NATURAL SUPPRESSION OF PLANT DISEASES: A RESEARCH UPDATE

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Can healthy soils help prevent root diseases? The answer is definitely "yes" and this has been known for many years. Can composts applied around the roots help prevent diseases above ground, for example leaf diseases? The answer is tentatively "yes", based on recent scientific research. A good understanding of this natural process opens a fascinating and exciting world in horticulture!

A study was published in 2007 in Phytopathology, a peer-reviewed scientific journal of high credibility [1]. Tomato seeds were placed in different peat-based potting mixes, either with or without the beneficial microbe *Trichoderma hamatum* 382. Five weeks after seeding, the leaves of emerged plants were sprayed with a solution containing *Xanthomonas euvesicatoria*, the cause of tomato bacterial spot.

The results: plants grown in a mix amended with *Trichoderma* had significantly less foliage disease than the control mix. The researchers identified 45 genes in the leaves that were expressed differently between the 2 treatments. Placing *Trichoderma* in the potting mix induced genes that are associated with biotic and abiotic stress. Microbial activity in the root zone triggered the production of proteins inside the plant that helped prevent a leaf disease!

"Lightly decomposed organic matter (derived from plant residues or organic wastes) likely drives general suppression in field soils" conclude the authors of a literature review published in 2004 and available on the web [2]. Suppression is sustained with the degradation of less decomposed coarse and mid-sized Particulate Organic Matter (POM) fractions, a size of organic matter comparable to the soil structure in the forest litter [3].

Composts are not created equal for prevention of plant diseases. In an article published in 2006, researchers have summarized current thinking on this topic [4].

Most composts can suppress root diseases.

Common 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 found in quality composts attack plant pathogens and feed on their content. This mechanism (mycoparasitism) is very effective against *Rhizoctonia* and *Fusarium*.

Few composts can suppress leaf diseases.

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

I. PREPARING DISEASE-SUPPRESSIVE COMPOST

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

Usually, three phases occur during composting [5]:
-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^{o}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 [6]. However, materials not composted properly may still contain pathogens. If kept wet for too long, the latter materials could trigger root and stem diseases.

The curing phase is important for natural disease suppression. After reaching peak heating, different micro-organisms naturally colonize the piles. They include many parasites of root rot pathogens, such as *Bacillus, Flavobacterium, Streptomyces* and *Trichoderma* [7].

Two specific factors will help those wishing to prepared disease-suppressive compost.

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* diseases [7].

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 floor [8].

Left

Adequate moisture is the key to proper composting, and a critical factor to obtain a finished product that is high quality and suppressive to plant diseases.
Rainfall is usually insufficient to ensure adequate moisture, especially during summer months.
Water must be added so the material readily forms a ball when pressed in the hand.

Composts produced properly 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 prevalent [5].

Natural suppression of diseases caused by *Rhizoctonia* is more difficult. It is a rapid colonizer of fresh organic matter and thus escapes general competition, described above to suppress *Pythium* and *Phytophthora*. Suppression of *Rhizoctonia* requires proper composting of organic matter to reduce the food resources available to the pathogen, and also natural recolonisation by specific microbial antagonists. However, this natural recolonisation is random and often inconsistent. To achieve consistent suppression of *Rhizoctonia* diseases, the material must be augmented with specific microbial products [3].

In Canada, commercial products made from naturally occurring soil microbes are available. They are excellent against specific plant diseases [9]. These products include Mycostop (*Streptomyces griseoviridis*), Prestop (*Gliocladium catenulatum*), Actinovate SP (*Streptomyces lydicus*), Rhapsody ASO (*Bacillus subtilis*) and RootShield (*Trichoderma harzianum*) [10].

These products are approved by OMRI (Organic Materials Review Institute) and thus allowed for use by certified organic farmers [11].

Left

Composting can be done on small sites and does not require large, expensive equipment.

A basic recipe is to mix fresh ground brush (or leaves) with grass clippings or poultry manure.

Maintain adequate moisture and turn often if practical. Material of reasonable quality should be ready in a few months.

III. 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 [12].

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 [2].

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 [13].

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 [14].

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* [15];
- bacterial leaf spot on vegetables, caused by *Xanthomonas campestris* [16];
- leaf blight of begonia caused by *Botrytis cinerea* [17].

