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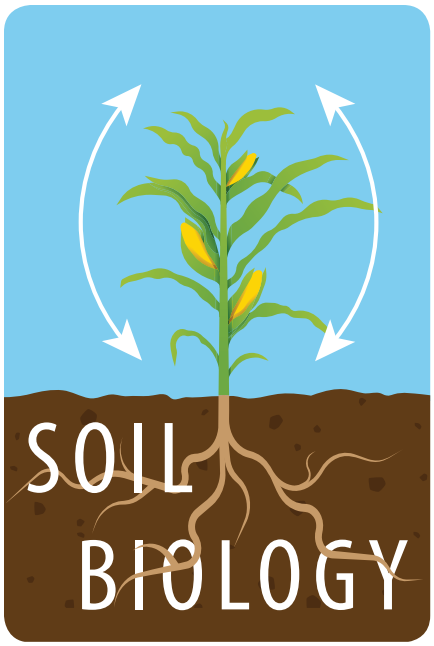

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The value of *Bacillus amyloliquefaciens* for crop production

Key facts

- BAA is a spore-forming soil bacterium that grows well near plant roots.
- BAA inoculants have the potential to stimulate plant growth.
- BAA inoculants have the potential to suppress plant-pathogenic bacteria and fungi, and can minimize disease damage from several root rot-causing fungi and fungal-like microbes including *Botrytis*, *Fusarium*, *Pythium*, *and Rhizoctonia*.
- BAA must be used preventively, as it will not cure diseased plants.
- No soil test is available to determine if BAA application is recommended; there is little data available to assess if BAA inoculants will be economically beneficial.

What is *Bacillus amyloliquefaciens*?

Bacillus amyloliquefaciens (BAA) is a bacterium active in the soil root zone (rhizosphere), and is commonly found in soil ecosystems worldwide, as well as on fresh produce and dried foods.[1]

BAA growth begins underneath the outermost cells (or "skin") of primary plant roots at the points where lateral roots grow and then spreads along the root surface.[2] BAA feeds on the numerous organic compounds (such as sugars, vitamins, and amino acids) that plants exude into the rhizosphere. Simultaneously, BAA produces plant growth-promoting compounds that are taken up by plant roots (figure 1).

Various BAA-formulated products are permitted for a wide range of foliar and soil-applied disease management uses on agricultural crops (e.g., grape, lettuce, potato, soybean, strawberry, cucurbits, fruiting vegetables, and pome fruits), ornamental plants, turfgrass, and in plant nurseries, greenhouses, and shade houses.

BAA inoculants are sold in two formulations: a wettable powder that can be applied using ground application equipment, aerial spraying, or irrigation, and a talc-based powder that can be applied using a dry planter box.

What is the difference between native and commercial BAA types?

Native BAA strains are present in soils worldwide. Commercial products contain strains of BAA known to colonize plant roots quickly and aggressively, and in controlled studies, promote plant health, plant disease control, or both. Several BAA strains are used in commercial inoculants, including *Bacillus amyloliquefaciens* D747, *Bacillus amyloliquefaciens* TJ-1000, and *Bacillus amyloliquefaciens* FZB42. Many of their impacts on crops are similar, but there are strain-specific interactions. Therefore, individual BAA inoculants may perform differently under similar field and weather conditions.

How can BAA help my crops?

The following summarized research shows that applying commercial BAA inoculant strains can potentially increase plant growth and disease resistance to provide both biocontrol and biofertilization.

Plant disease management

BAA controls other soil pathogens by competing with them for nutrients such as iron and by producing antibiotics or bacterial-destructive (lytic) enzymes.[3]

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- BAA has not successfully controlled black scurf, silver scurf, or common scab of potato when applied at the time of planting in Wisconsin.[4]
- BAA can outcompete other soil bacteria because its genetic makeup is more resistant to plant defense mechanisms.[5]
- BAA promotes general plant disease defenses and increases the "immunity" (acquired resistance) of inoculated plants.[6]
- In soybean, BAA has increased plant systemic resistance against bacterial pustule pathogen.[7]
- In lettuce, BAA has reduced the severity of bottom rot disease.[8]

