

Biological Control of Plant Disease: Role of Beneficial Microorganisms in Horticulture

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Abstract

Biological control using beneficial microorganisms to suppress plant diseases is increasingly central to sustainable horticulture. This article explores the major groups of microbial allies (bacteria, fungi, actinomycetes and yeasts), their modes of action, practical application methods and how growers can integrate them into everyday crop management. Emphasis is placed on realistic benefits, limitations and on-farm considerations: formulation stability, environmental sensitivity, timing of application and compatibility with other practices. A practical table lists 20 widely used beneficial microbes, their targets and common use methods to help practitioners choose appropriate agents. The tone is practical and grower-focused: biologicals are powerful tools, not magic bullets they work best when chosen and applied thoughtfully and when combined with good sanitation, cultivar choice and integrated pest management. This article closes with pragmatic recommendations for horticulturists who want to add microbial biocontrol to their toolbox.

Keywords: biological control, beneficial microorganisms, horticulture, Trichoderma, Bacillus, Pseudomonas, yeasts, disease suppression, integrated pest management

Introduction

Horticulture from backyard tomatoes to high-value fruit orchards and greenhouse ornamentals constantly battles disease pressure. Synthetic chemicals have been effective, but concerns about residues, resistance, pollinator safety and consumer preference drive interest in alternatives. Beneficial microorganisms offer a way to reduce disease while supporting plant health and soil life. Unlike chemical fungicides, biological control agents (BCAs) act through living interactions: they colonize plant surfaces or soil, compete with pathogens, produce inhibitory compounds, or stimulate the plant's own defences. Because BCAs are diverse and context-dependent, success can feel like learning a craft: the right microbe, used at the right time and in the right way,

can transform disease outcomes. This article aims to bring clarity and practical guidance the biological principles, the on-farm reality and a compact reference table of commonly used microbes.

Beneficial microorganisms in horticulture: who they are and where they work

Beneficial microbes fall into a few practical categories:

- **Bacillus spp. (Gram-positive bacteria):** hardy, spore-forming, tolerate drying and high temperatures. Widely used as seed treatments, soil drenches and foliar sprays.
- **Pseudomonas spp. (Gram-negative bacteria):** strong root and rhizosphere colonizers; excel at competition and nutrient scavenging.
- **Trichoderma spp. (fungi):** aggressive colonizers of root and soil niches that parasitize other fungi and produce lytic enzymes.
- **Streptomyces spp. (actinomycetes):** soil-dwelling filamentous bacteria known for antibiotic production and suppression of soil borne pathogens.
- **Yeasts (Saccharomyces, Metschnikowia, Pichia, Candida):** often used for postharvest protection and surface colonization of fruit and flowers.
- **Other plant-growth-promoting rhizobacteria (PGPR)** such as Azospirillum and Paenibacillus: they promote vigour while indirectly reducing disease pressure.

Each group brings a different set of strengths. Some are best in the soil (Trichoderma, Streptomyces), some on foliage or fruit (certain yeasts, Bacillus foliar products) and some offer both disease suppression and growth promotion (PGPRs).

Modes of action: how beneficial microbes actually reduce disease

Understanding how BCAs work helps set realistic expectations.

1. **Antibiosis (chemical warfare):** Many microbes produce antibiotics, volatile compounds, or secondary metabolites that directly inhibit pathogens. This is a fast-acting, target-specific effect but can be affected by environmental dilution and degradation.
2. **Competition for space and nutrients:** Rapid colonizers occupy infection sites or tie up essential nutrients (iron, carbon sources), denying pathogens the resources they need. Strong rhizosphere colonizers or epiphytes excel here.
3. **Parasitism and mycoparasitism:** Some fungi (e.g., Trichoderma) attach to pathogenic fungi, penetrate them and degrade their cell walls with enzymes. This is especially useful against soil borne fungal pathogens.
4. **Induced systemic resistance (ISR):** Beneficial microbes can "prime" the plant immune system so it responds faster and stronger to pathogen attack. ISR does not kill pathogens directly but strengthens host defences.
5. **Siderophore production and nutrient sequestration:** Certain bacteria produce siderophores molecules that bind iron tightly making it unavailable to pathogens.

6. **Biofilm formation and niche exclusion:** Microbial communities that form stable biofilms on roots or leaves create a protective layer that resists pathogen invasion.
7. **Enzymatic degradation:** Some microbes release chitinases, glucanases and proteases that break down pathogen structures.

