Biologicals 101 for Ag Retailers, Farm Advisors and Growers

Including Tips for Evaluating Biological Products

The agricultural biologicals marketplace is evolving rapidly with many new exciting and proven products. But the biological marketplace is also confusing, with no-agreed upon definitions and a lack of industry-specific regulatory oversight.

What is the difference between biostimulants and biofertilizers? What qualifies as a biocontrol? A biodigester? Are non-living, naturally derived materials biologicals, or something else? What do current regulations say (if anything)?

This has created a messaging nightmare for ag retailers and farm advisers. How do they explain biologicals to their farm customers in a way that makes sense, inspires trust and helps them evaluate the best products for their crop needs?

A 2021 *Farm Journal* survey of farmers found that 35% "see potential" in using biologicals, 21% "don't know" and 41% "need to know more" before using biologicals. An October 2021 industry report on biologicals by *Meister Media* found that despite the growing market share of the biological sector many growers and farmers "have yet to receive the message" about biological products.

> *"They might be relatively unaware of biologicals, or maybe don't understand the products that are available or how they work. Some remain unconvinced about efficacy and affordability. Using biologicals as a preventive in a system built around solving the problem you see in front of you right now calls for a big shift in the production mindset for many people." – Meister Media*

Prepared by DPH Biologicals® as a resource guide.
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If farmers and growers don't understand biologicals and how they can be successfully implemented within their production system, they can't evaluate products and will be unlikely to risk using them.

Regardless of regulatory and market uncertainty, the use of biologicals has grown rapidly and will continue to become an integral part of modern agriculture. As consumer demands shift and the ag supply chain tightens, consistently performing biological products are in high demand as an alternative to synthetic fertilizers and crop protection products. Every farmer should have access to refined, proven bio-based technology.

But how do growers distinguish proven products from 'snake oil?'

The rise of biological products is the direct result of growing industry and societal demands for sustainable products plus industry commitment and investment in innovative technology. The confusion is the result of a marketplace and regulatory authority lagging the rate of innovation when it comes to defining and quantifying this new approach to crop production and plant and soil health.

At DPH Biologicals, we understand the uncertainty that comes with developing new market segments. With 130-years combined experience in production agriculture, our leaders have spent their careers developing new products and markets, through the introduction of novel technologies and product concepts. We understand firsthand how confusing the biologicals landscape can be. We put together this "Biologicals 101" reference as a resource guide to help ag retailers, advisers and growers understand, evaluate and ultimately be successful at choosing the most transformative and effective biological products for their production needs.

QUICK REFERENCE LINKS:

Introduction – What are Biologicals?

Biologicals are naturally derived products, living or non-living, used in wide range of growing practices.

Biological products can do and are doing all the things that farmers and growers need their agricultural inputs to do. They act as crop protection technologies, amendments and fertilizers.

While biologicals may be isolated and reproduced in a laboratory setting to create more transformative results and effective modes of action, biologicals do not originate via laboratory chemical manipulation and synthetization. Biologicals are derived via extraction or fermentation.

While biologicals initially gained a foothold with organic producers, not all biologicals are approved for organic production systems. Conversely, most biologicals are entirely appropriate for use in conventional production systems and work in tandem with conventional, chemical-derived products. For instance, when DPH Biologicals SP-1 Classic™ is applied in-furrow with starter fertilizer, growers have reliably replaced up to 50% of their starter fertilizer, and in many cases have improved crop yield and profitability.

Biologicals offer solutions to:

- Traditional crop protection products that have lost their efficacy, due to an increase in pesticide-resistance.
- The rising costs of conventional agriculture inputs. The biological marketplace is maturing with better shelf-stable products, lowered costs and increased efficacy while conventional inputs are becoming more expensive and subjected to unpredictable price swings.
- Local and state regulations limiting the use of traditional chemically derived agricultural inputs (like nitrogen-based fertilizers).
- Soil health in the face of climate extremes. Many biological products specifically target the soil microbiome, improving tilth, water retention and nutrient uptake and ultimately increasing crop yields, quality and resiliency to pest, disease and weather extremes.
- Consumer demand for natural and environmentally friendly food production offering growers new market potential, qualification for ecosystem-based services and even new revenue streams (like carbon credits).

