



The soil sample analyzed had *Pythium*, *Phytophthora*, *Fusarium* and *Rhizoctonia* at levels that can potentially cause a root rot problem, particularly if soil stays excessively moist for periods of time, or if there is excess nitrogen in the soil. Plants stressed from any other factors such as insect infestations, foliar pathogens, etc. are more susceptible to infections by root pathogens. Roots examined had several feeder roots that were either dead or dying back. Roots tested were infected with *Phytophthora* and *Basidiomycetes* (wood decay fungi).

A soil drench with the fungicide metalaxyl (Ridomil Gold; Subdue MAXX) will help reduce *Pythium* to manageable levels. If feasible plant on a berm to allow rapid drainage. Soils kept moist are more prone to infections by *Pythium*.

***Pythium* Cultural control measures include:**

1. Add **Aged** manure + **composted** materials. This will improve microbial activity that will be antagonistic to *Pythium*. If partially composted or raw manure is applied, *Pythium* will be **increased**.
2. Make sure than nitrogen is applied at recommended rates only. Do not over-fertilize with nitrogen fertilizers. If possible use a slow release form of nitrogen. Excess nitrogen in the soil will often increase infections by *Pythium*, *Fusarium* and *Rhizoctonia*. Applications of calcium nitrate or ammonium sulfate reduce *Pythium* infections.
3. Alfalfa straw, meal or pellets, barley straw, elemental sulfur or superphosphate reduce *Pythium*.
4. Regulate the amount and duration of irrigation water very carefully. *Pythium* species generally require free water for a long duration to infect plants.
5. Applications of mycorrhizae will help improve root development and increase resistance to infections by fungus pathogens.

***Fusarium*** is a difficult pathogen to control in the soil. *Fusarium* cultural controls include:

1. Avoid the use of quick release N fertilizers. Excessive N will rapidly increase the levels of *Fusarium* as well as *Pythium*.
2. There is considerable evidence that the addition of organic matter reduces all types of *Fusarium* losses. Peat and sawdust incorporated into the soil have been reported to be beneficial.
3. Careful scheduling of fertilizer applications is critical in controlling *Fusarium* diseases. Delayed applications of N until after planting, has been recommended. Applications of Phosphorus and Potassium before sowing improved seedling resistance in some crops.
4. Soil compaction has been shown to increase the severity of *Fusarium* root rot of beans (Miller & Burke 1974, *Phytopathology* 64:526-529).
5. Soil temperatures lower than optimum for plant growth often increases the potential of *Fusarium* root rot (Burke, 1965, *Phytopathology* 55:757-759).
6. Loose soil and temperatures favorable for plant growth reduce *Fusarium* root rot (Burke & Nelson, 1965, WA Agr. Exp. Sta. Bull: 664
7. Liming the soil to pH 6.5-7.0 has been reported to reduce *Fusarium* infections of cucurbits.

*Rhizoctonia* is a difficult pathogen to control. **Composted** bark chips used as mulch have been reported to reduce the levels of this pathogen in the soil. Uncomposted amendments that are high in cellulose (straw, bark chips, etc.) increase disease. Deficiency of potassium, nitrogen, or calcium also increases *Rhizoctonia*. Infections increase with excess nitrogen applications. NP, PK or NPK applied as ammonium nitrate or potassium sulfate have been reported to reduce *Rhizoctonia* root rot.

Some fungicides registered for the control of this pathogen are: Companion (biological fungicide), Chipco 26019, Compass, Heritage, Medallion, PCNB (Engage, Revere, Terraclor), Spectro 90, and Thiophanate-methyl (Cleary's 3336, Cavalier, Fungo). Check to see which ones of these fungicides are available for use in your State for particular situation. More than one soil drench may be required for control



### Nutrient interactions

1. Optimal nutritional release occurs when soil pH is 6.2 to 6.5. As pH rises, iron and manganese becomes increasingly unavailable resulting in chlorosis.
2. Yard wastes are usually alkaline (pH 7.4-7.8). If added to already alkaline soils, soils become highly alkaline resulting in unavailability of microelements.
3. Applying sulfur to reduce pH can result in injury to plants.
4. Adding amendments with excess phosphorus results in unavailability of iron, manganese and zinc resulting in chlorosis.
5. Adding iron sulfate or calcium to bind up some phosphorus are short term solutions.
6. Yard wastes are usually high in phosphorous - so adding yard wastes continually can affect plant growth.
7. Yard wastes also contain excess potassium and boron. High potassium limits the soil's ability to hold calcium and magnesium. Excess K and B result in yellowing of leaf tips, necrosis, marginal and interveinal leaf scorch and premature leaf drop.
8. Yard wastes often contain excess soluble salts. These can move down and accumulate in the plants root zone causing poor root development resulting in low overall and stunted plant growth. Applying fertilizers to remedy these problems only compound the problem.
9. Excess sodium takes the place of calcium, magnesium and potassium, resulting in a rise in pH (Alkaline). The remedy is usually gypsum – slow acting.
10. Always remember the interconnection between micronutrients, cation exchange capacity, level of organic matter and soil percolation rates.