Efficacy of Trichoderma-fortified composts in nursery container production [2]

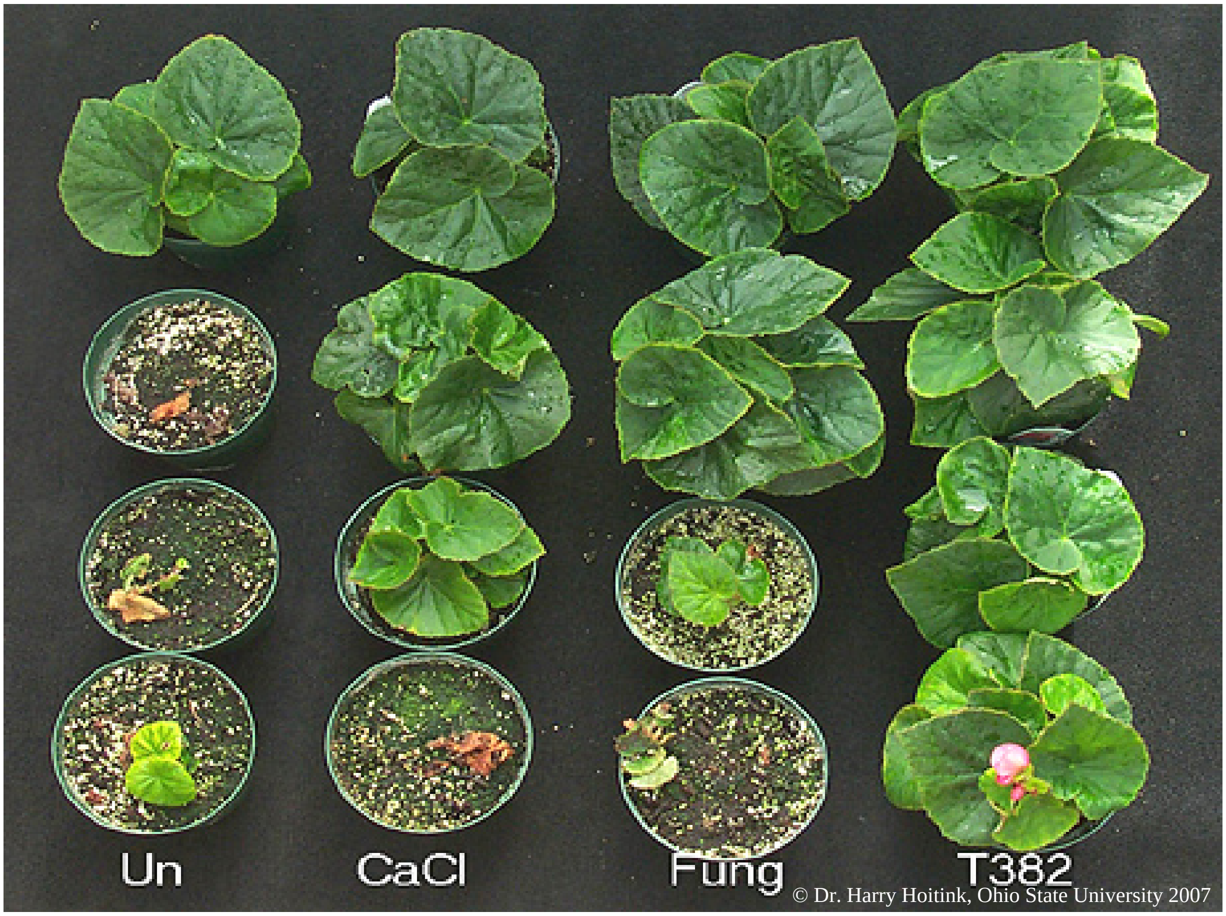
Plant tested	Disease	Regular potting mix	Same mix plus *T.* 382
Myrica pennsylvanica	Botryosphaeria stem dieback	21 % killed	6 % killed
Pieris japonica	Phytophthora shoot blight	24 % killed	4 % killed
Rhododendron Roseum e.	Phytophthora shoot blight	84 % killed	72 % killed
Begonia cv. Barbara	Powdery 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 that lack the "resistant genes" [2].