The Evolution of Biological Products

When discussing biologicals, it is important to pause for a moment and remember that all farmers, even those that have never used a product marketed as a biological, are already ‘managing biology’ — they are growing a biological organism (plants) in a biologically-active medium (soil).

But even so, the use of biologicals isn’t new. Even if the rapid growth in the sector may make it seem like it. Most farmers already are incorporating some type of biological within their

production methods and have done so for generations. Manure, for example, could be considered a "biological."

In modern farming, standard seed treatments are where most farmers are already benefiting from biological technology. Conventional seed treatments routinely use biostimulants and biopesticides often combined with chemically derived, non-biological, seed treatment products. Together, these products offer unparalleled crop protection solutions in an easy and effective application and have become the industry standard and ultimately been a game-changer for advancing precision farming practices.

Many think of biologicals as technology derived of living organisms, such as Plant Growth Promoting Rhizobacteria (PGPR) or fungi like *Trichoderma*. But the biologicals umbrella has expanded, both in marketing and via regulation, to encompass many non-living, nature-derived products, such as amino acids, seaweed-based products, plant extracts, and humic and fulvic acids.

In some cases, a biological product may be comprised of both living and non-living, nature-derived products offering additional benefits either to the crop or in support of the living micro-organisms in the formulation.

Ultimately, whether it is living or not, a biological product must always be derived from nature.

Four Classes of Biologicals Used in Crop Production

We break down biologicals into four classes, defined by how the products are used:

- Biocontrols
- Biostimulants
- Biofertilizers
- Biodigesters

Class One - Biocontrols

Biocontrols, aka biopesticides, are the "crop protection" side of biologicals.

Biocontrols protect against crop pests (above and below ground), insects, diseases, and weeds. The most commonly known and used biocontrol (biopesticide) agent are commercial *Bacillus thuringiensis* (Bt)-based products, approved by the EPA in 1961. However, the biocontrol market is rapidly expanding as scientists discover new modes of action in naturally derived materials, revealing exciting new ways to combat some of farmers' most persistent agricultural pests and diseases.

Biocontrols are often derived from living organisms like strains of bacteria, fungus, viruses or protozoa. But they can also be naturally occurring, non-living substances like fatty acids, pheromones or plant extracts. Biocontrols may even be bugs (aka beneficial insects) — like lady bugs used to reduce aphids or leaf-eating beetles that control St. John's Wort.

With so many modes of actions, biocontrols are marketed with many different functionalities. You may see biocontrols that are marketed as a:

- Biofungicide – Like strains of *Bacillus* (bacteria) or *Trichoderma* (fungus) species, that target seedling and foliar pathogens.
- Bionematicides – Such as spores of *Pasteuria nishizawae*, a type of bacteria, used to combat cyst nematodes in soybeans and sugar beets.
- Biomolluscicide – A good example would be neem oil used for snails.
- Bioinsecticide – The classic example is Bt for moth larvae or Bt strains specific to controlling fly or mosquito larvae.
- Biomiticide – For example, *Chromobacterium subtsugae* strain PRAA4-1T, isolated under an eastern Hemlock tree, is used to control mites.
- Bioherbicides – Such as the control of Canada thistle by a combination of insects (weevils and gall flies).

How are Biocontrols Applied?

Biocontrols, as already noted, are often applied as a seed treatment. But they may also be applied through in-furrow or foliar field applications, or, in the case of beneficial insects, released. The use of drones for spraying or releasing biocontrols is increasing farmers ability to use this new method of crop protection.

Biocontrols are rarely used alone and are typically used within IPM programs that include conventional pesticides. This helps growers reduce the risk of developing pesticide resistance and extends the efficacy of their other crop protection products. Biocontrols are also popular for operations that value shorter field reentry and pre-harvest intervals or are selling to supply chains asking for products with reduced exposure to post-harvest residues.

Current Regulatory Status for Biocontrols?

The EPA requires registration of biopesticides, which it defines as "naturally occurring substances that control pests by non-toxic mechanisms" or "microbial pesticides consisting of a microorganism (e.g. a bacterium, fungus, virus or protozoan) as the active ingredient."

Some biologicals commonly used in biofertility products, like PGPR's, may have an impact on plant pathogens. However, a company cannot market their product as a biopesticide unless they go through the pesticide registration process including a lengthy (and expensive) study process and they must have the intent to market the product as a biopesticide.