<b>NUTRIENT IMBALANCES</b>	
<b>IF EXCESSIVE:</b>	<b>THEN INHIBITS:</b>
N	K
NH <sub>4</sub>	Ca, Cu, Mg
K	N, Ca, Mg
P	Cu, Fe, Zn, B
Ca	Mg, B, K
Mg	Ca, K
Na	Ca, K, Mg
Mn	Fe, Mo
Fe	Mn, P
Zn	Mn, Fe
Cu	Mn, Fe, Mo
Mo	Cu

\*Zinc (Zn) is less available in cool wet soils or soils in high organic matter.

N=Nitrogen, P= Phosphorus, K= Potassium, Ca = Calcium, Mg = magnesium, Mn = Manganese, Fe = Iron, Zn = Zinc, Cu = Copper, Mo = molybdenum, B = Boron, NH<sub>4</sub><sup>+</sup> = Ammonium.

## History

The use of ultraviolet light (UV) is becoming more common to sanitize 'cleaner' water sources, since it does not require the addition of any chemicals. Some hospitals, hotels and nursing homes are using UV light to sanitize potable water sources to ensure that water is free of human pathogens. When properly used in some nursery facilities, UV light may help kill any remaining organisms that may remain in the water after all clarification and filtering processes have been performed. The use of UV treatment in nurseries is in the developmental stages. Since water sources and the degrees of water cleanliness vary among nurseries, small pilot systems should be installed and tested to ensure that UV treatment processes will work for specified nurseries.

## What is UV Light and How Does it Work in Water Treatment?

Ultraviolet light fits into the light spectrum of wavelengths from 100-400 nanometers (nm). This is the same light wavelength that is notoriously known to cause skin cancer in humans. Visible wavelengths range from 390-810 nm. The UV light, like chlorine treatments, kills the pathogens (bacteria, fungi, and viruses) suspended in water. However, since it is a light source, the water must be clean of suspended clays and organic acids for the light to pass through the water column to kill pathogens. Because of this limitation, UV light treatment is more suitable for hydroponic systems rather than production facilities that use organic media (peat, pine bark) or run water over soils that contain clays since the dissolved organic acids and clays will reduce water clarity and thus reduce the effectiveness of UV treatments.

## Ultraviolet Light Sources

There are three types of UV sources: (1) low pressure mercury vapor lamps; (2) Xenon flashlamps; and (3) excimer lasers. Low-pressure mercury lamps emit a wavelength of 254 nm. The use of 'high' pressure mercury lamps may also be used, but they also emit wavelengths of 190 nm, which results in the formation of ozone in the water. This ozone can also sanitize the water to a certain degree. Xe-

non flashlamps emit pulses of light that is a higher power source of emission. However, Xenon lamps also emit wavelengths over a larger spectrum, some of which are not UV, making Xenon lamps less energy efficient. The third source of UV light is the excimer laser, which emits pulses of light (248 nm).

## Ultraviolet Light Usage in Nursery and Floriculture Production

Ultraviolet light treatments are used in the water recycling system at the point after all other water clarification processes such as sand/charcoal filtration or flocculation have occurred. This ensures that the water is clear enough for the most effective UV light penetration into the water column.

### Advantages

+OPERATION COSTS – The cost of operation will be low if the water source is already clarified. Cost of treatment will increase with the degree of water cloudiness.

+INSTALLATION COSTS – Relatively lower for cleaner water supplies such as those of hydroponic systems.

+CHEMICALS – No chemicals, regardless of the light source utilized.

+TECHNICAL COMPONENTS – Few technical components or control systems.

+MAINTENANCE – low (occasional replacement of copper electrodes.)

+PATHOGEN EXTERMINATION – Pathogens such as bacteria and fungi and viruses will be killed.

+CHEMICAL EFFECTS – No effect on water pH.

+SPACE – Relatively small space required for installation of light source and power supply.

+ALGAE CONTROL – The system will kill algae suspended in the water source.

+NONTOXIC TO PLANTS – UV treated water has no toxic effect on plants.

### Disadvantages

-NEW TECHNOLOGY – The use of UV light in nursery systems is still being studied. Therefore, much of the troubleshooting needs to be conducted.