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 beneficial activities. The "microbial carrying capacity" of parent material (carbohydrates in peat, lignin-protected cellulose in tree bark) determines the longevity of the suppressive effect [18].

The bottom line

Programs using disease-suppressive composts 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 fungicides or other cultural practices [7].



Above: The begonia plants were grown in a standard peat moss mix.
Treatments were, columns from left to right, “Untreated”, “Calcium chloride” (a fertiliser), “Fungicide” (a synthetic product) and “*Trichoderma h.* 382” (a beneficial soil microbe).
The disease *Botrytis* was injected into the leaves at increasing levels from “none” (top row) to “lots” (bottom row).
Note the dead plants for most treatments when placed under high disease pressure (bottom row), but absence of symptoms on plants grown with *Trichoderma* in the potting mix (right column).
Picture courtesy of Dr. Harry Hoitink at Ohio State University.

IV. "RECIPES" FOR COMMERCIAL APPLICATIONS

Home gardens

Supply the soil with beneficial microorganisms and nutrients from composted products [19].

- 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.

Field production

Compost can be used as a general soil amendment [20].

- Compost application should not exceed 50 dry tons per acre, or 4 cubic yards per 1000 ft^2.
- 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 [19].

- 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 [3].

- 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 [21].

- 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.

Landscape mulches

A number of considerations are important for proper use of landscape mulches [22].

- 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.
- Keep the mulch away from plant trunks to avoid wet conditions leading to stem rot diseases.

Use slightly immature materials that are likely inoculated with beneficial microbes [23].

- 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.

Nursery and greenhouse container production

Potting mixes and growing media are often suppressive to diseases caused by Pythium [3].

- 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 [15].

- 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 bottom line

"The biocontrol-fortified and compost-based mixes may also prove useful for organic transplant production where the use of pesticides is limited." [16]

The growing media must be prepared with high quality materials [24].

- Peat moss that is light and fibrous has the potential to reduce root rots with suppressive effect up to 6 months. Conversely, 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 yard wastes are better suited for landscape use. When used in potting mixes, they are added at 15 to 25% by volume. This compost does not cause nitrogen immobilization.
- Composted manures vary in nitrogen concentration. They offer control of soil-borne diseases when added at rates no higher than 15% in potting mix. They can also be used as top-dress.
- 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.

Soil health and disease suppression

Can we relate soil health to disease suppression? "Yes", says Ariena van Bruggen, of Wageningen University, in the Netherlands. "A healthy soil is expected to be suppressive to diseases and pests."

Dr. van Bruggen was speaking at the annual meeting of the American Phytopathological Society (scientists of plant diseases), held in 2007 in San Diego, California. She defined healthy soil as "a stable soil system with high levels of biological diversity and activity, low available carbon and nitrogen, and resilience to disturbance" [27].

Her research group examined the daily changes in soil microbial populations following disturbances. After incorporation of cover crop, manure or compost, soil microbe numbers increase rapidly in the presence of new substrate (food), then decrease as food is used. The up-and-down change in microbial populations is termed "oscillation", similar to the waves created by a rock thrown in a pond.

One study examined a grass – clover cover crop. Following soil incorporation, soil bacteria numbers increased daily for 5 days, followed by increases in bacterial-feeding nematodes, *Pythium* causing damping off and *Fusarium* causing flax wilt, all feeding on food residues generated by the increases in soil bacteria. Damping-off was highest 8 days after incorporation and lowest 35 days after incorporation. Healthy soils, such as those found on organic farms, have lower peak heights of bacterial populations and more suppressed *Fusarium* wilt than conventional soils.

Thus, cover crop incorporation results in a short-term "bloom" of noxious soil microbes, who feed on readily available food. Based on these results, the researcher recommended waiting at least 12 days before planting a field crop following cover crop incorporation.

Right
After a cover crop is tilled, readily degradable plant materials stimulate the growth of noxious pathogens present in the soil, including those responsible for damping-off.
As this population declines, more recalcitrant plant materials serve as food for beneficial soil microbes. Their population growth help protect plant roots from disease infection.
Growers wishing to take advantage of this process should wait at least two weeks after cover crop incorporation before planting a crop.

FOOTNOTES

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Soil biology to improve plant health

with Mario Lanthier
CropHealth Advising & Research

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