COMMON SENSE PEST CONTROL QUARTERLY

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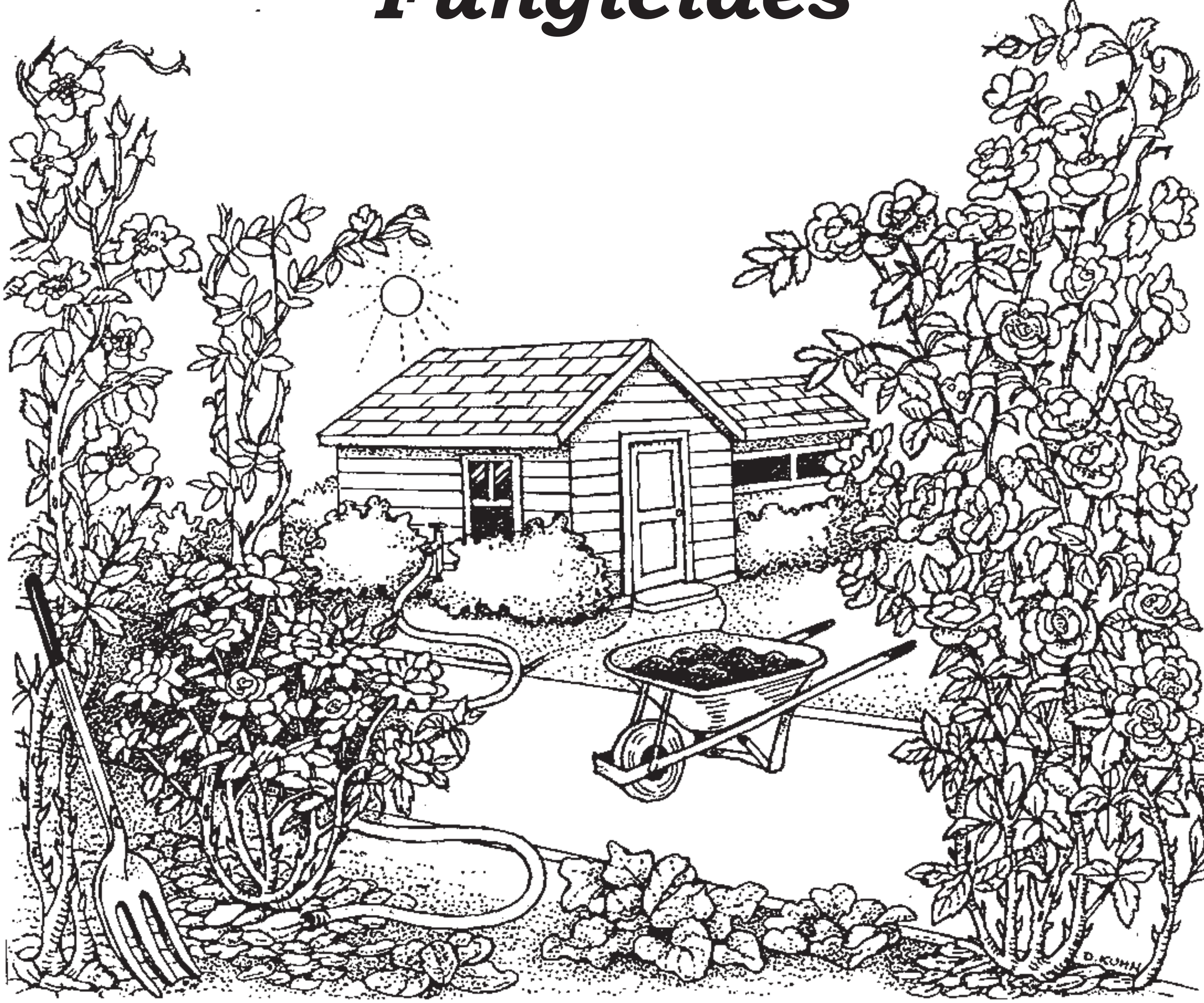
Drawing courtesy Diane Kuhn

Non-Toxic Fungicides



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Global Warming and Pathogenic Fungi

By William Quarles

Global warming and climate change has led to major problems with fungi (Frazer 2013). Warming has encouraged fungus attacks on humans, other mammals and plants. For instance, worldwide human deaths each year from *Aspergillus*, *Cryptosporidium*, and *Candida* now exceed those from malaria and tuberculosis combined (Berweij et al. 2009; Brown et al. 2012; Fisher et al. 2012). And human *Aspergillus* infections are now often resistant to the azole fungicides used for treatment (Berweij et al. 2009).