Class II — Biostimulants

Biostimulants are biological products that directly stimulate a desired response in the plant, such as additional growth, nutrient uptake or resiliency to abiotic stress. Biologicals are an exciting new class of biological products with elements of fertilizer, pesticide and soil amendment modes of action, but their broad functionality has created a lot of confusion.

Biostimulants can improve plant vigor, optimize nutrient update, increase growth, yield, production and resiliency. Some biostimulants stimulate a plant's natural defense mechanism against pests. Called the Systemic Acquired Resistance (SAR) or Induced Systemic Resistance (ISR), biostimulants that do this are clearly acting as a form of pesticide.

Most, though not all, biostimulants are comprised of non-living products. Biostimulant products may include materials like:

- Humic and Fulvic Acids. Complex organic molecules that form in the soil through decomposition and microbial metabolism of crop and animal residues.
- Amino Acids. Protein sources typically gleaned from recycled waste products of crop residues like soybean or cereals or animal processing, such as collagen.
- Plant Hormones. Like gibberellins, a naturally occurring plant hormone that can stimulate plant growth.
- Seaweed Extracts. Long used in agriculture production, they improve the uptake and utilization of plant nutrients.
- Plant Extracts (aka Botanicals). Active plant compounds extracted from plants like yucca, or stinging nettle extract, that promote a plant response.
- Beneficial Elements. Such as silicon which helps plants tolerate stress from drought.
- Plant Growth Promoting Rhizobacteria (PGPRs). When they are used to directly enhance plant growth.

How are Biostimulants Applied?

Biostimulant products are most often applied through tank mixes and spray regimes, as a seed treatment or via fertigation.

Current Regulatory Status for Biostimulants?

There is, as of yet, no agreed-upon definition or regulatory framework designed specifically for biostimulants in the U.S. and biostimulants are currently regulated under the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) the regulatory authority overseeing pesticide approval. Because of this most biostimulant products, if marketed as such, come under the definition of a plant growth regulator which FIFRA considers a pesticide.

EPA Definition of a Plant Growth Regulator (Current)

A plant growth regulator, through physiological action, is intended to accelerate or retard growth, or alter plant behavior or the produce of the plant. Examples of claims that can be considered to be plant growth regulator claims include increased blossom set, stimulation of root or plant growth, prevention of sucker growth, delayed onset of sprouting of harvested root crops, abscission stimulation of fruit crops, stimulates plant growth and fruiting, promotes fruit and seed development, increases stem and stalk strength, and increases fruit size.

However, U.S. biostimulant manufacturers argue that scientifically, many biostimulants do not actually alter plant growth in a way consistent with FIFRA pesticide or plant growth regulator definitions. And, when they are not intended for use as a pesticide, they should be exempt from FIFRA as are other crop amendments like soil amendments or plant nutrients (aka fertilizers).

However, there is currently no regulatory oversight that captures biostimulant's unique attributes, biostimulant manufacturers must either register their product under FIFRA as a pesticide ***or*** they cannot claim their products have direct stimulating effects on plant growth.

State regulation is also confusing for biostimulant products, with an inconsistent framework from state to state. In some states, biostimulant products are not considered fertilizers and therefore exempt from regulation.

Class III — Biofertilizers

Biofertilizers are biological products, typically including living microorganisms, that target the microbes in the rhizosphere that interact with plants. Biofertilizers' primary mode of action is to impact the soil and the rhizosphere, not the plant itself.

A good way to understand the difference between biostimulants and biofertilizers is that biostimulants treat the "symptom" of a crop problem while biofertilizers address the "cause."

Biofertilizers work by supporting rhizosphere microorganisms that colonize plant roots and internal tissues. These microorganisms indirectly support plant growth and resiliency to abiotic stress by increasing the solubility of nutrients already in the soil, aiding in nitrogen fixation, stimulating root growth which increases a plants nutrient uptake and supporting other symbiotic relationships between soil microorganisms and plant growth.

Biofertilizers also have significant secondary benefits in cropping systems. For instance, some biofertilizer products improve soil tilth by flocculating, aggregating and loosening the surface of tight soils. This helps farmers plant earlier and achieve more uniform stands. Many biofertilizers also help improve the water-holding capacity of soil, aiding crops through times of drought. Traditional fertilizer needs are also typically reduced with the use of biofertilizers, because the microorganisms give plants better access to nutrients already in the soil.