Commonly used beneficial microorganisms and their practical uses

S.No.	Microorganism	Typical targets (pathogen types)	Main modes of action	Common application method	Typical horticultural crops
1	<i>Bacillus subtilis</i>	Foliar and soil fungal pathogens	Antibiosis, competition, ISR	Foliar spray, seed treatment	Tomato, cucumber, leafy greens
2	<i>Bacillus amyloliquefaciens</i>	Soil borne fungi, damping-off	Antibiosis, competition, enzymes	Soil drench, seed coating	Lettuce, peppers, ornamentals
3	<i>Bacillus pumilus</i>	Post-planting root diseases	Antibiosis, colonization	Seed treatment, soil drench	Vegetables, herbs
4	<i>Bacillus megaterium</i>	General pathogen suppression	Competition, growth promotion	Soil amendment, seed coating	Fruit trees, vegetables
5	<i>Pseudomonas fluorescens</i>	Soil borne pathogens, root rots	Competition, siderophores, ISR	Seed treatment, root dip	Potatoes, ornamentals, vines
6	<i>Pseudomonas putida</i>	Rhizosphere pathogens	Competition, nutrient cycling	Soil drench, transplant dip	Vegetable transplants
7	<i>Trichoderma harzianum</i>	Soil and root pathogenic fungi	Mycoparasitism, enzymes	Soil amendment, potting mix	Ornamentals, nursery stock
8	<i>Trichoderma viride</i>	Fusarium, Rhizoctonia	Mycoparasitism, competition	Seed treatment, soil drench	Roses, greenhouse crops
9	<i>Trichoderma asperellum</i>	Broad soil borne fungi	Enzymes, colonization	Potting mix, root dip	Potted plants, ornamentals
10	<i>Streptomyces lydicus</i>	Soil fungi and some bacteria	Antibiotics, competition	Soil amendment, root dip	High-value vegetables, ornamentals
11	<i>Streptomyces griseus</i>	Soil borne fungal complexes	Antibiosis, enzyme production	Soil incorporation	Nurseries, transplant production
12	<i>Gliocladium catenulatum</i>	Root pathogens	Mycoparasitism, competition	Soil application, potting mix	Container-grown plants
13	<i>Saccharomyces cerevisiae</i>	Postharvest molds	Competition, volatile compounds	Postharvest dip/spray	Fruit, cut flowers
14	<i>Metschnikowia pulcherrima</i>	Fruit surface pathogens	Competition, pulcherrimin production	Postharvest sprays	Table grapes, berries
15	<i>Pichia guilliermondii</i>	Postharvest rot organisms	Competition, colonization	Fruit coating, dips	Apples, citrus

16	<i>Candida oleophila</i>	Wound-invasive fungi on fruit	Competition, biofilm formation	Postharvest spray	Pome fruit, citrus
17	<i>Aureobasidium pullulans</i>	Blossom and fruit surface pathogens	Competition, surface colonization	Blossom spray, postharvest	Stone fruit, apples
18	<i>Paenibacilluspolymyxa</i>	Soil pathogens, seedling diseases	Antibiosis, growth promotion	Seed coating, soil drench	Vegetables, herbs
19	<i>Azospirillumbrasilense</i>	Indirect suppression via vigour	Growth promotion, ISR	Seed inoculation, soil inoculant	Vegetable and flower transplants
20	<i>Rhizobium leguminosarum</i>	Soil borne pathogens (indirect)	Nitrogen-fixation, root health	Seed inoculant for legumes	Legumes (peas, beans)

Application and formulation: making microbes work on the farm

Microbial products come as wettable powders, granules, liquid concentrates, or encapsulated formulations. Key practical points:

- **Timing matters.** Many BCAs are preventive: apply before disease establishes (e.g., seed treatment, at transplanting, or early in the season). Post-infection rescue is less reliable.
- **Compatibility.** Check whether the microbial product can be tank-mixed with other inputs. Many biologicals are sensitive to copper, strong oxidizers, or certain pesticides; incompatibility reduces viability.
- **Environmental fit.** Temperature, UV exposure, soil moisture and pH affect survival. Spore-forming *Bacillus* tolerates harsher conditions than many non-spore-formers; yeasts often work well on fruit surfaces.
- **Adjuvants and carriers.** Use of proper carriers (peat, compost, talc) and humectants can improve survival when applying to seeds or soil.
- **Quality control.** Buy products from reputable manufacturers with clear colony-forming unit (CFU) counts and expiry dates. Store as recommended some need refrigeration.

Integration with integrated pest management (IPM)

Biologicals are not stand-alone silver bullets. They are most effective when integrated with cultural practices:

- Select resistant cultivars where available.
- Ensure good sanitation: remove diseased plant debris that can overwhelm BCAs.
- Use crop rotation and proper irrigation management (avoid waterlogging).
- Pair BCAs with precise chemical use: if a fungicide is necessary, use selective products or apply at times that minimize harm to beneficial.
- Monitor and record: keep simple disease and yield logs to evaluate what works.

Limitations and challenges: realistic expectations

- **Variability of field performance.** Environmental variability leads to inconsistent results across seasons and sites.
- **Short shelf life and sensitivity.** Many microbes lose viability if stored or handled improperly.
- **Regulatory and market hurdles.** Registration costs, labelling and farmer awareness can limit adoption.
- **Complex interactions.** Native soil microbiomes can outcompete introduced strains or alter their behaviour.

Practical tips for growers

- Start with seed treatments and transplant dips small, low-risk investments with clear benefits.
- Use Bacillus-based foliar sprays for reduced-risk disease suppression when foliar diseases are anticipated.
- For soil borne fungi, choose Trichoderma or Streptomyces products incorporated into potting mixes or used as soil drenches.
- For postharvest protection, trial yeast or Aureobasidium products on a subset of fruit and compare storability.
- Keep a simple log: product, application date, weather notes and disease observations. After two seasons you'll have a realistic sense of what helps.

Research frontiers and where the field is heading

Current directions include multi-strain consortia that combine complementary modes of action, microencapsulation technologies to extend shelf life and controlled release and precision microbiome management that aims to shift the native community toward disease-suppressive states. Early-warning diagnostics and decision-support tools that predict when biologicals will be most effective are also emerging. For now, practical advances most growers benefit from are improved formulations and clearer instructions that reduce the “black box” feel of biologicals.

Conclusion

Beneficial microorganisms are potent, climate-friendly tools for disease management in horticulture. They reduce reliance on synthetic chemicals, can improve plant vigour and align well with consumer and regulatory demands for sustainable production. That said, success depends on choosing the right microbe for the crop and disease, paying attention to timing and environmental conditions and integrating biologicals into a wider IPM strategy. Think of biologicals as partners rather than replacements: when chosen and used thoughtfully, they strengthen the farm's resilience and often improve crop quality. Start with manageable trials, keep good records and favour products and suppliers that provide clear viability information and use recommendations that's the fastest route from curiosity to reliable results.

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