Increased crop yield

BAA colonization of crop roots can lead to increased yields.[9]

- At 75% of recommended fertilizer rates, greenhouse-grown tomato plants inoculated with BAA showed growth, yield, and nutrient (N and P) uptake equal to non-inoculated plants that received the full fertilizer rate.[10]
- BAA increased the growth of inoculated corn plants and stimulated corn growth under phosphate-limited conditions compared to non-inoculated plants.[11]
- BAA-inoculated soybean seeds showed increased nutrient content in plant residue (K, P, Zn, Fe, Cu, and Mn) and seeds (K, P, Fe, and Mn) over non-inoculated seeds.[12]
- In years conducive to infection by *Fusarium verticillioides* and fumonisin production, seed-applied BAA may improve quality of corn grains by reducing toxin content.[13]
- BAA applied to potatoes at the time of planting in Wisconsin did not significantly increase yield compared to non-treated controls in multiple years of study.[14]

Nematode control

- In tomato production, BAA reduced the number of nematode eggs in roots, juvenile worms in soil, and plant galls on tomato.[15]
- Industry patent filings indicate that BAA inoculants may be useful in controlling a range of root-knot, cyst, lesion, and ring plant parasitic nematodes.[16]

Pesticide use

Herbicides, nematicides, and most fungicides do not normally affect BAA activity. Antibiotics would potentially impact BAA, but in crop production antibiotics are only commonly applied to apple and pear orchard foliage to control fire blight. Copper-based fungicides are also antibacterial but are foliar applied only. Foliar-applied compounds are highly unlikely to affect soil inoculants.[17]

Will my crop management practices impact BAA growth?

In contrast to other soil microorganisms like arbuscular mycorrhizal fungi (AMF) which remain viable year-to-year, BAA are host dependent and must regrow annually. Thus, crop management practices in any single year will have little impact on BAA.

- BAA colonize plant roots and grow best under conditions that are also favorable to plant growth (moderate temperatures and adequate soil moisture).