Biofertilizers typically include some sort of live microorganism, classified as a "Plant Growth Promoting Rhizobactera" (PRPR), and are often a proprietary mix of PGPR strains developed by the company. They may also include nutrient sources which might also have secondary biostimulant effects on plant production but are, in this case, intended to support, aka "feed," the microorganisms in the biofertilizer product.

Biofertilizer products may include:

- Plant Growth Promoting Rhizobacteria (PGPRs). When they are used to indirectly enhance plant growth. PGBR's are a group of free-living bacteria, typically *Bacillus* and *Pseudomonas* species, that colonize the rhizosphere and benefit root growth.
- Mycorrhizal Fungi. Colonize plant roots, feeding off carbon from the plant while helping to solubilize and bring phosphorus, nitrogen and micronutrients to the roots.
- Blue-Green Algae (cyanobacteria). Technically another type of PGPR. Cyanobacteria can fix nitrogen, water and nutrients and solubilize phosphates.
- Humus (sometimes called 'biohumus.') Decomposed organic matter (aka carbon) which support microorganisms in the rhizosphere. A source of pre-digested humic acid.
- Many of the same components found in biostimulants (such as plant or animal waste extracts) but used with the express purpose of supporting the establishment of rhizospheric and endospheric microorganisms.

How are Biofertilizers Applied?

Biofertilizers are typically applied via a liquid formulation and very close to crop establishment as these rhizosphere microbes flourish with the developing plant root system. Biofertilizers may be available in a broadcast formulation.

Biofertilizers are also often used on established perennial plantings like fruit and nut trees, berries, and vegetables as well as sports fields and golf courses around the world.

Current Regulatory Status for Biofertilizers

There is currently no federal regulatory oversight of biofertilizers. These products are regulated at the state level in the U.S. under current fertilizer registration requirements except in states that exempt biological products. Plus, the still emerging language and regulatory confusion over biostimulants has meant there is no oversight of scientific data requirements and marketing language for biofertilizer products.

This has meant that some products have been sold without the backing of scientific data. This has had an unfortunate result of creating a "snake oil" reputation even for those biofertilizer products with years of field testing and scientific data to back them up. Fortunately, there are a strong set of biofertilizers currently on the market that have demonstrated consistent performance year over year and are experiencing double-digit growth.

Class IV — Biodigesters

Biodigesters target crop residues, efficiently cycling the carbon from left-over harvest waste into forms that ultimately are returned to the soil microbiome for the benefit of soil and crop health.

Biodigesters are often considered a subset of biofertilizers and are similar in that they include living microorganisms to carry out their functions. But biodigesters are an important and distinct enough emerging biological function to warrant their own classification.

Biodigesters could be considered nature's soil conditioners and are often recommended after a harvest and in conjunction with other production practices and inputs. They take a free and widely available source of bulk carbon (post-harvest waste) and turn it into nutrients for soil and plants.

Biodigesters are important in a crop production system for several reasons.

1) Biodigesters remove barriers to production, for instance, a layer of thatch or left-over crop residue that prevents seeding or transplanting.
2) Biodigesters reduce and even eliminate toxic, left-over chemistries from previous production that can impede new plantings. This might be herbicide residues or even natural growth-retardant compounds, like terpenes left over in a former field of evergreen trees.
3) Biodigesters improve soil structure through the rapid conversion of carbonaceous materials. This aids in binding soil particles into aggregates, improving soil tilth and nutrient uptake is enhanced while soil health is improved.

Biodigesters are often made up of things like:

- Saprophytes. A fungus or microorganism that lives on dead or decaying organic matter.
    - *Phanerochaete chrysosporium* a fungus that aids in the organic breakdown of the woody part of plants.
    - *Trichoderma reesei* a wood-decaying fungus that produces an enzyme that converts cellulose into microorganism-available nutrients.
- *Bacillus species.* A helper bacterium that supports saprophytes and their carbon-processing functions.
- Products like humic acids which feed and support the microorganisms introduced through the biodigester product.

Current Regulatory Status for Biodigesters

Biodigesters currently fall under the same class as biofertilizers, with state fertilizer regulatory oversight.

