

NATURAL SUPPRESSION OF PLANT DISEASES: A RESEARCH UPDATE

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In 1996, researchers at Ohio State University published a landmark study.

When cucumber seeds were grown in a composted bark medium, then injected with the disease anthracnose, the plants showed fewer symptoms of infection than similar plants grown in aged peat moss. Also, the cucumber plants growing in composted bark had a much higher level of peroxidase activity, a natural marker of systemic acquired resistance in plants ¹.

This work by Dr. Harry Hoitink and his group was the first scientific report of a direct link between root growth in compost and suppression of foliage disease. Since, much progress has been made to understand the mechanisms at play. Today, nursery growers, greenhouse growers and landscape managers can take advantage of the natural phenomena when preparing and using potting mixes, mulches and soil amendments.

I. COMPOSTING AND ROOT ROT PATHOGENS

Composting is the biological decomposition of organic waste under controlled conditions.

Usually, three phases occur during composting ²:

- An initial hot phase of 1 or 2 days, during which the smaller material is rapidly degraded.
- A period of many weeks when temperatures reach 45 to 65°C and most microbes are killed.
- A final curing phase when temperature declines and the material is re-colonized by microbes.

Materials properly composted will reach the hot temperatures required to kill the microbes responsible for plant diseases ³. However, materials not composted properly may still contain pathogens. If kept wet for too long, these materials could trigger root and stem diseases ⁴.

As a routine procedure, our company is testing the root pathogen content in products used by our clients for soil amendments, mulches or potting mixes. The table below presents results for five products. Products #1, 2 and 3 are excellent quality, but products #4 and 5 are poor quality.

Presence of root rot pathogens in five different commercial compost products

Product tested	<i>Phytophthora</i>	<i>Pythium</i>	<i>Fusarium</i>	<i>Rhizoctonia</i>
Hemlock-fir mulch	0	Very low	0	0
Fir bark	0	0	0	0
Hemlock-fir compost	0	0	0	0
Hemlock-fir compost	0	Very high	Low	Moderate
Tree planting soil	0	Very high	Moderate	Moderate

Rating based on number of propagules per gram of soil. Testing at Ribeiro Plant Lab, Inc., Washington State.

II OBTAINING DISEASE-SUPPRESSIVE COMPOST

Materials that are properly composted are exposed to high temperatures between 45 and 65°C, usually sufficient to destroy disease pathogens. This period of hot temperatures may last 2 to 3 months and is followed by the curing phase, when decomposition processes are stabilizing².

The curing phase is important for natural disease suppression. After peak heating, different micro-organisms naturally colonize the piles. Among these micro-organisms are many parasites of root rot pathogens, such as *Bacillus*, *Flavobacterium*, *Streptomyces* and *Trichoderma*⁵.

Two specific factors will help those wishing to take advantage of this natural process.

Select composts produced near a forest. Final quality is improved by colonization of beneficial microbes native to the area. Such composts are routinely testing positive for the presence of *Trichoderma*, a beneficial fungus commonly found in the humus layer of the forest floor⁶.

Maintain moisture on the outside of the pile. A film of moisture must be present on the surface for microbes, especially bacteria, to successfully colonize the piles during curing. Moisture content of 40 to 50% is necessary for microbial colonization that will induce disease suppression. Compost that is stored dry (less than 35% moisture) become conducive to *Pythium* diseases⁵.

Composts produced in this way are usually naturally suppressive to *Pythium* and *Phytophthora*. The pathogen spores in the soil or potting mix cannot germinate and infect the host plant because of competition from the high number and variety of beneficial micro-organisms found in the compost. The same mechanisms are probably at play in soils of organic farms, where soil-borne diseases are less prevalent².

DISEASE SUPPRESSION BY COMPOSTS⁷

Most composts can suppress root diseases

Beneficial microbes out-compete pathogens for food and space around plant roots.
This mechanism (direct competition) is very effective against *Pythium* and *Phytophthora*.