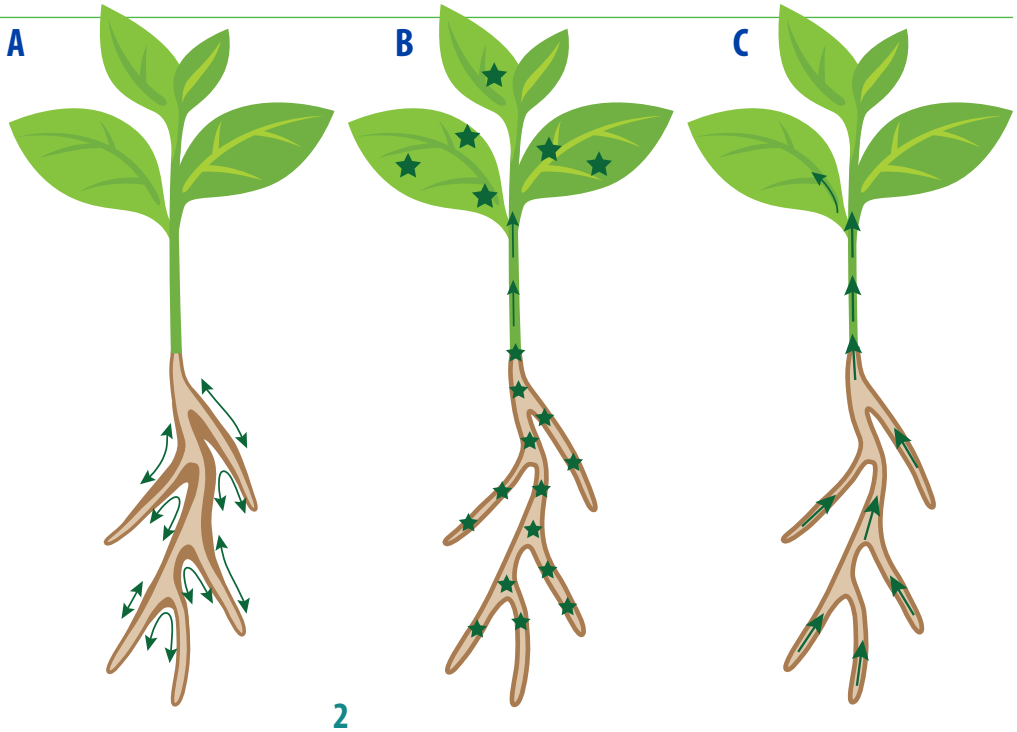

FIGURE 1

A. BAA growth begins underneath the outermost cells of primary roots at the point where lateral roots grow and then spreads along the surface. The BAA layer physically blocks other pathogens from contacting the root surface.

B. BAA colonization can increase plant systemic resistance to a range of plant disease causing organisms.

C. BAA produces plant growth-promoting compounds that are taken up by plant roots and can increase crop yield.

- While conservation tillage and legume-based crop rotations generally improve microbial diversity over conventional tillage and monoculture, their specific effects on BAA have not been studied.[18]
- BAA are not crop specific and will colonize all crops regardless of rotation.

Can I use BAA and other inoculants at the same time?

BAA inoculants and other inoculants can generally be used together. BAA, *Trichoderma* and AMF naturally coexist in the rhizosphere. Monsanto's QuickRoots® product, for example, contains both BAA and *Trichoderma virens*.

Should I inoculate my seeds/soil with BAA?

Research has indicated that BAA can potentially benefit plant health in crops such as corn, soybean, ornamentals, and vegetables. Commercial use of BAA inoculants in field and vegetable crops is limited but growing. Benefits to potatoes have been documented elsewhere,[19] but research in Wisconsin has not yet shown improvement. Limited adoption of BAA in field crops may be the result of multiple factors including cost, relative efficacy compared to conventional pesticides and fertilizers, and lack of research on specific crops. In addition, field studies on non-traditional products such as BAA are not often published, especially if there was no increase in yield, leading to a bias in published literature toward studies with positive results.

It is important to remember that BAA should be used preventively as it will not cure diseased plants.

Bacillus explained

The *Bacillus* bacterial genus contains many different species that have been proven beneficial to agriculture in very different ways. It is important to realize that these *Bacillus* species have dramatically different behaviors and are not interchangeable—just as tomatoes, potatoes, and nightshade (all members of the *Solanum* genus) are not. Below is a list of *Bacillus* species that you may see listed in products or mentioned in the news.

***Bacillus* spp.**
A catch-all term for all species of the genus *Bacillus*.

***Bacillus amyloliquefaciens* (BAA)**
A soil inoculant used to promote plant growth and disease control.

***Bacillus thuringensis* (Bt)**
A *Bacillus* species containing many subspecies with insect control capabilities (e.g., Bt-corn contains a section of Bt genetic material that is toxic to the corn borer).

***Bacillus thuringensis israelensis* (Bti)**
Widely used for mosquito, black fly, and fungus gnat control. Bti produces compounds toxic only to those insect larvae.

***Bacillus thuringensis kurstaki* (Btk)**
Widely used for control of gypsy moth larvae.

Bacillus subtilis
Sold as a plant disease suppressive inoculant (Helena Chemicals HiStickN/T® for example). Until 1987, BAA was classified as a *B. subtilis* subspecies, but is now recognized as a distinct species.

Bacillus anthracis
The species responsible for the anthrax disease harmful to humans.

Bacillus polymyxa
A nitrogen fixing species. It is not widely available as an inoculant and its effectiveness is not well researched.

Bacillus azotofixans
A nitrogen fixing species. It is not widely available as an inoculant and its effectiveness is not well researched.

BAA has a shorter shelf life than most conventional pesticides and must be stored under conditions recommended on the label to remain effective.

Inoculants will need to be reapplied each season, as they do not cause long-term changes in the soil microbial community composition. Plant impacts result from direct interaction with inoculant strains.[20]

Further reading

Iowa State University Agronomy Extension (NCR-103). "Compendium of Research Reports on Use of Non-Traditional Materials for Crop Production." **http://extension.agron.iastate.edu/compendium/index.aspx**

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