Cultivation Insights

Plant Growth Promotion and Resilience Products for Protected Culture Vegetables

- Treating plants with specific strains of bacteria and fungi has been shown to help promote plant growth, suppress some plant diseases, and help plants tolerate stressful growing conditions.
- Plant growth promotion can result from increased availability of nutrients and the enhancement or suppression of phytohormones.
- Disease suppression can result from direct interactions between biological agents and plant pathogens or indirectly through the stimulation of the plant's defense systems.

Using biological products to help promote plant growth and better tolerate pests, diseases, and stress-inducing conditions is becoming more viable as research increases our understanding of the processes involved and identifies beneficial agents that can potentially be commercialized. Organisms, such as bacteria and fungi, that inhabit the plant's rhizosphere and interact with the plant to help enhance growth and induce the plant's defense mechanisms are of particular interest and may be well suited for use in protected culture vegetable production systems.

Bacteria that colonize the rhizosphere, the area on and closely around plant roots, have been associated with aiding plant growth by helping increase nutrient mobilization and acquisition, the production of growth-regulating phytohormones, increasing plant stress tolerance, suppressing pathogens, and inducing plant defense mechanisms.[1,2] Plant roots exude nutrients that help attract and support populations of these beneficial organisms, resulting in the establishment of mutualistic relationships between the plant and the rhizosphere microbes.

Enhancing Nutrient Availability

Certain species of plant growth-promoting rhizobacteria (PGPR) have been shown to fix atmospheric nitrogen into plant-available forms. Some can also solubilize phosphate ions and produce siderophores to help increase the availability of iron for plant roots, helping reduce the need for chemical fertilizers. These bacteria have also been shown to help increase plant growth by producing or suppressing certain phytohormones. The PGPR organisms benefit from the carbohydrates, amino acids, and inorganic nutrients released by the plant roots while providing nutritional and other benefits to the plants.[3]

Biological nitrogen fixation (BNF) involves the reduction of atmospheric nitrogen (N_2 gas) to plant available ammonia (NH_3) through the use of the enzyme nitrogenase. The rhizobium bacteria found in root nodules of legumes are capable of BNF in the low oxygen environment of the nodule, but several other species of bacteria are also capable of BNF.[3] Some PGPR organisms can also convert plant-unavailable forms of phosphorus (P), such as $Ca_3(PO_4)_2$, $FePO_4$, and $AlPO_4$, into forms that plants can absorb and use, such as $H_2PO_4^-$ and HPO_4^{2-}. The bacterium *Bacillus amyloliquefaciens* strain FZB45, the active ingredient in the commercial product Utrisha® P, is an example of a PGPR organism that can be used in hydroponic systems to help increase the availability P by helping to keep phosphate ions in a form that plants can use.[3] Microflora SA is an example of a PGPR product that is sold to help improve nutrient availability to plants, including plants in protected culture and hydroponic production systems.

Siderophores are iron (Fe) chelating agents that help regulate the plant-availability of Fe in the rhizosphere.[2,3] Fe can become toxic to plants when present in high amounts, such as in acidic environments. Iron availability can also be low in aerobic environments or in high pH environments, resulting in Fe deficiencies in plants. Siderophores produced by PGPR organisms can sequester Fe and keep it available to plants, helping to prevent issues of Fe toxicity or deficiency. Several species in the bacterial genera *Pseudomonas* and *Bacillus* have been found to produce siderophores in the rhizosphere and are being evaluated and developed for use in agricultural systems.

Phytohormones

Many rhizosphere bacteria have been found to produce indolic compounds that can function as auxin-like phytohormones (indol-3-acetic acid – IAA). IAA compounds influence the way that plants grow, including root growth. The release of the amino acid L-tryptophan by plant roots into the rhizosphere can stimulate the production of IAA by bacteria, and this can help to increase plant growth.[3] Ethylene is another phytohormone that acts in the regulation of plant growth, development, and senescence. Ethylene can be released into the rhizosphere by plants when they experience stressful conditions, such as low moisture or high salinity levels, leading to senescence of root tissues. Bacteria that produce the enzyme ACC deaminase can help reduce the amount of ethylene in the rhizosphere, which helps plants better tolerate these kinds of environmental stress factors.[3] The biological product DuoKare, a combination of the bacterium *Bacillus simplex* and the fungus *Coniochaeta nivea*, is a product available in some states in the U.S. that can help plants better tolerate stressful conditions.