White nose fungus caused by *Geomyces destructans*, has killed millions of bats in the U.S. since 2006 (Quarles 2013). Global warming may be causing fungi to adapt to higher temperatures. As a result, the gap between mammalian temperatures and optimum temperatures for fungi is becoming smaller (Casadevall 2012; Garcia-Solache et al. 2010).

But other animals are also seeing increased infections. Amphibians are dying from the chytrid fungus, *Batrachochytrium dendrobatidis.* The fungus has been present in the environment since 1928, but was not noticed as a lethal amphibian pathogen until 1998 (Quarles 2017). Global warming may be encouraging proliferation of the fungus, and amphibian immune suppression due to exposure to fungicides such as chlorothalonil may be part of the problem (McMahon et al. 2011; Pounds et al. 2006; Mason et al. 2012).

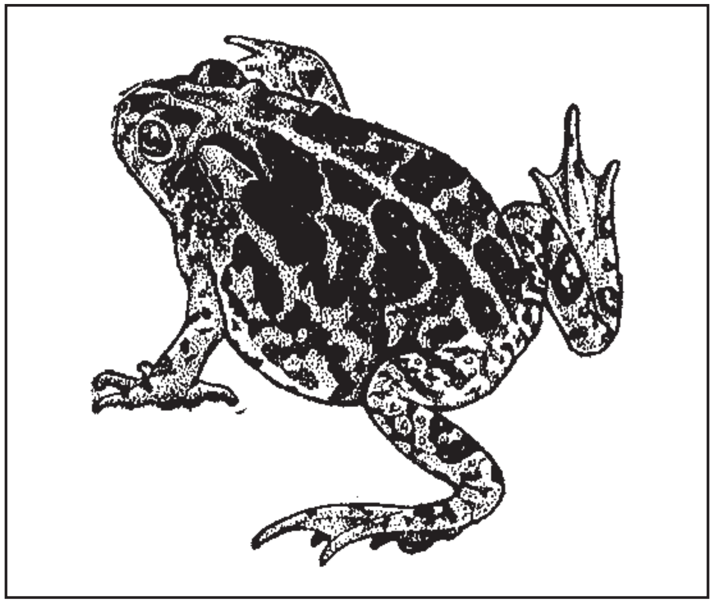
Plant Disease

Plants are also at risk. Moisture from extreme weather combined with increased temperatures has led to an increased growth rate of plant pathogenic fungi (Quarles 2007). Fungi have attacked agricultural crops, orchards, and the hopes of backyard gardeners (Quarles 2017).

Backyard rose gardens are plagued with powdery mildew, blackspot, and rust. And the *Cannabis* industry is finding that greenhouse crops are susceptible to powdery mildew and botrytis (Horst 1983; Horst and Cloyd 2007; MacPartland et al. 2000).

Increased Applications of Fungicides

An increase of plant disease due to pathogenic fungi has led to increased applications of fungicides. For example, fungicide applications to corn, soybeans, and wheat increased 10-15 fold from 2004 to 2009. About 2% of 89 million ha (220 million acres) were treated in 2004 and 25-30% were treated in 2009 (USGS 2018; Battaglin et al. 2011). Applications of synthetic fungicides to U.S. soybeans have increased 10-fold, due to soybean rust and other diseases (Quarles 2017).



Drawing by Stebbins 1954

***Bufo cognatus* amphibians are killed both by pathogenic fungi and toxic fungicides.**

In areas where soybeans are grown, streams are frequently contaminated with fungicides. In a USGS survey, azoxystrobin was found most often (45% of streams surveyed), followed by metalaxyl (27%), propiconazole (17%), myclobutanil (9%), and tebuconazole (6%) (USGS 2018). Some of these are potentially carcinogenic or can have other health effects (see below).

Environmental Contamination

Applications of fungicides are leading to environmental contamination and toxic exposures. Chlorothalonil is extremely toxic to amphibians and is also synergistic with other pesticides, contributing to honey bee decline and colony collapse disorder (McMahon et al. 2011; Zhu et al. 2014; Quarles 2008). Environmentally relevant concentrations of chlorothalonil and other fungicides are killing amphibians. Concentrations of pyraclostrobin (Headline®) as low as 15 µg/liter (1/10 label rates) are 100% lethal to *Bufo cognatus* tadpoles. Label rates killed about 65% of adults. Label rates (74 µg/liter) of propiconazole and trifloxystrobin (Stratego®) killed about 40% of tadpoles (Belden et al. 2010).