-CHEMICAL EFFECTS – light sources

will chemically denature chelates that may be used to keep micronutrients such as iron in a soluble form.

-EFFECTIVENESS REDUCED WITH DIRTY WATER – Since the UV light must pass through the water, any dissolved or suspended substances such as organic acids or clay will reduce efficacy of the UV light treatment.

-HERBICIDE AND PESTICIDE REMOVAL – Does not remove other chemicals from the water. The effects of UV light may break down light-sensitive herbicides and pesticides. Consult manufacturer for specific chemical questions.

-FLOATING DEBRIS REMOVAL – Does not break down or remove floating debris.

-DISSOLVED ORGANIC MATTER – Coloration due to dissolved organic matter and acids is not removed from the water.

-CLAY AND SILT REMOVAL – Clays and other soil particles are not removed.

-EXPOSURE TIME – UV light may require an exposure time of 30 seconds or longer, depending on the clarity of the water. Slower flow rates will be required, but lower flow rates will also reduce water turbulence and efficiency of treatment.

**Conclusions.** When used properly, UV light treatment may be used on some nursery systems to kill pathogens. However, the most successful use of this technology will be with cleaner water systems such as those used in hydroponic systems. However, if using chelated micronutrients such as iron chelates, the use of UV light may cause denaturing of the chelates. ♦

**Caution:** When treating recycled waters, always check for effective control of pathogens, regardless of the treatment process being used.

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## EFFECT OF ORGANIC AMENDMENTS ON INCREASING OR DECREASING PLANT PATHOGENS

The quality of composts and amendments varies depending on the starting materials. There is no perfect mix for every plant and every situation. However, general guidelines are available. Composts have the potential to provide biological control of foliar as well as root pathogens. Before employing the use of mixes/composts/amendments and/or fertilizers in controlling plant pathogens, the following must first be addressed:

- **Sanitation:** Root rotting pathogens are easily carried on implements, shoes or contaminated plants. Sterilize all used containers with hot water, steam or Clorox prior to re-use.
- **Irrigation Management:** Avoid excessive wetting of the foliage and soil. Treat contaminated irrigation water with chlorine, ozone or UV filtration.
- **Adding products containing beneficial fungi** such as *Trichoderma* or other beneficial microorganisms such as *mycorrhizae*.
- **Manipulating pH and moisture:** *Pythium* & *Phytophthora* propagules are reduced by low pH and low soil moisture.
- **Avoiding overkill of soil microorganisms:** Elimination of microorganisms by heat or chemical sterilization increases the chances for introduced pathogens to become established. Selective kill of pathogens is a better approach as this allows other microorganisms to survive that may have antagonistic activity against an introduced pathogen.

### Considerations when using organic amendments:

1. Composts must be of consistent quality and maturity to be used successfully for the control of plant diseases
2. Heat exposure during composting kills or inactivates pathogens as well as biocontrol agents
3. Some pathogens use amendments as an energy-source thereby, increasing inoculum potential
4. Decomposition level of the compost will determine the level of disease suppression obtained. At completion of decomposition process, humic compounds are produced which induce a variety of responses in plants and soil microbes.
5. In undecomposed organic matter, pathogens such as *Rhizoctonia* are actively colonizing the substrate and competing with other microflora. **Biological control is therefore, not possible in immature composts.**
6. Immature composts serve as food for pathogens even when biocontrol agents are present
7. Excessively decomposed composts do not support biocontrol agents. Instead, they often can result in the accumulation of toxic products.
8. High salinity and high nitrogen in composts negate disease suppression. Concentrations of soluble salts and plant nutrients in yard waste composts vary enormously. This is usually due to the amount of grass clippings in yard waste. Most of the salinity in yard waste composts is due to potash rather than chlorides as in manures.
9. Wood content of the bark. *Phytophthora* was not suppressed when bark was mixed with more than 60% wood chips.
10. Mulches that are rich in cellulase enzymes are effective against *Phytophthora* and *Pythium* whereas mulches rich in chitinase are effective against most other pathogens such as *Fusarium*, *Rhizoctonia*, *Cylindrocladium*, etc.  
This is because *Phytophthora* and *Pythium* have cellulose and glucan cell walls while other pathogens have chitin in their cell can cause injury to plant root hairs, which will reduce nutrient and water uptake.
11. Soil nitrogen and calcium levels influence infections by *Phytophthora* & *Pythium*.



**Organic Amendments and Soilborne Plant Diseases:** The effect of organic amendments depends on the kind of material added and state of decomposition. Early in the decomposition process, toxic chemicals can be released which often damage plant roots. Some pathogens use amendments as an energy-source increasing inoculum potential. Residue products stimulate germination of pathogens, which then die in the absence of a host plant. Organic amendments stimulate microbial activity, which depletes N level or changes its form so that infection process by the pathogen is impaired.