Tips for Evaluating Biological Products

Understanding the four different ways biologicals work within crop production helps to understand which biological products to choose for what problem. The good news is with more investments in innovation than ever before, ag retailers and growers can be more confident in evaluating the efficacy and reliability of a product.

Here are some helpful criteria to consider:

- If a product is marketed as a biocontrol with specific pest control claims on the label, it must be registered as a pesticide under FIFRA.
- If your purpose is to support the growth and resiliency of your crop, check to see if a product is registered as a fertilizer (but keep in mind, not every state recognizes biologicals in the fertilizer category).
- Look for products with detailed descriptions of their functionality, ideally backed up with scientific evidence. Beware of products with no claims other than "increases plant growth."
- Look for reliable, independent research trials not just manufacturer's trials.
- Has the product been tested in the field (versus just the lab?). For how many seasons and one how many locations? Ideally a company should be able to provide at least two, years of data sets from at least five locations.
- Has the product been tested on multiple crops? In multiple regions? And on multiple soil types?
- In the case of biofertilizer products that contain live microbial strains, does the product include a food source for the microbes that will be applied to ensure good microbial establishment?

In addition, look for specific recommendations in using a biological. Such as:

- How should they be applied and application frequency.
- Tank mix compatibility with other products.
- Do they include adjuvants to maximize efficacy, such as wetting agents, surfactants, etc., appropriate to your crop and the product being applied?
- What is the product's shelf life and storage requirements?

Conclusion

In conclusion, we hope this resource guide helps to clear up some of the confusion around biologicals and can serve as a useful resource when evaluating biologicals. For information on **DPH Biologicals** line of biological products, including **TerraTrove™,** our complete line of biofertilizers and **Companion® WP**, our FIFRA registered biofungicide, visit us at www.dphbio.com

For more reading on the biologicals see the following sources:
https://www.epa.gov/ingredients-used-pesticide-products/what-are-biopesticides
https://www.bpia.org/solutions-provided-by-biological-products-biopesticides/
https://www.bpia.org/wp-content/uploads/2017/08/Regulatory-Oversight-of-Biostimulants.pdf
https://ag.purdue.edu/hla/fruitveg/Presentations/Hoagland-BiostimulantsBiofungicidesBiofertilizers-IVGS2018.pd

GLOSSARY

Commonly Used Terms in Biologicals

Actinomycetes: Organisms that are very similar to bacteria in structure but differ regarding the shape of their colonies. They give soil an 'earthy' smell. Among this group are beneficial species good at lignin decomposition, as well as species that are biopesticidal. There are also problematic actinomycetes species, including the organism which causes common scab on potato tubers.

Adjuvant: Products that improve the effectiveness of fertilizers, biofertilizers, pesticides, and biopesticides. Biological products should include adjuvants appropriate to their mode of action and the crop applied.

Adsorption: A specific type of chemical bonding. When used in biologicals, it refers to the negative charge on clay bonding with positively charged nutrients like Ca, K and organic particles doing the same. The bond between the clay or organic colloid (charged particle) and the nutrient is very strong when the soil is dry. When moisture is present the bond is weak.

Aerobic: Refers to air being present though soils are not simply aerobic or anerobic (see definition). The degree to which air is free to move in and out of the soils pore spaces is highly variable. Generally, more aerobic soil is valuable in crop production.

Aggregation: Refers to soil particles that have been bound together by organic carbon. As roots grow, they roll soil particles in their wake, and at the same time, exude polysaccharides and mucilage which glues together the rolled-up particles. Good aggregation, a 'coffee ground' structure, is a sure sign of good fertility.

Allelochemicals: Secondary metabolites produced by organisms (including plants, animals or microorganisms) which help ecological functions by counteracting abiotic and biotic stressors.

Amino Acids: Protein sources typically gleaned from recycled waste products of crop residues like soybean or cereals or animal processing, such as collagen.

Anerobic. Without air, a scenario is to be avoided as much as possible in soil management. Anerobic conditions kill plants.

Anions: Nitrate, Phosphate, Sulfate, Chloride, Borate, Molybdate. Negatively charged nutrients, which, excepting phosphates, are soluble to very soluble.

Antioxidant: Products used to help plants avoid or recover from stress. When plants experience stress, they produce compounds that quickly slow down or shut down their metabolism. However, plants often over-react to stress, and burn off (or oxidize) internal energy reserves in

the process, even when growers are intervening to help. An antioxidant product keeps plants from taking too many steps backwards before moving forward again.