Fungicide Toxicity

Though chemical fungicides tend to have low acute toxicity, many are potentially carcinogenic. Common fungicides such as manocap, zineb, maneb, mancozeb, benomyl, carbendazim, captafol, folpet, and tridemorph may cause developmental toxicity or cancer (Gupta 2018).

A comparison of 25 common fungicides such as mancozeb, chlorothalonil, boscalid, and others with the EPA list of carcinogens shows that 18, or about 72% of them, are linked to cancer (EPA 2014). (See Table 1)

Fungicides can also be endocrine disruptors (propiconazole), or cause reproductive or developmental problems in mammals (benomyl, carbendazim) (Costa et al. 2015).

Resistance

Another problem is that synthetic fungicides often have a specific mode of action. Azoxystrobin and other targeted materials attack mitochondrial respiration or enzyme metabolism. Pathogens can then become rapidly resistant by simple DNA point mutations that produce altered enzymes. For instance, *Alternaria alternata* causes brown spot on citrus. Because strobilurin fungicides such as azoxystrobin have been repeatedly applied, the disease is no longer controlled by fungicides of this type (Pasche et al. 2005; Dewdney 2010).

The 21st century reality is that there are greater numbers of fungal infections and fewer materials to treat them (Hahn 2014). Fortunately, a number of fungicides have been developed with several simultaneous modes of action, such as desiccation, induced resistance, and alteration of pH. Resistance to these materials is less likely compared to those that target specific enzymes (Quarles 2000).

Table 1. Carcinogenic Potential of Common Fungicides*

Fungicide	Carcinogenic Potential
azoxystrobin	not likely
benomyl	possible human carcinogen
boscalid	suggestive evidence
bromoxynil	possible
captafol	probable human carcinogen
carbendazim	possible
chlorothalonil	likely human carcinogen
difenoconazole	possible
epoxiconazole	likely human carcinogen
fenbuconazole	possible
folpet	not likely unless dose irritates mucosa
hexaconazole	possible
mancozeb	probable
maneb	probable
metalaxyl	non-carcinogenic
myclobutanil	non-carcinogenic
picoxystrobin	suggestive evidence
propanil	suggestive evidence
propargite	probable
propiconazole	possible
pryraclostrobin	not likely
tebuconazole	possible
terrazole	probable
thiram	not likely
trifloxystrobin	not likely

*EPA 2014

Conclusion

Global warming has led to a proliferation of pathogenic fungi. Increased disease incidence caused by fungi has led to increased fungicide applications. Overuse of fungicides has led to environmental contamination, increased toxic exposure, and fungicide resistance. Thus, there is a need for non-polluting fungicides with low toxicity that are less likely to cause resistance. Fortunately, extensive research has been done and many alternatives are commercially available. Least-toxic and non-toxic fungicides are reviewed in the following article.

References

Battaglin, W., M. Sandstrom, K. Kuivila et al. 2011. Occurrence of azoxystrobin, propiconazole, and selected other fungicides in US streams, 2005-2006. *Water, Air and Soil Pollution*, V. 218, nl. 1-4, pp. 307-322. [cited in USGS 2018]

Belden, J., S. McMurry, L. Smith et al. 2010. Acute toxicity of fungicide formulations to amphibians at environmentally relevant concentrations. *Environ. Tox. Chem.* 29(11):2477-2480.

Berweij, P.E., E. Snelders and G.H.J. Kema. 2009. Azole resistance in *Aspergillus fumigatus*: a side-effect of environmental fungicide use? *Lancet Infect. Dis.* 9:789-795.

Brown, G.D., D.W. Denning, N.A.R. Gow et al. 2012. Hidden killers: human fungal infections. *Sci. Transl. Med.* 4(165):1-7.

Casadevall, A. 2012. Fungi and the rise of mammals. *PLoS Pathog.* 8(8):e1002808.

Costa, O.C., M.L. Vieira, V. Sgarioni et al. 2015. Evaluation of the reproductive toxicity of the fungicide propiconazole in male rats. *Toxicol.* 335:55-61.

Dewdney, M. 2010. Fungicide resistance. *Citrus Industry*, March 2010.