Disease Suppression

There has been a lot of research on the use of biological agents for the suppression of plant diseases. Biological control (biocontrol) agents use several different mechanisms to help suppress plant diseases. Biocontrol agents can directly impact plant pathogens through competition for nutrients, by the release of antimicrobial compounds, and by attacking (parasitizing) the plant pathogens, and these types of biocontrol agents are commercially available to help manage plant diseases in agricultural systems.[3] The fungi *Trichoderma harzianum* and *Trichoderma virens* are active ingredients in several commercial biocontrol products including RootShield® Plus+ WP Biological Fungicide.

Disease suppression can also result from the indirect effects of some bacterial and fungal biocontrol agents or through the application of chemicals that help activate the plant's own defense mechanisms. Plants have inducible mechanisms of resistance that can be triggered by factors including infection by pathogens, the presence of non-pathogenic microorganisms, and the application of certain chemicals such as salicylic acid. In some cases, inducing resistance in one part of the plant can result in resistance developing systemically in other parts of the plant, a phenomenon known as systemic acquired resistance (SAR).[4,5] SAR is defined as "a state of enhanced defensive capacity elicited by specific environmental stimuli."[5] The resistance reaction is expressed in the vicinity of infection as well as in more distant parts of the plant.[6] Salicylic acid molecules spread throughout the plant and signal the need for defense reactions. The resulting resistance can be effective against many kinds of pathogens including bacteria, fungi, nematodes, and viruses, and the resistance can remain effective for several weeks.[6,7]

SAR responses can be induced by the application of salicylic acid and similar compounds.[8] 2,6-dichloro-isonicotinic acid (INA) and benzo (1,2,3) thiadiazole-7-carbothioic acid-S-methyl ester (BTH) are two of the best studied SAR-inducing chemicals. BTH is rapidly transported within the plant to the apical leaves and has been shown to be one of the safest and most efficient SAR inducers available. BTH provides protection against some bacterial and biotrophic fungal pathogens (obligate parasites), such as powdery mildew and rust fungi. It is not as effective against diseases, such as anthracnose, that are caused by necrotrophic pathogens.[8] BTH is commercially available in the U.S. as the product Actigard® 50WG Plant Activator.[5]

Induced systemic resistance (ISR) is a phenomenon that is similar to, but distinct from, SAR. ISR can be induced in plants by the presence of microorganisms, including PGPR organisms. Several strains of bacteria, including species of *Pseudomonas, Bacillus*, and *Streptomyces* have been shown to elicit ISR responses in plants, as have some kinds of fungi. Unlike SAR reactions, ISR reactions do not depend on salicylic acid to trigger the defense response. Other plant chemicals, including jasmonate and ethylene, are involved in the ISR-associated defense responses.[5,8] Similar to SAR elicitors, ISR elicitors activate or prime (pre-activate) plant defense mechanisms that can then be more rapidly triggered to help protect the plant against infection.

The QST 713 strain of *Bacillus subtilis*, a bacterium, is available as the commercial products Serenade® ASO, Serenade® Opti, and Minuet™.[5,9] Also, the bacterium *Bacillus amyloliquefaciens* subspecies *plantarum* (available as Bexfond™ Biological Fungicide) and the bacterium *Streptomyces lydicus* WYEC 108 (Actinovate® SP Biological Fungicide) have also been developed as commercial ISR inducing products for agricultural use. ISR responses were initially found to be associated with the colonization of roots by the ISR eliciting microorganisms. However, some of these products can also elicit an ISR response when applied as foliar sprays. Application options of soil drench, chemigation, and foliar sprays are indicated on the product labels. In addition to eliciting the ISR response, *Bacillus subtilis* QST 713, the bacterium in Serenade® products, also produces several antimicrobial substances that inhibit spore germination and the growth of fungal pathogens.[5,9]

Sources

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Websites verified 12/2/2024

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