Some composts can suppress damping-off diseases

Specific microbes actively attack plant pathogens and feed on their cell content.
This mechanism (mycoparasitism) is very effective against *Rhizoctonia* and *Fusarium*.

Few composts can suppress leaf diseases

Specific microbes placed near the plant roots can protect against leaf diseases.
This mechanism (Induced Systemic Resistance) stimulates defensin-encoded genes.

Natural suppression of diseases caused by *Rhizoctonia* is more difficult. It is a rapid colonizer of fresh organic matter and thus escapes general competition, the mechanism at play with *Pythium* and *Phytophthora*. Suppression of *Rhizoctonia* requires proper composting of organic matter to reduce the food resources available to the pathogen, but also natural recolonisation by specific microbial antagonists. This natural recolonisation is random and often inconsistent. To achieve consistent suppression of *Rhizoctonia* diseases, the material must be augmented with specific microbial products⁸.

III. COMMERCIAL MICROBIAL PRODUCTS

In Canada, commercial products made from naturally occurring soil microbes are now available. They are excellent against specific diseases. Other products will soon be registered, including disease-suppressive strains of the bacteria *Bacillus subtilis* and the fungus *Gliocladium c.*⁹.

The following products are approved by OMRI (Organic Materials Review Institute) and thus allowed for use by certified organic farmers¹⁰.

Mycostop (Streptomyces griseoviridis strain K61)

The active ingredient, *Streptomyces*, is an actinomycete bacteria widely distributed in most soil types. It is known to colonize the root area of plants, where it feeds on exudates and out-competes root pathogens. The strain in this product can also produce antifungal metabolites and lysis of the pathogen cell wall. Research also indicates it can improve plant growth and yield¹¹.

The product registration was amended in 2005 and now includes suppression of damping off and stem rot caused by *Fusarium*, *Pythium* and *Phytophthora* in many greenhouse-grown ornamentals and vegetables. The product is preventive and, for seedling production, it is best applied soon after plant emergence¹².

Extensive research was done in Canada with this product. At the Agriculture and Agri-Food Canada Vineland Station, scientists working with container-grown poinsettia reported that Mycostop was “as effective” as the fungicide Ridomil (active ingredient metalaxyl) for reduction of symptoms caused by *Pythium*¹³. At Simon Fraser University in British Columbia, scientists worked with germinated cucumber seeds grown in rock-wool cubes. They applied soil drench treatments at seeding and 11 days later, before inoculating the root zone with *Pythium*. Results indicated that Mycostop was effective against *Pythium*¹⁴.

Rootshield (Trichoderma harzianum strain KRL-AG2)

The active ingredient, *Trichoderma*, is a fungus commonly found in many soils, especially in the forest humus layer. After growing towards the pathogen, it secretes enzymes that degrade cell walls, allowing it to invade its prey and feed on the cell content. For *Rhizoctonia*, *Pythium*, and *Fusarium*, researchers indicate a suppression effect rather than complete control¹⁵.

This product is registered for suppression of *Pythium*, *Rhizoctonia* and *Fusarium* in many greenhouse-grown vegetables and ornamentals¹⁶. There is a large body of scientific papers on the mode of action and impact of *Trichoderma harzianum* (also called strain T-22). Extensive work was done at Cornell University¹⁷.

Mycorrhizal products

Mycorrhizal fungi are specialized organisms that live on plant roots in a mutually beneficial relationship. They are very common in nature, but less common in disturbed managed soils or in potting mixes. Plants colonized by mycorrhizal fungi have a higher tolerance of environmental stresses caused by drought, cold, replant, low fertility, or presence of root rot pathogens¹⁸.

Plants grown in the presence of commercial mycorrhizal formulations consistently show improved root growth¹⁹. Different commercial products are currently available²⁰.