EPA (Environmental Protection Agency). 2014. *Chemicals Evaluated for Carcinogenic Potential.* Office of Pesticide Programs. October 2, 2014.

Fisher, M.C., D.A. Henk, C.J. Briggs et al. 2012. Emerging fungal threats to animal and ecosystem health. *Nature* 484:186-194.

Frazer, J. 2013. Fungi on the march. *Sci. Amer.* 309(6):50-57.

Garcia-Solache, M.A. and A. Casadevall. 2010. Global warming will bring new fungal diseases for mammals. *mBio* 1(1):e00061-10.

Gupta, P.K. 2018. *Veterinary Toxicology*, 3rd ed.. Chapter 45 toxicity of fungicides. Academic Press, pp. 569-580.

Hahn, M. 2014. The rising threat of fungicide resistance in plant disease: botrytis as a case study. *J. Chem. Biol.* 7(4):133-141.

Horst, R.K. 1983. *Compendium of Rose Diseases.* American Phytopathological Society, St. Paul, MN. 50 pp.

Horst, R.K. and R.A. Cloyd. 2007. *Compendium of Rose Diseases and Pests*, 2nd ed. American Phytopathological Society, St. Paul, MN. 83 pp.

Mason, R., H. Tennekes, F. Sanchez-Bayo et al. 2012. Immune suppression by neonicotinoid insecticides at the root of global wildlife declines. *J. Environ. Immunol. Toxicol.* 1:3–12.

McMahon, T.A., N.T. Halstead, S. Johnson et al. 2011. The fungicide chlorothalonil is nonlinearly associated with cortisone levels, immunity, and mortality in amphibians. *Environ. Health Perspectives* 119(8):1098-1103.

McPartland, J.M., R.C. Clarke and D.P. Watson. 2000. *Hemp Diseases and Pests, Management and Biological Control.* CABI Publishing, New York. 251 pp.

Pasche, J.S., L.M. Piche and N.C. Gudmestad. 2005. Effect of the F129L mutation in *Alternaria solani* on fungicides affecting mitochondrial respiration. *Plant Dis.* 89:269-278.

Pounds, J.A., M.R. Bustamante, L.A. Coloma et al. 2006. Widespread amphibian extinctions from epidemic disease driven by global warming. *Nature* 439:161-167.

Quarles, W. 2000. Least-toxic fungicides. In: B. Hanson, ed. *Natural Disease Control.* Brooklyn Botanic Garden. Brooklyn, NY. 89-103 of 111 pp.

Quarles, W. 2007. Global warming means more pests. *IPM Practitioner* 29(9/10):1-9.

Quarles, W. 2008. Pesticides and honey bee colony collapse disorder. *IPM Practitioner* 30(9/10):1-10.

Quarles, W. 2013. Bats, pesticides, and white nose syndrome. *IPM Practitioner* 33(9/10):1-6.

Quarles, W. 2017. Glyphosate, GMO soybean yields, and environmental pollution. *IPM Practitioner* 35(11/12):1-9.

Stebbins, R.C. 1954. *Amphibians and Reptiles of Western North America.* McGraw Hill, New York. 536 pp.

USGS (United States Geological Survey). 2018. Understudied fungicides common in U.S. streams draining agricultural land. Environmental Health, Toxic Substances Hydrology Program. USGS website, December 11, 2019. https://toxics.usgs.gov/highlights/fungicides_streams.html

Zhu, W., D.R. Schmehl, C.A. Mullin et al. 2014. Four common pesticides, their mixtures, and a formulation solvent in the hive environment have a high oral toxicity to honey bee larvae. *PLoS ONE*: January 8, 2014. 12 pp.

Non-Toxic Fungicides for Roses

By William Quarles

This is an update of a Common Sense Pest Control Quarterly article called "Non-toxic Fungicides for Roses" published 16 years ago. At the time, most of the commercially available fungicides were synthetic chemicals such as chlorothalonil, a likely human carcinogen. Many of the non-toxic fungicides mentioned in the article were not commercially available, and the formulations had to be mixed by homeowners. The market for these items has surged, and many are now commercially available.

Part of the reason for commercial success is that the same non-toxic fungicides used for roses can also be used for high value crops such as strawberries and Cannabis sativa. Non-toxic fungicides are important for Cannabis because some of the synthetic fungicides used become more toxic when they are heated. For instance, one of the possible degradation products of the fungicide myclobutanil is hydrogen cyanide.

