TECHNICAL BRIEF · SIGMA BIO

The biology in Sigma Bio, and the research behind it

What each beneficial bacterium, endomycorrhizal fungus and Trichoderma in Sigma Bio does in the root zone, with the published science that supports it.

4

Bacillus-group bacteria that cycle nitrogen and phosphorus and promote root growth

4

Arbuscular mycorrhizal fungi that extend the root system's reach for nutrients

2

Trichoderma fungi that colonize roots and free bound phosphorus

Driven by nature. Backed by science.

Label composition

From the Sigma Bio guaranteed analysis. Several genus names on the label have since been updated by taxonomists; the current names, which the research literature uses today, are shown alongside.

ORGANISM (AS ON LABEL)	CURRENT SCIENTIFIC NAME	PER ML
Beneficial bacteria · 17.0 billion CFU per gallon		
Bacillus subtilis	*Bacillus subtilis*	750,000 CFU
Bacillus amyloliquefaciens	*B. amyloliquefaciens* group (includes *B. velezensis*)	750,000 CFU
Bacillus licheniformis	*Bacillus licheniformis*	1,500,000 CFU
Brevibacillus laterosporus	*Brevibacillus laterosporus* (formerly *Bacillus laterosporus*)	1,500,000 CFU
Endomycorrhizae (arbuscular mycorrhizal fungi) · 37,800 propagules per gallon		
Glomus intraradices	*Rhizophagus intraradices*	2.5 propagules
Glomus mosseae	*Funneliformis mosseae*	2.5 propagules
Glomus etunicatum	*Claroideoglomus etunicatum*	2.5 propagules
Glomus aggregatum	*Rhizophagus aggregatus*	2.5 propagules
Trichoderma · 2.8 billion CFU per gallon		
Trichoderma harzianum	*Trichoderma harzianum*	375,000 CFU
Trichoderma viride	*Trichoderma viride*	375,000 CFU

Endomycorrhizae, not ectomycorrhizae. All four fungi are arbuscular mycorrhizal fungi (AMF). They grow inside root cortex cells and form branched exchange structures called arbuscules. This is the type that partners with turfgrasses, vegetables and most crops; ectomycorrhizae are mainly partners of trees.

How the three groups work together

GROUP	WHERE IT WORKS	MAIN JOBS
Bacillus	Root surface and the thin soil film around roots (rhizosphere), as biofilms	Release enzymes and organic acids that break down organic matter and free bound phosphorus and iron; produce plant growth hormones; prime the plant's own defense responses
Endomycorrhizae	Inside root cells, with a hyphal network running out into the soil	Extend the root system's reach for phosphorus, zinc, copper and nitrogen; build soil structure through glomalin; improve stress tolerance
Trichoderma	Root surface and outer root tissue	Colonize roots, solubilize phosphorus and micronutrients, stimulate root growth and compete with other fungi for space on the root

The four Bacillus-group bacteria

All four form spores. The spore is a dormant, protected form of the cell, which is why these bacteria survive storage, tank mixing and dry soil far better than non-spore formers, then germinate and colonize roots when warmth and moisture return. Across the genus, the published mechanisms are nitrogen and phosphorus cycling, potassium and iron solubilization, plant hormone production, biofilm formation on roots, and induced systemic resistance (ISR) in the plant.

> **Nutrient mineralization.** These bacteria secrete enzymes (proteases, phosphatases, phytases) that break organic nitrogen and phosphorus compounds down into the forms plants take up: ammonium and orthophosphate. They also release organic acids that dissolve phosphate bound to calcium, iron and aluminum.

Bacillus subtilis

The most studied plant growth promoting rhizobacterium; the root colonizer

- **Root colonization:** follows root exudate signals (L-malic acid is one) to the root and builds a structured biofilm held together by its own matrix proteins and polysaccharides. Strains that cannot build this matrix fail to colonize.
- **Hormones:** produces auxin (IAA), gibberellins and cytokinins, which drive root and shoot cell division and elongation.
- **Nutrients:** solubilizes and mobilizes phosphorus and iron.
- **Plant defense:** triggers induced systemic resistance, priming the whole plant's natural defense responses.

