by restoring biodiversity to agricultural systems.

End-O-Fite Enterprises