Three fungal diseases, powdery mildew caused by *Sphaerotheca pannosa* var *rosa*; blackspot caused by *Diplocarpon rosae*; and rust caused by *Phragmidium* spp. are often encountered in the home garden. Two other fungal diseases, grey mold caused by *Botrytis cinerea*, and downy mildew caused by *Peronospora sparsa* are found more often in commercial greenhouses (Horst 1983; Horst and Cloyd 2007) (see Box A for a description of these diseases).

Chemical fungicides are often used for these problems. For instance, commercial rose growers rely on up to 20 sprays per season of chemical fungicides to control powdery mildew. Fungicides employed include dodemorph (Milban®), which is an EPA Class I pesticide, the most toxic group. Repeated applications of fungicides not only have potential to poison the user, but they may cause shortened stems or other plant damage (phytotoxicity), and over a period of time resistance can occur (Pasini et al. 1997; Schulman 1996). There is thus a need to replace chemical fungicides with approaches that are better tolerated by gardeners and the environment.

The number of effective non-toxic or least-toxic approaches are increasing each year. Fungal diseases on roses and other plants have been suppressed by antitranspirants, oils, soap, baking soda, phosphate salts, phosphite salts, silicate salts, botanical extracts, vinegar, and garlic (See Quarles 1994a; 2000; 1999b; 2002). Beneficial microbials are also used for suppression of some rose diseases (Tjosvold and Koike 2001; Hajlaoui and Bélanger 1993; Hajlaoui et al. 1992; Elad et al. 1996; Suthaparan et al. 2011; Quarles 2013). Compost often

Drawing by Diane Kuhn

contains these microbes, and compost teas isolated from mature compost will suppress some plant diseases (Elad et al. 1996; Michalak and Gilkeson 1994; Quarles 2001; Stevic et al. 2014).

Although these non-toxic fungicides are not perfect, their advantages and disadvantages are somewhat complementary, making them good candidates for an integrated control program. As with any spray used on prize foliage, all concoctions should be spot tested for phytotoxicity before general use. The following is an overview of practical methods, giving both strengths and limitations of non-toxic fungicides.

Favorable Conditions

Many of the non-toxic sprays work best as preventive rather than as curative treatments. Sprays should be applied at the first sign of disease, or when weather conditions are favorable for disease.

Powdery mildew can be expected on roses when rainfall is low or absent, and when cool temperatures (15.5°C, 60°F) and high humidity (90-99% RH) at night are followed by high temperatures (26.7°C, 80°F) and low humidity (40-70% RH) during the day. The fungus grows well only on new growth, so treatment measures should focus on these vulnerable parts.

For blackspot to thrive, leaves must be continuously wet for 7 hours. Optimal temperatures for the formation of disease symptoms is about 24°C (75°F), and thus blackspot is a major rose disease in the South. Preventive sprays should be used when these hot, wet conditions persist.

Rust is favored by cool, moist conditions (18-21°C; 64-70°F) found on the Pacific Coast. High temperatures (27°C; 80°F) discourage development, and preventive sprays should not be necessary in the South (Horst 1983).

Baking Soda

Baking soda (sodium bicarbonate) has been used for control of harmful fungi since at least early in the 20th century (Barger 1928; Marloth 1930; Depasquale et al. 1990). A number of theories have been proposed to explain its antifungal action. For instance, it may inhibit an enzyme that allows fungi to use energy (blockage of oxidative phosphorylation) (Corral et al. 1988). Or it may present an unfavorable pH for pathogen growth. The mechanism of action is important, because if bicarbonate works by blocking a single enzyme, pathogens are more likely to become resistant.

Professional interest in bicarbonate for horticulture surged with some Japanese work in the early 1980s (Homma et al. 1981). Israeli researchers followed, and now there is general interest in the international scientific community. Most of the published work with roses has been on suppression of powdery mildew (Hsieh et al. 2005; Dik et al. 2003; Tjosvold and Koike 2001; Ziv and Zitter 1992; Ziv and Hagiladi 1993; Horst et al. 1992).

Advantages and Disadvantages

Bicarbonate has the advantage that it is non-toxic, effective, readily available, and very inexpensive. It has the disadvantage that it must be applied weekly, and a surfactant or liquid detergent must be added to the spray solution so that bicarbonate is spread evenly, preventing crystallization on rosebushes and other treated plants. The recommended amount of 0.5% (w/w) is about 1 Tbsp baking soda per gallon of water. Add about 1/4 to 1/2 teaspoon of liquid detergent (see Table 1). Be careful, as the detergent can cause plant damage (phytotoxicity) if too much is used (Horst et al. 1992).