Why colonization matters: reviews agree that the benefit depends on the bacteria establishing and persisting on the roots. That is why biofilm formation is the key trait in this species (Blake et al. 2021; Adjei et al. 2025).

Bacillus amyloliquefaciens

The lipopeptide producer and growth promoter

- **Lipopeptides:** produces the surfactin, iturin and fengycin families. Surfactin helps the bacteria spread across the root and form biofilm; iturins and fengycins help it compete with other microbes in the root zone.
- **Growth promotion:** strains in this group are widely used as plant growth promoters; hormone production and nutrient release are the main routes.
- **Stress:** members of the group are studied for drought and salt stress relief through ACC deaminase, which lowers the plant's stress hormone ethylene.

Taxonomy note: this species is now treated as an "operational group" that includes *B. velezensis*, *B. siamensis* and *B. nakamurai* (Ngalimat et al. 2021). Many well-known "amyloliquefaciens" research strains are now classified as *B. velezensis*.

Bacillus licheniformis

The enzyme producer and phosphate solubilizer

- **Phosphate solubilization:** repeatedly isolated from crop root zones as an efficient phosphate solubilizer; dissolves tricalcium phosphate and rock phosphate in laboratory tests.
- **Organic phosphorus:** phytase-producing strains release phosphorus from phytate, the main organic phosphorus form in plant and manure residues.
- **Enzymes:** one of industry's main protease producers, the class of enzyme that breaks proteins down toward ammonium.
- **Hormones and stress:** produces IAA and siderophores (iron-binding compounds); halotolerant strains improved germination and seedling growth under saline irrigation (Mahdi et al. 2020).

Field evidence: a 2025 field study used a liquid *B. licheniformis* formulation with a second phosphate solubilizer to improve potato growth, yield and nutrient content.

Brevibacillus laterosporus

The hydrolytic enzyme producer

- **Nutrient release:** secretes hydrolases, enzymes that break down organic polymers, improving nutrient availability to the plant.
- **Root growth:** some strains carry additional IAA synthesis genes; strains from apple and maize root zones showed strong growth promoting traits.
- **Hardiness:** tolerates pH 3 to 7 and grows from 4 °C (39 °F), useful traits for a soil inoculant.

Evidence: reviewed in Liu et al., *Microorganisms* (2024), covering its crop uses, hormone production and enzyme activity.

The four arbuscular mycorrhizal fungi

Arbuscular mycorrhizal fungi partner with roughly 80% of land plants. The fungus lives partly inside root cells, where it trades nutrients for plant sugars at the arbuscules, and partly in the soil as a network of fine threads (extraradical hyphae) that reach far past the roots.

How far the network reaches: measured results

MEASUREMENT	PUBLISHED RESULT	SOURCE
Distance hyphae spread from roots	Constant hyphal density out to **11 cm (4 in.)** from the roots at 47 days, spreading about 3 mm per day	Jakobsen, Abbott & Robson, *New Phytologist* 1992
Hyphae in the soil	Up to **111 meters of hyphae per cubic centimeter** of soil (tallgrass prairie); 81 m per cm^3 in pasture	Miller, Reinhardt & Jastrow, *Oecologia* 1995
Share of plant phosphorus delivered by hyphae	**34% to 90%** of total phosphorus uptake, and 53% to 62% of copper uptake	Li, Marschner & George, *Plant and Soil* 1991
Nutrients from beyond the roots (*F. mosseae*)	Hyphae supplied **49% of phosphorus and 35% of nitrogen** from soil several centimeters from the root	George et al., *Canadian Journal of Botany* 1992

In practical terms: a cubic centimeter of soil is about the size of a sugar cube. Mycorrhizal hyphae can fill that sugar cube with more than 100 meters of thread and reach about 4 inches out from the root. Phosphorus barely moves in soil, so a root alone draws it only from a thin shell around itself; the hyphae go out and bring it back.