#### Two Types of Peat:

- **Sphagnum Peat:** Slightly decomposed peat (light color) suppresses *Pythium* believed to be due to *Trichoderma* and *Streptomyces*. Decomposed peat (dark color) will not suppress *Pythium*.  $\text{KNO}_3$  and Calcium Nitrate greatly increase the EC (salt levels). Some peats have been known to be contaminated with *Pythium* and *Fusarium*.
- **Hypnum Peat:** pH 5.8-6.6. High bulk density and water holding capacity. N content is usually over 2%. Calcium is very high (10,000 ppm or greater). Cation Exchange Capacity (CEC) is higher than Sphagnum peat. Hypnum has a higher capacity to bind fertilizers salts and some soil toxins and a greater capacity to form aggregate upon drying than other peats tested.

**Sawdust and Shredded Bark:** Nitrogen deficiency. (Softwoods have an N requirement @ 0.59% of the weight of the wood, hardwood requires 1.1 % N of the weight of the wood). May produce substances toxic to plants (resins, turpentine, and tannins such as those found in walnuts, cedar, incense cedar, some pines, redwood shavings, and sawdust). Serious damage reported after steam sterilization of redwood shavings.

**Composts:** Many soilborne diseases are suppressed by properly manufactured composts. However, improperly cured composts often have *Pythium* and *Rhizoctonia* present. Heating pile to 55°C (130°F), destroys disease-suppressive effect. If still undergoing decomposition, promotes low oxygen tensions that reduce plant growth. Cu and Zn are usually high in compost mixes (aluminum is high in some peat). Nitrate N causes a big increase in compost salinity - apply very little in base fertilizer.

**Composted Hardwood Bark:** Suppresses soilborne plant pathogens and nematodes. CHB (Composted Hardwood Bark) has suppressed soilborne pathogens for at least 2 years. After 15 years of use in Ohio Nurseries, CHB has inhibited epidemics caused by soilborne plant pathogens. Unlike Pine Bark, CHB is N-immobilizing.

**Aged Hardwood Bark:** Moderately acid and low salts. Good level of P, K, Ca, and Mg. Low in N. Very high in Fe and B. C: N ratio 120:1 - so further composting required. Good soil texture improvements. Low in organic matter N-immobilizing.

**Aged Fir/Hemlock Bark:** Strongly acidic and low in salts. Deficient in N, P, K, Ca, and Mg. Low in Zn, Fe and S. C: N 500:1. Need further composting to stabilize. High in organic matter.

**Biosolids:** These are conducive to plant pathogens immediately after their production. Recontamination with antagonists, either cultured or natural, is necessary to render this type of compost suppressive to plant pathogens.

**Manures:** High in salts due to ammonium-N, phosphate and potassium. Low in Mn and Fe. High in organic matter. C: N ratios are 50:1 to 20:1 for well-rotted manure. Soluble salts accumulate when high levels of manure are applied for a few years.



Organic amendments: page 3 of 3

**Nitrogen Form and Plant Disease:** Form of N plays an important role in plant disease. Of all the elements, N is required by the plant in the greatest quantity. Assimilation of N is complicated since the plant can use both the cation ( $\text{NH}_4^+$ ) and anion ( $\text{NH}_3^-$ ) forms. Disease control depends on the specific form of N, rate of N, soil microorganisms, and rate of change of  $\text{NH}_4\text{-N}$  to  $\text{NH}_3\text{-N}$ .

***Phytophthora & Pythium.***

- Applications of calcium nitrate or ammonium sulfate reduce *Phytophthora* infections.
- Alfalfa straw, meal or pellets, barley straw, elemental sulfur or superphosphate reduce *Phytophthora* and *Pythium*.

**Fusarium**

- There is considerable evidence that the addition of organic matter reduces all types of *Fusarium* losses. Peat and sawdust incorporated into the soil have been reported to be beneficial.

***Rhizoctonia***

- Composted bark chips used as mulch has been reported to reduce the levels of this pathogen in the soil.
- Pure cellulose amendments increase *Rhizoctonia*. Addition of cellulose to composted hardwood bark removes suppressive effect of bark.
- Fresh amendments increase disease.

\**Rhizoctonia* is often found in poorly composted bark or yard waste.