Bacteria: Single-cell organisms and the biggest group of organisms harnessed for the sake of increased crop productivity through the use of biologicals.

Biodigester: A class of biological products that turns crop residues into carbon, cycling organic matter back into the soil microbiome for the benefit of soil and crop health.

Biofertilizer: A biological product which contains selected, living microorganisms that colonize the root rhizosphere or the interior of the plant and promote growth by increasing the supply or availability of plant nutrients. Some sequester and release nitrogen, others solubilize tightly bound phosphorous, and still others release metal cations such as zinc, calcium, or iron into the soil solution for plant uptake.

Biocontrol: Biological products that are used to control crop pests and diseases. In the U.S., a biological product that claims biocontrol modes of action must be registered with the EPA.

Biofungicide A biological product that targets seedling and foliar pathogens.

Bioherbicides: A biological product used to control weeds.

Bioinsecticide: A biological product that targets insect pests.

Biomiticide: A biological products used to control mites.

Biomolluscicide: A biological product used for control of snails or slugs.

Bionematicides: A biological product used to combat crop damaging nematodes.

Biopesticide: Aka 'BioControl' (see definition). Biopesticide is a term used to describe two major types of pesticides. One is microbially based, such as *Bacillus subtills* or *Beauveria bassiana*, the other are plant extracts such as garlic oil or neem oil.

Biostimulant: The term biostimulant is used in North America as a catch all term for biofertilizers, biopesticides, and for those products that stimulate the first two, but which have not been given a category of their own. However, at DPH, because of the current regulatory uncertainty around biostimulant products, we define biostimulants as products that directly stimulate a desired response in the plant, such as additional growth, nutrient uptake or resiliency to abiotic stress.

Blue-Green Algae or Cyanobacteria): Technically another type of PGPR (see definition). Cyanobacteria can fix nitrogen, water and nutrients and solubilize phosphates.

Cations: Ammonium, Potassium, Calcium, Magnesium, Iron, Zinc, Manganese, Copper, Nickel. Positively charged nutrients which range from soluble to insoluble. The single charged molecules ammonium ($NH4^{+}$) Potassium (K^{+}) and Sodium (Na^{+}) are the most soluble. The heavier metals which can have a plus 3 state (e.g., Fe^{+++}) are the least soluble.

CFU: Colony Forming Unit. The standard unit of measure used to describe biofertilizers and biopesticides. A single colony forming unit is either a fungal spore, a fragment of fungal hyphae, a bacteria or a bacterial endospore. They are counted and labeled using scientific notation based on a given volume of product and reported based on how many CFU's there are per gram or milliliter. Each CFU can start its own colony, if it has the conditions and food sources to support its establishment.

Chelator: Organic molecules that wrap partly or completely around plant nutrients with the purpose of preventing those nutrients from reacting immediately with the soil and becoming unavailable to the plant. The effects of a chelator depends largely on soil pH and the chelator chosen. Medium strength chelators like Citric Acid are adequate when soils are neither excessively acidic nor alkaline. For soils with high pH's a strong chelator like EDTA may be needed.

Compatibility (aka Buffering) Agent: An adjuvant which allow things to be tank mixed which might otherwise not be possible.

Complexor: Organic molecules that act similar to chelators (see definition) but are less aggressive in action. Lignosulfonate is a complexor.

Cuticle: The outermost covering of the leaf. It is a waxy, but not solid sheet of little wax platelets arranged like scales. The cuticle slows down the movement of water out of plants and the movement of nutrients into plants, but does not stop it. The structure of the cuticle can be affected positively and negatively based on what is applied.

Edaphosphere: The bulk soil area, or all biological activity that is not influenced by a growing plant encompassing what is going on in the soil.

Elicitor: Elicitors are products, or naturally occurring stimuli, that cause plants to activate one or more of their immune response systems, a very energy intensive process. Hence elicitors should only be used when we are fairly sure that the plant can supply the elicited immune response with energy *without* taking energy away from the saleable portion of that same plant.

Endosphere: The community of microorganisms which live inside the plant symbiotically interacting with each other and the plant's functions.

Enzymes: Enzymes are protein molecules which catalyze reactions. The beneficial bacteria and fungi applied via biologicals use enzymes to feed and support their functions.