What the fungi do

- **Phosphorus, zinc, copper:** the strongest evidence. Hyphae take up these slow-moving nutrients and deliver them into the root cells.
- **Nitrogen:** hyphae also carry ammonium and nitrate (35% of plant N in the George study); reviews link AMF to better nitrogen use efficiency.
- **Soil structure:** AMF hyphae produce glomalin, a sticky, durable glycoprotein. In a survey of 37 soils, glomalin explained 86% of the variation in aggregate stability (Wright & Upadhyaya 1998). *F. mosseae* and *R. intraradices* both raised glomalin and aggregate stability in a direct test (Bedini et al. 2009).
- **Drought tolerance:** mycorrhizal plants hold up better under water stress through improved nutrition, changes in roots and hormones, osmotic adjustment and stronger antioxidant systems (Cheng et al. 2021).

By species

SPECIES	RESEARCH HIGHLIGHTS
Rhizophagus intraradices	The most widely used and most thoroughly sequenced AMF species. Raises glomalin and soil aggregate stability; improved phosphorus uptake and yield in field-grown maize (*Scientific Reports* 2023).
Funneliformis mosseae	The species in the George 1992 hyphal transport study (49% of P, 35% of N). A mix of *F. mosseae* and *R. irregularis* improved growth of two turfgrass species under water stress (*J. Soil Sci. Plant Nutr.* 2019).
Claroideoglomus etunicatum	Significantly increased phosphorus accumulation in maize when inoculated alone (2022). Paired with a phosphate solubilizing Bacillus, it increased mineralization of organic phosphorus and plant P content (*J. Fungi* 2023), the same bacteria plus fungi pairing found in Sigma Bio.
Rhizophagus aggregatus	In the same maize study, the mixed inoculation of *R. aggregatus*, *C. etunicatum* and *F. mosseae* significantly increased nitrogen and potassium accumulation.

The two Trichoderma fungi

Trichoderma are free-living soil fungi that colonize the root surface and outer root tissue. Work at Cornell University showed that much of their value comes from changing the plant itself: more root growth and a primed defense system (Harman et al. 2004).

Trichoderma harzianum

The best documented Trichoderma in turf

- **Root colonization:** rhizosphere-competent strains grow along with the root system as it extends and increase root growth.
- **Plant response:** root colonization triggers localized and whole-plant responses similar to the plant's own systemic acquired resistance (Harman et al., *Nature Reviews Microbiology* 2004).
- **Nutrients:** releases organic acids (gluconic, citric, fumaric) that solubilize phosphate and micronutrients; increased phosphorus uptake from rock phosphate in field-grown chickpea (Rudresh et al. 2005).
- **Competition:** occupies root surface space and competes with other fungi for nutrients there.

Turf evidence, creeping bentgrass greens: in four years of Cornell field trials with monthly applications, *T. harzianum* populations in treated greens rose 100-fold and persisted over winter (Lo, Nelson & Harman 1996). In 2025, *T. harzianum* and Bacillus inoculants were evaluated on heat-stressed creeping bentgrass (*HortScience* 60:2346).

Trichoderma viride

The phosphorus specialist

- **Phosphorus:** both solubilizes and mineralizes insoluble phosphorus, raising plant P content and changing root architecture to explore more soil (*Scientific Reports* 2023).
- **Grass evidence:** improved phosphorus uptake, photosynthesis and growth of the grass *Chloris virgata* under phosphorus-deficient conditions (*Frontiers in Microbiology* 2024).
- **Fertilizer efficiency:** seed treatment with *T. viride* allowed up to a 20% cut in recommended phosphorus in soybean through higher soil phosphatase activity (Paul & Rakshit 2021).

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This brief summarizes published research on the species listed on the Sigma Bio label. Studies were conducted with specific research strains under specific conditions; they describe what these organisms do and are not a guarantee of results with Sigma Bio, which vary with soil, climate and management. Sigma Bio is a soil amendment and is not a pesticide; it is applied as a companion to, not a replacement for, a crop protection program. Confirm product registration in your state and always read and follow label directions.