Another disadvantage of bicarbonate use is that concentrations larger than 0.5% (w/v) may be phytotoxic to roses, although other ornamentals can tolerate higher concentrations (Ziv and Hagiladi 1993; Pasini et al. 1997). Repeated applications to roses could lead to slower plant growth. For instance, when the bicarbonate concentration in irrigation water reaches about 0.5 g per liter (0.05% w/v), roses grow at a slower rate (Fernández-Falcón et al. 1986). Increased bicarbonate in soil can lead to removal of calcium (Ca) and magnesium (Mg) ions due to the formation of insoluble carbonates. Large amounts of bicarbonate can also prevent the absorption of iron and lead to chlorosis (Garg and Garg 1986).

The worst case for bicarbonate build-up in soil would be in drought-stressed areas where there is little rain to flush it away. Concentration of bicarbonate in soil would also be more likely when it is used in a small space, and when drip-type irrigation is used.

The number of greenhouse roses produced start to decrease when there is about (6.8 mmoles) 1/3 tsp of baking soda per gallon of irrigation water. Garden situations are so complex, it is hard to predict the point at which adverse effects would be observed. Bicarbonate sprays should be stopped, however, at the first sign of phytotoxicity or lower quality blooms.

Potassium ion also seems to suppress disease. For instance, potassium nitrate and potassium chloride suppress cucumber powdery mildew (Reuveni et al. 1995). Sodium phosphate salts give less powdery mildew protection than their potassium counterparts (Reuveni et al. 1993) (see below). Thus, potassium bicarbonate may be

Photo courtesy Dr. Parthasavathy Seethapathy, Tamil Nadu Agricultural University, Bugwood.org

Rose powdery mildew caused by *Sphaerotheca pannosa* var. *rosa* can be a serious disease of roses.

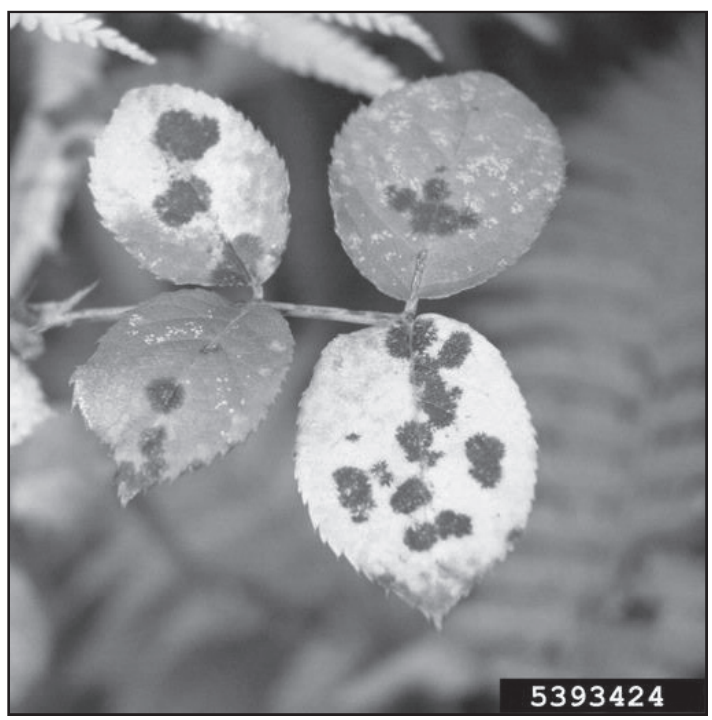


Photo courtesy Yuan-Min Shen, Taichung District Agricultural Research and Extension Station, Bugwood.org

Rose blackspot is caused by *Diplocarpon rosae.* Black spots appear, leaves turn yellow, then drop off.

Box A. Fungal Diseases of Roses

Powdery mildew of rose has been around since at least 300 BC, but the fungus was first described and characterized in 1819. At 20°C and near 100% relative humidity, conidia begin to germinate 2 to 4 hours after being deposited on the leaf. The germinating spores penetrate the leaf cells within 24 hours, producing white, thread-like mycelia that give the white powdery appearance. Within 72 hours, new spores are able to break loose to continue the infection. On rainless days airborne spores reach a maximum around an infected plant in the early afternoon. The disease overwinters in diseased leaves and buds.