Epiphytes: An organism that grows on the surface of a plant and derives its moisture and nutrients from the air, rain, water or from debris accumulating around it. Epiphytic organisms play an important role by occupying niches on the leaf's surface thus making it harder for newly landed pathogens to get a foot hold.

Fulvic Acids: Small organic particles often associated with humic acids (see definition). Fulvic acids more easily penetrate through tough cell walls and mitochondria bringing with them vital nutrients and trace minerals to support plant growth and health.

Fungi: Spore-producing organisms that feed on organic matter. Many types of fungi, like mycorrhiza, have beneficial applications when used in biologicals.

Gram Negative Bacteria: A fragile type of bacteria that cannot be easily delivered via a biological application. If used in biologicals an appropriate delivery method must be employed to ensure they survive all the way to the ground.

Gram Positive Bacteria: A 'tough' type of bacteria that can be easily be premixed with many substances, including fertilizer.

Guard Cells: Specialized cells that serve as the gate in the stomatal apparatus, opening and closing depending on conditions and the time of day. They are the area on a plant leaf that hosts the largest concentrations of microorganisms. Since a lot of foliar pathogens infect plants between the guard cells and through the stomates, covering this area with beneficial organisms will allow a plant to resist and even repel pathogen attack.

Flocculation: The process by which clay and humus particles chemically merge into larger particles. This keeps clay from going into solution but doesn't prevent the nutrients adsorbed on the clay from entering the soil solution. The opposite of flocculated is dispersed, which is usually assumed by excess potassium and/or sodium.

Flash Flocculated: How quickly a bit of broadcast calcium can loosen the surface of a soil, particularly soils whose clay particles have been dispersed or broken apart such that they lie flat against one another. Flocculating soils is a first step for forming aggregates.

Humectant: An adjuvant that attracts moisture. Used to increase the time before a spray product dries on crop residue, giving microorganisms in the product more time to become established.

Humic Acids: An organic compound found in humus (see definition) which attach to mineral ions and help prevent them from being locked up in the soil. Humic acids help make nutrients more plant available.

Humus: The organic portion of soil, brown or black in color, consisting of partially or wholly decayed plant and animal matter. Humus provides nutrients to plants and increases the ability of soil to retain water. Soil humus is not a stable material and changes are brought about by

variations in irrigation, drainage, timber removal, annual removal of crops, and modifications in normal crop cultivation which can lead to a rapid and marked change in the balance of the soil humus.

Hydrophilic: Something that attracts water, most especially root cap mucilage. But other substances also attract moisture like sugars and gums (Gaur and Xanthan gum).

Hydrophobic: Something that does not attract water. Many substances, like the wax on leaves, repel water.

ISR: Induced Systemic Resistance. A state of enhanced defensive capacity a plant can be induced into through the introduction of non-pathogenic rhizobacteria.

Macroaggregate: Soil particles formed when there is an abundance of microbes, lots of carbon, and the stirring action of soil fungi and plant roots.

Microorganisms: Organisms that are too small to be seen, unaided, with the human eye. Each of these broad categories contain plant beneficial, plant neutral, and plant pathogenic microbes.

Mineral Nutrition: Meeting all the needs plants for the 17 essential nutrients (plus silicon and cobalt) fundamental to crop production. The addition of biologicals may change the amount of nutrient (fertilizer) application needed and/or change the best and most economical method for delivering fertilizer – i.e. 'spoon-feeding' nutrients as needed rather than in bulk all at once.

Mucilage: A compound excreted by the caps (tips) of growing roots. It is a lubricant that eases root penetration into the soil mainly because it powerfully attracts moisture.

Mycorrhizal Fungi: Colonize plant roots, feeding off carbon from the plant while helping to solubilize and bring phosphorus, nitrogen, water and micronutrients to the roots. Mycorrhizal fungi are critical to a healthy soil microbiome.

Nutrient Cycling: The flow of mineral nutrients between plant-available and unavailable, sequestered forms. Soil microorganisms are critical to nutrient cycling. They decompose, transform and cycle nutrients through the soil microbiome so they are available to plants.

Penetrant: An adjuvant that helps applied material more rapidly or effectively get inside the plant's tissues. They work by softening the waxy cuticle of leaves, appropriate for oil-soluble products. Or, in the case of water-soluble products, the penetrant bonds with the product (such as a fertilizer) aiding its entryway into the plant interior.