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## MICROELEMENTS

**Manganese (Mn):** Plants require very small amounts of Mn for growth and maturity. However, a deficiency of Mn can cause major plant problems. Diseases caused by Mn deficiency have descriptive names such as Gray Speck of oats, White Streak, Dry spot of cereals, Marsh Spot of peas, etc. In some cases, addition of certain types of organic wastes can raise the soil pH sufficiently to reduce plant uptake of Mn.

**Magnesium (Mg):** High concentrations of magnesium cause injury by altering the calcium: magnesium ratio. This affects the roots since these are particularly sensitive to calcium deficiency. High magnesium fertilizer applications can reduce manganese uptake. High Mg levels can also inhibit potassium uptake by plants in low potassium soils resulting in poor growth.

**Boron (B):** The humus content of soils has an influence on boron adsorption. Acid humus adsorbs approximately twice as much boron as humus that is saturated with calcium (Keren & Bingham, 1985).

**Copper (Cu):** The use of copper to prevent plant diseases was known as early as 1761. Today, many copper-based fungicides are routinely used for the control of many foliar plant pathogens on a wide range of plant spp. Excess copper can result in reduced growth, chlorosis of the foliage, and abnormal, stunted root development of many plants.

**Molybdenum (Mb):** Although required in very small amounts, this element has a major impact on plants. It plays a vital role in nitrogen fixation by microorganisms and other nitrogen transformation processes in plants. Plants cannot transform nitrate nitrogen into amino acids without molybdenum. Iron chlorosis in Flax caused by Cu, Mn, Zn or Co, can be cured by the applications of heavy applications of molybdenum fertilizer (Bergmann, 1992). **Note:** High Mo levels in forage plants can be harmful to livestock.

**Effect of fertilizers on insect infestations:** Fertilization decreases insect resistance e.g. survival of tent caterpillar larvae was 33% higher on fertilized trees compared to unfertilized trees. Japanese beetles preferred to feed on birch trees that were fertilized with nitrogen.

**Natural organic fertilizers:** The nutrient levels in natural organic fertilizers depend on the source e.g. guano, manure, green manure, sea kelp, bone/blood meal, biosolids, etc. It is therefore important to know the particular requirements of the area to be fertilized before selecting a natural organic fertilizer.

EFFECT OF pH RANGE ON NUTRIENT AVAILABILITY		
pH RANGE:		
5.5 ————— 6.5		
<b>Deficient:</b>	<b>READILY AVAILABLE</b>	<b>Deficient:</b>
Calcium (Ca)		Iron (Fe)
Magnesium (Mg)		Manganese (Mn)
Phosphorus (P)		Boron (B)
Potassium (K)		Copper (Cu)
Sulfur (S)		Zinc (Zn)
Molybdenum (Mo)		Magnesium (Mg)
High pH levels result in the tie up of Phosphorus, Iron, Manganese, Zinc, Copper, and Boron.		



## EFFECT OF FERTILIZERS ON INCREASING OR DECREASING PLANT DISEASES

The impetus to reduce pesticides has resulted in evaluating alternative methods for the control of plant diseases. One such alternative is the use of fertilizers. However, the role of various macro- and micro-elements in either increasing or decreasing plant diseases is complex and is often difficult to discern since many interactions occur between soil nutrients, soil microorganisms and pH. It is important to recognize these interactions before employing nutrients as a tool in plant disease control.

Examples of the effect of nutrients on plant disease include:

1. Reducing the severity of *Verticillium* wilt by controlling the amount of nitrogen applied. Nitrate-N usually increases *Verticillium* severity. Ammonium-N increases resistance. Level of resistance varies with the host species.
2. *Fusarium* wilt of vegetables and ornamentals is controlled by the application of lime to raise the pH to 6.5-7.5, addition of nitrate-N, and keeping the phosphate level low.
3. Bacterial (*Erwinia*) soft rot of potato tubers. The application of calcium at tuber formation reduced soft rot severity.
4. Root rots caused by *Pythium* spp. The severity of several diseases incited by *Pythium* spp. has been successfully reduced by the application of Calcium.

### Nitrogen Form and Plant Disease

1. Form of Nitrogen plays an important role in plant disease.
2. Of all the elements, Nitrogen is required by the plant in the greatest quantity.
3. Assimilation of N is complicated since the plant can use both cation ( $\text{NH}_4^+$ ) and anion ( $\text{NH}_3^-$ ) form.
4. Disease control depends on specific form of N (ammonium, nitrate, urea, etc), rate of N, soil microorganisms, and rate of change of  $\text{NH}_4\text{-N}$  to  $\text{NH}_3\text{-N}$

### Interactions between microorganisms and nitrogen in plant disease control:

There are several reports in the literature that show the importance of microorganisms in influencing the suppression of plant diseases by nitrogen. Much of this information has been documented by Huber & Watson (1974) e.g. the suppression of pea root rot by nitrate nitrogen was shown to be correlated with an increase in bacteria and actinomycetes. This increase in microorganisms was not observed with ammonium nitrogen. Other reports indicate the importance of increased microbial activity with certain forms of nitrogen in controlling diseases caused by *Rhizoctonia*, *Phytophthora* and *Fusarium*.