IV. INDUCING RESISTANCE TO LEAF DISEASES

More recently, researchers have identified composts that can suppress leaf diseases. In this type of disease suppression, specific micro-organisms found near the roots trigger the production of pathogenesis-related proteins that form physical barriers at infection sites on the leaf ²¹.

This mechanism has been called “Induced Systemic Resistance” and in effect increases the natural disease resistance of the plant. It is different from “Systemic Acquired Resistance”, a process where defence proteins are produced *before* the challenge by a foliage disease ⁷.

In a study published in 2003, only one of 79 commercial composts was found to suppress bacterial leaf spot of radish. Eleven micro-organisms were recovered that could induce systemic resistance, with certain strains of *Bacillus* and *Trichoderma* being the most effective ²².

To obtain consistent disease-suppression, beneficial micro-organisms must be introduced to the potting mix, mulch or soil amendment. Scientists are currently looking at these “fortified” composts and their efficacy to reduce foliage diseases ²³.

Early results are encouraging. A group of researchers at Ohio State University recently concluded that composts used as one component of growing media in container production, when “fortified” with *Trichoderma hamatum* strain 382, suppressed many foliar plant diseases:

- leaf blight of cucumber caused by *Phytophthora capsici* ²⁴;
- bacterial leaf spot on vegetables, caused by *Xanthomonas campestris* ²⁵;
- leaf blight of begonia caused by *Botrytis cinerea* ²⁶.

Efficacy of Trichoderma-fortified composts in nursery container production ⁷

Plant tested	Disease	Regular potting mix	Same mix plus <i>T. 382</i>
<i>Myrica pennsylvanica</i>	Botryosphaeria stem dieback	21 % killed	6 % killed
<i>Pieris japonica</i>	Phytophthora shoot blight	24 % killed	4 % killed
<i>Rhododendron Roseum</i> E.	Phytophthora shoot blight	84 % killed	72 % killed
<i>Begonia</i> cv. Barbara	Powdery mildew	1402 cumulative disease severity	100 cumulative severity

Several factors impact the ability of root-colonizing beneficial microorganisms to protect the plant from foliage disease. First, in many cases the disease resistance is inducted by activation of “resistant genes” present in the plant before the pathogen arrives. This pathway may not work in host plants that are highly susceptible to a specific disease or lacks the “resistant genes” ⁷.

Second, the potting media or field soil must have food to support colonisation and growth of beneficial microorganisms. Recalcitrant materials resistant to decomposition generally sustain these activities. The “microbial carrying capacity” of parent material (carbohydrates in peat, lignin-protected cellulose in tree bark) determines the longevity of the suppressive effect ²⁷.

Programs using disease-suppressive amendments are now available for commercial production. These systems are effective in situations of low disease pressure. However, situations of high disease pressure still require the use of synthetic fungicides or other cultural practices ⁷.

V. “RECIPES” FOR COMMERCIAL APPLICATIONS

Home gardens

*Supply the soil with beneficial microorganisms and nutrients from composted products*²⁸.

- Apply one inch of finished compost on the soil surface.
- Spread in the fall and leave on the surface over the winter to allow slow leaching into the soil.

Landscape mulches

*A number of considerations are important for proper use of landscape mulches*²⁹.

- Place a layer of decaying organic matter on the surface, cover with coarse wood chips or bark.
- Aim for a total thickness of 10 to 15 cm on heavy soils in regions with frequent rainfall.
- Aim for a total thickness of 15 to 20 cm on well-drained soils in regions with dry climate.
- A layer too thick (over 20 cm deep) may decrease oxygen flow and trigger root problems.

*Use slightly immature materials that are likely inoculated with beneficial microbes*³⁰.

- Avoid fresh mulches (sawdust or wood chips) which may be colonized by plant pathogens.
- Compost mulch products with grass clippings, manure or urea for at least 6 weeks.
- Maintain moisture at 40% water content during composting, storage and application.
- Keep the mulch away from plant trunks to avoid wet conditions leading to stem rot diseases.