Photosynthesis: The biochemical process where plants, using solar energy, convert CO_2 and water into stored chemical energy (glucose).

Photosynthates: The product of photosynthesis, glucose, which is rapidly converted into other sugars, mainly sucrose (common table sugar), and transported throughout the plant to serve as building blocks for all organic molecule as well as providing the fuel to do the worked needed to build those molecules.

Phytosphere: Naturally occurring, yet manageable associations between microorganisms and plants that occur just outside the plants, between the cells of plants, and even within plant cells.

Plant Extracts (aka Botanicals): Active plant compounds extracted from plants like yucca, or stinging nettle, that promote a plant response.

Plant Growth Promoting Rhizobacteria (PGPRs): A diverse group of free-living rhizospheric bacteria that can enhance plant growth by a wide variety of mechanisms, including colonizing the rhizosphere and benefiting root growth or by having a direct stimulant response on plant functions. PGPR's are used in biostimulants, biofertilizers and biocontrol products

Plant Hormones or Phytohormones: Organic substances, like gibberellins, that regulate plant growth and development.

Protozoans: Single-celled microscopic animals, such as amoebas, flagellates, cilates and sporozoans. In the soil microbiome protozoans play a key role in nutrient delivery to plants, essentially 'eating' bacteria then excreting unneeded nitrogen in the form of ammonium, a plant available form of N.

Rhizoplane: See 'Rhizosphere.' The actual interface where the roots come into contact with their microbial partners.

Rhizosphere: The region of soil in which plant root secretions and associated soil microorganisms interact in a mutually-beneficial fashion. Most nutrient cycling and disease suppression needed by plants occurs immediately adjacent to roots due to root exudates and communities of microorganisms.

Salts: Refers to a huge number of compounds that are simply two substances ionically bonded together that no longer have any charge. Salts are very tightly bonded when dry but can be broken apart more or less easily when in a water solution.

Saprophytes: A fungus or microorganism that lives on dead or decaying organic matter.

SAR: Systemic Acquired Resistance. A state of enhanced defensive capacity a plant can be induced into after inoculation with necrotizing pathogens or the application of some chemicals like Salicylic Acid.

Soil Peds or Peds: Mineral particles (clay, silt, sand) and organic matter combined into secondary soil particles. They are described by their shape, for example: blocky, columnar, massive, single grain or platy (plate-like).

Spreader: Also known as surfactant. An adjuvant that works by breaking the surface tension of water making the water less prone to bead up, and instead to spread out over a wider area. However, because it encourages the product to be spread out, a product with a spreader in it will dry out more quickly after application, giving less time for uptake.

Sticker: An adjuvant that acts similar to a humectant in that it attracts moisture. Its primary function though is to keep as much of what is sprayed stuck to the plant as possible. A sticker is valuable when dealing with wavy leaves that easily shed solutions or grasses with an upright habit which shed solution via gravity.

Stomata: Stomata refers to the gated opening in leaf surfaces through which oxygen and water vapor move out and carbon dioxide moves in. In healthy plants, stomata open during the day due to low internal CO2 concentrations and close during the night. But high temperatures, drought, or high internal CO2 concentrations can cause stomata to close during the day, slowing or even halting plant growth. Supporting a healthy rhizosphere and endosphere through the use of biofertilizers reduces these stress events, leading to better yields.

Structure: The combination of primary soil particles, sand, silt, and clay into naturally occurring secondary particles called soil peds (see definition). A soil's structure isn't fixed; therefore, compaction or flooding can transform a blocky structure to a platy (plate-like) structure. Excess sodium and potassium can cause structures to deteriorate, seal over and decrease water, air and root movement.

Texture: Used to categorize soils based on their relative percentages of sand, silt, and clay particles. Knowledge of texture provides information as to how a particular soil will behave, particularly in relationship with water.

Tilth: The physical condition of soil as related to its ease of tillage, quality of seedbed, impedance to seedling emergence, and root penetration. Healthy, well managed soils nearly always have good tilth, due to an active microbiology.

Tubersphere: Microbial communities closely associated in nutrient absorption in crops like potatoes, with tubers that actually absorb nutrients directly from the soil.