### Phosphorus (P):

1. Foliar sprays containing phosphates (especially with a wetting agent) has been reported to control foliar diseases such as powdery mildews and rusts. (Crop Protection. Vol. 17, pages 111-118 (1998).
2. It is important to note that although the typical symptom of Phosphorus deficiency is a reddening of the leaves, this type of reddening is also caused by cold temperatures, high light intensity, insect damage and/or drought.
3. Excess Phosphorus applications inhibit mycorrhizae development.
4. The presence of organic matter, and level of microbial activity, influences the amount and availability of phosphorus.
5. Microelement deficiencies may often prevent crop response to applied phosphorus fertilizers.

### Factors Affecting Phosphorus Availability

1. **Aeration:** Oxygen is necessary for plant growth and nutrient absorption. It is also needed for processes that increase the phosphorus supply through the mineralization and breakdown of organic matter.





2. **Compaction:** Compaction reduces the degree of aeration by decreasing the pore sizes in the root zone of the growth media.
3. **Moisture:** Increasing moisture in the soil increases the availability of phosphorus to plants and the availability of fertilizer phosphorus. However, excessive moisture reduces aeration, root extension, and nutrient absorption and increases susceptibility to infections by fungus root-rotting pathogens.
4. **Soil Particle Size:** Small soil particles, such as clay, usually tie up more phosphorus than larger soil particles such as sand.
5. **Temperature:** Increases the rate of organic matter decomposition, which in turn releases phosphorus to plants. Temperatures excessive for optimum plant growth interfere with active phosphorus absorption. The utilization of phosphorus within the plant is greatly reduced under low temperatures.
6. **Soil pH:** Soil pH regulates the form in which soil phosphorus is found. Acid soils may contain a large amount of iron, aluminum, and magnesium, and in some cases sodium. All of these elements combine with phosphorus to form compounds of varying solubilities and degrees of availability to the plant.
7. **Other Nutrients:** Other nutrients may stimulate root development, thus increasing phosphorus uptake. The ammonium form of nitrogen may stimulate the uptake of phosphorus because of the resulting acidity as ammonium-N is nitrified to nitrate-N.
8. **Organic Matter:** The presence of organic matter, and level of microbial activity, influences the amount and availability of phosphorus.
9. **Mycorrhizae:** These help increase the uptake of phosphorus.
10. **Microelement Deficiencies:** Deficiencies of microelements may prevent crop response to applied phosphorus fertilizers.

**Potassium (K):** Unlike nitrogen, phosphorus and sulfur, potassium is not a constituent of organic matter (Bergmann, 1992). It is usually supplied to roots by the addition of fertilizers, manures and/or mulches. Potassium is perhaps best known for its ability to increase resistance to cold injury and its resistance to pathogen infections. Potassium deficiency results in an inhibition of water uptake resulting in wilting symptoms

**Calcium (Ca):** The most studied effect of calcium is in the suppression of soilborne plant pathogens. Soil applications of gypsum (calcium sulfate) have been the most effective form of calcium used thus far. The soilborne plant pathogens—*Phytophthora* and *Pythium* that infect a very wide number of plants were shown to be controlled by applications of gypsum. For foliar control of plant pathogens such as powdery mildew of grapes, calcium has been effective when used as calcium chloride.

**Sulfur (S):** Excess Sulfur increases EC (electrical conductivity), thus reducing water uptake of roots resulting in drought-like symptoms. Sulfur was first used in 1824 to control powdery mildew and is still used today as a primary defense against this disease. Sulfur is not effective on any other foliar disease.

**Silicon (Si):** Silicon forms a physical barrier in epidermal cells. This helps the plant resist penetration by fungi and insects. Applications of silicon are routinely used by growers in Europe for the control of powdery mildew and other diseases of cucumber (*Cucumis sativa*) and rose (*Rosa* spp.).