Field production

*Compost can be used as a general soil amendment*³¹.

- Compost application should not exceed 50 dry tons per acre, or 4 cubic yards per 1000 ft².
- In general, 50 dry tons per acre is equivalent to a 1-inch layer of compost containing 50% water.
- For best uniformity during top-dressing, the compost should contain less than 40% moisture.
- Only 8 to 12% of the nitrogen in the compost is available for plant growth the first year.
- Supplemental feeding with mineral fertiliser is necessary for crops with high nitrogen demand.

*Balance compost application rate with nutrient content, soil testing and crop needs*²⁸.

- Manure or biosolid (high nitrogen content): apply 2.5 cm deep; incorporate in top 10 cm of soil.
- Plant residue compost (low N content): apply 10-15 cm deep, incorporate in top 20 cm of soil.
- For plants sensitive to high nitrogen or salts, apply the materials several weeks before planting.
- For plants susceptible to root rot, apply the materials several months ahead of planting.
- Fall or winter application is preferred for leaching of salts and decomposition of fresh material.

*Lightly decomposed organic matter likely drives general suppression in field soils*³¹.

- Biocontrol organisms are usually present but lacking the environment to support their activities.
- Soils low in organic matter content and microbial activity are conducive to root rot diseases.
- Higher application rate (20 to 30 dry tons / ha) can generate disease suppression the first season.
- Lower application rate (10 to 16 dry tons / ha) can generate suppression after two years.
- Long term low rate annual amendment is more economically and environmentally desirable.

*Avoid application of “fresh” materials or immature composts*²⁷.

- Non-composted materials may release nutrients favouring the growth of plant pathogenic fungi.
- Encourage breakdown of crop residues with poultry manure or incorporation ahead of planting.
- Green manures plowed into the soil need 10 to 14 days to decompose before planting.
- Mature composts must be applied 4 to 6 weeks before planting to prepare for disease control.

Nursery and greenhouse container production

*Potting mixes and growing media are often suppressive to diseases caused by Pythium*⁸.

- Suppression comes from lightly decomposed organic matter colonized by a diverse microflora.
- Suppression lasts weeks for peat moss, 9 months for pine bark, and 2 years for hardwood barks.
- The process is aided by adding a mixture of biocontrol agents, or inundating with compost tea.

*Specific microorganisms are required to prevent difficult diseases such as damping-off*²⁴.

- Biocontrol agents can be inoculated into the compost during curing, after peak heating.
- Or, they can be added during preparation of the potting mix, after the addition of fertilisers.
- The process is systemic: disease control is transferred from one set of roots to another.

*The growing media must be prepared with high quality materials*³².

- Peat moss that is light and fibrous has the potential to reduce root rots with suppressive effect up to 6 months. Fine, particulate peat fills pore space and may increase root rot.
- Pine bark is high in materials that resist decomposition and is used at 65 to 100% of volume.
- The product must be composted to avoid a short period of nitrogen immobilization and kept moist (50 to 60% moisture) during composting to avoid growth of problem fungi after potting.
- Hardwood bark must be composted before use. It has the best disease-suppressive properties of all composts and is typically added at 15% of total volume for root-rot susceptible crops.
- Composted biosolids are a potential source of mineralized plant nutrients. No more than 20% is added by volume to avoid excessive fertility or ammonium toxicity problems.
- Composted yard wastes are ideal for landscape use. They are added to potting mix at 15 to 25% by volume. This compost does not cause nitrogen immobilization.
- Composted manures vary in nitrogen concentration. They can be top-dressed on containers. They offer control of soil-borne diseases when added at rates no higher than 15% in potting mix.
- The final potting mix must be analysed for physical properties of air space and water retention. Air capacity must be above 20% for most crops and above 25% for crops sensitive to root rot.

VI. REFERENCES

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