**Note:** Silicon for horticultural purposes has not yet received official approval in North America.

## Symptoms & Control of Pumpkin Diseases\*

Disease	Conditions	Timing	Leaves	Stems	Fruit	Seed Borne	Control
<b>Angular Leaf Spot</b> ( <i>Pseudomonas syringae</i> pv. <i>lachrymans</i> )	Wet leaves (70-80°F)	early-mid season	Small (1-3mm) angular brown spots & holes	Water-soaked; white crust	Sunken crater; white crust	Yes	Seed treatment with Maxim or Dery (biological control). Copper (Kocide, Champ)
<b>Bacterial Wilt</b> – ( <i>Erwinia tracheiphila</i> ).	Cool weather (52-60°F)	early-mid season	Sudden drooping of leaves	Stem collapse	Shriveling & wilt.	No	Soil and foliar insecticide applications for beetle control
<b>Gummy Stem Blight</b> ( <i>Didymella Mycosphaerella</i> / <i>Phoma</i> )	Warm, wet (68-75°F)	mid-late season	Black dots in tan lesions to entire leaf blighted	Gummy exudate; black dots within lesions	White to tan concentric circles with black dots or black decay	Yes	Seed treatment with Maxim or Dery (biological control). Agri-Fos; Amistar; Daconil (Bravo); Mancozeb; Medallion (Quadris); Topsin M70W.
<b>Downy Mildew</b> ( <i>Pseudoperonospora cubensis</i> )	6 hr. of 100% relative humidity (59-68°F)	mid-late season	Yellow areas on upper surfaces; tan-gray fuzz on underside	Lesions present in later stages	-----	No	Aliette; Subdue (Ridomil); Dinethomorph (Acrobat); Azoxystrobin (Quadris, Medallion).
<b>Fusarium crown &amp; fruit rot</b> ( <i>Fusarium solani</i> f. sp. <i>cucurbitae</i> )	Low pH, low moisture	early-mid-late season	Yellowing & wilt	Soft, mushy rot. White-pink growth at soil line	Sunken craters – may have fungal growth	Yes	Seed treatment with Maxim or Dery (biological control). 4-year rotation.
<b>Phytophthora Blight</b> ( <i>Phytophthora capsici</i> )	Warm, wet soil	mid-late season	Dark areas on leaf surface	Soft-rot or water-soaked lesions; collapse of plant	Water-soaked or sunken spots; gray fruit decay	Yes	Seed treatment with Maxim or Dery (biological control). Rotate out of cucurbits for years. Subdue (Ridomil); Aliette; Chlorothalonil; Mancozeb; Copper; Sulfur 80%; Mineral oil; Myclobutanil (Nova); Potassium bicarbonate; Trifloxystrobin (Flint); Thiophanate-methyl (Cleary's 3336, Topsin M). Azoxystrobin (Quadris, Medallion).
<b>Powdery Mildew</b> ( <i>Sphaerotheca fuliginea</i> & <i>Erysiphe cichoracearum</i> ).	Dry, then cool/wet (68-80°F)	mid-late season	Talc-like; appears on older leaves first	Talc-like	-----		

\* Partially Based on University of Massachusetts Extension Service .

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## Mycorrhizae: An Essential Part of Plant Roots

Mycorrhizae are “fungus roots” that have a symbiotic relationship with living cells of plant roots. They cannot live and reproduce without the plant association. Mycorrhizae are living components of all soils. There are two kinds of Mycorrhizae (beneficial fungi), **Endomycorrhizae** and **Ectomycorrhizae**. Endomycorrhizae are also known as vesicular-arbuscular Mycorrhizae (VAM). These fungi grow inside the roots and send out fungus filaments into the surrounding soil to obtain nutrients. 85 % of 300,000 plant species worldwide contain VAM fungi. Ectomycorrhizae occur naturally on over 2000 plant species of trees including pine, oak, spruce, willow, cedar, eucalyptus etc. Ectomycorrhizae form a hyal mantle on the outside surface of the roots. They emerge from soil as puffballs and various mushroom structures.

### Advantages of Mycorrhizae inoculated plants:

1. Increases the root system's absorbing ability. Roots thus function better.
2. Plants are more drought resistant. Mycorrhizae boost plants' accumulation of carbohydrates in cells. This helps cells retain water.
3. Reduces transplant shock.
4. VAM fungi are synergistic with nitrogen-fixing bacteria.
5. Improve plant growth in nutrient poor soils.
6. Increases plant photosynthesis
7. Reduces negative effects of salinity or toxicity
8. Increased absorption of phosphorous and zinc.
9. Enhance uptake of K, Fe, Ca, Mg, Mn and S.
10. Reduces the need for large amounts of fertilizers in container grown plants.
11. Decreases the severity of infections caused by root pathogens such as *Phytophthora*, *Pythium*, *Rhizoctonia*, *Fusarium*, *Thielaviopsis*, and *Cylindrocarpon*
12. Protects plants against nematode infections. This is believed to be due to the increased levels of amino acids in Mycorrhizal roots. Amino acids inhibit nematodes.
13. Some Mycorrhizal plants are more resistant to insects.
14. Increased tolerance to high soil temperatures.
15. Increased tolerance to heavy metals in the soil.
16. Enhanced rooting of cuttings.
17. Enhanced root regeneration.
18. Increased root longevity.

### Conditions that inhibit Mycorrhizal establishment:

1. If soil is compacted, dry or contaminated, the chances of mycorrhizal fungi establishment is poor.
2. Certain soils contain microbes that inhibit development of Mycorrhizae.
3. Some nematodes such as *Aphelenchoides* feed on VAM fungi.
4. VAM fungi are reduced by fumigation.
5. Increased fertilization decreases VAM colonization. Excess phosphates will inhibit mycorrhizae in the early stages of establishment. Balanced fertilizers are less detrimental. Fertilization through drip irrigation encourages VAM development.
6. Broccoli strongly inhibits mycorrhizae. Therefore, do not follow broccoli with a crop such as strawberries.

**Note:** Applying Mycorrhizae requires careful planning. Mycorrhizae are living organisms that need oxygen, moisture and organic matter. Just putting these organisms in a mycorrhiza-deficient soil will not work.

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Mycorrhizal Fungi can be quite sensitive to some fungicides, but not all. Some fungicides can actually stimulate mycorrhizal fungi, while other fungicides are detrimental.

Because no one has been able to test any fungicide against all mycorrhizal fungi, some basic assumptions have been made:

1. A fungicide is considered to be inhibitory if it was reported to inhibit, regardless of other contradictory reports.
2. The two major groups of mycorrhizal fungi, VAM and Ectomycorrhizae are treated separately, as fungicides detrimental to one group, need not be detrimental to the other.

#### Fungicide Effects on VAM

No Inhibitory Effect	Inhibitory Effect
Carbamate (Ferbam, Fermate)	* Aliette (Fosetyl-Al)
Carbendazim (Bavistan)	Benomyl (Benlate, Tersan-1991)
Chloroneb (Tersan, Demosan)	Captan (Orthocide)
Chlorothalonil (Bravo, Daconil-2787, Exotherm)	Copper Oxychloride Sulfate (CDCS)
Difolatan (Sulfonimide, Difosan, Captafol)	Formalin (Formaldehyde)
Mancozeb (Dithane M-45, Manzate, Fore)	* Metalaxyl (Subdue, Ridomil)
Manate (Dithane M-22, Maneb)	PCNB (Terraclor, Tri-PCNB)
Rovral (Chipco-26019)	Phaltan (Folpet, Thiophal)
Thiabendazole (Mertect)	Terrazole (Truban, ETMT)
Thiram (Tersan 75, Arasan)	Tilt (CGA-65250, Banner, Propiconazol)
Topsin-M (Easout, Fungo, Duosan)	Thiophanate Methyl (Cleary's 3336)
Triforine (Funginex)	Triadimefon (Bayleton)
	Vitavax (Carboxin, DCMO)

\* There are some published reports indicating that these fungicides actually stimulated VAM development. (See notes below).

#### Fungicide Effects on Ectomycorrhizae

No Inhibitory Effect	Inhibitory Effect
Aliette (Fosetyl-Al)	Banrot
Benomyl (Benlate, Tersan-1991)	Chlorothalonil (Daconil-2787, Bravo)
Captan (Orthocide)	Mancozeb (Dithane)
Carbamate (Fermate, Ferbam)	PCNB (Terraclor, Tri-PCNB)
Carbendazim	Triadimefon (Bayleton)
Dexon	Zineb (Ziram, Zerlate)
Difolatan (Sulfonimide, Difosan, Captafol)	
Fuberidazole	
Metalaxyl (Subdue, Ridomil)	
Thiophanate Methyl (Cleary's 3336)	
Thiram (Arasan)	

#### Notes

- ⇒ For this list, a fungicide is considered to have no detrimental effect whether it had no effect, or whether it had a positive effect on mycorrhizal development.
- ⇒ There are often many different trade names for the same fungicidal chemical. There may be other names not shown here.
- ⇒ No fungicide eradicates mycorrhizae; they only decrease development for a short time after application. This time of this effect depends on the duration in which the chemical persists in the environment.
- ⇒ Most foliar spray fungicides, if applied correctly (except those that are systemic, like Bayleton), do not affect mycorrhizae because the fungicide does not come in contact with the mycorrhizae in the soil (in significant quantities).
- ⇒ There are no reports of any insecticide or herbicide, applied at label rates, affecting mycorrhizal development.

*Courtesy of Plant Health Care, Inc., Pittsburgh, PA*