Spraying roses with water under high pressure discourages powdery mildew (Yarwood 1939b; Liu 2001), but encourages other pathogens, such as blackspot (Horst 1983; Horst and Cloyd 2007; Gullino and Garibaldi 1996). Growing disease-resistant roses is a good idea, but there are several races of powdery mildew in the U.S., and each has a slightly different host range. Roses that are resistant in one part of the country may be susceptible in other areas (Bender et al. 1984; 1986).

Blackspot

Blackspot caused by *Diplocarpon rosae* was first described in Sweden in 1815, and was found in the U.S. in 1830. The black spots are actual colonies of fungus. The surrounding tissue then turns yellow due to toxic fungal metabolites. Finally, the leaf falls off. Young leaves are most susceptible. Spores landing on a wet leaf can germinate within 24 hours, and symptoms appear within 3-16 days. New spores, which are produced within 10-18 days after infection, are spread by splashing water, by cultivation, and by insects. Fallen leaves disperse the fungus locally. Airborne spread is limited to water droplets. The fungus does not survive in soil, and contaminated tools and benches are infective for no longer than a month (Horst 1983; Horst and Cloyd 2007).

Blackspot is a serious disease of field-grown or garden roses. The conventional treatment is repeated sprays of the fungicide chlorothalonil, which sometimes cause toxicity to the plant (Gullino and Garibaldi 1996; Schulman 1996). To avoid or reduce chemical fungicides, an integrated approach should be used. Resistant species should be planted. The spores will not grow in soil, so diseased foliage and fallen leaves should be removed and destroyed. Mulches such as oat straw, pine straw, pine bark can be combined with least-toxic sprays such as oils and baking soda (Bowen et al. 1995). Good ventilation and air circulation discourages the organism.

Rust and Grey Mould

Rust caused by *Phragmidium* spp. can be a serious disease of garden roses. Nine species of the rust fungus *Phragmidium* are found on roses, but two species are the most common on cultivated roses: *P. mucronatum and P. tuberculatum* (Horst 1983; Horst and Cloyd 2007). Rust is a complicated organism that travels through five different spore forms. Spores are transmitted through air, and enter through stomatal openings in leaves. Free moisture for several hours is needed for germination. Black pustules appear late in the season, and overwinter within leaf and stem tissues. To control rust, infected leaves should be removed during the growing season. Winter pruning helps to reduce inoculum levels.

Grey mold caused by *Botrytis cinerea* is more a disease of greenhouse roses than garden varieties. It can be reduced by adequate spacing in plantings, increased ventilation and heating to reduce greenhouse moisture. Adding calcium to the soil will make plants more resistant. Cut flowers can be made more resistant by soaking in warm (50°C, 90°F) tap water for 30-40 minutes (Gullino and Garibaldi 1996). Foliage sprays of biocontrol agents such as *Trichoderma harzianum* (Trichodex®) have been used to control grey mold under greenhouse conditions (see Resources) (Elad et al. 1996; Elad et al. 1990).

Downy Mildew

Downy mildew caused by *Peronospora sparsa* usually attacks new growth. With humid, cool conditions (>85% humidity, 18°C, 64.4°F) grey spores proliferate on the undersides of leaves, causing purplish red or dark brown spots. Infected leaves turn yellow and drop off. When cold, humid conditions prevail, preventive antitranspirant sprays may be necessary (Horst 1983; Horst and Cloyd 2007; Chaplin 1994).

more effective than sodium bicarbonate (see Resources). Hsieh et al. (2005) found that sprays of 0.5% (w/v) potassium bicarbonate reduced powdery mildew on tomatoes, peas, and roses by more than 80%. Pace et al. (2016) found that it was more effective than sulfur for powdery mildew of tomato. Potassium bicarbonate is commercially available as Milstop® or Greencure® (see Resources).

Phosphate Salts

Reuveni et al. (1995) found that potassium dihydrogen phosphate (KH_2PO_4), unlike most of the non-toxic sprays, will actually cure as well as prevent powdery mildew on cucumber. "The most significant suppressive effect, which was expressed as the disappearance of 99% of the lesions, was recorded as early as two days after the foliar spray." Effects of each spray lasted about 12-15 days. When the experiment was repeated on roses, similar results were obtained, and suppressive effects lasted more than 23 days (Reuveni et al. 1994). Pasini et al. (2007) found it was just as effective as the synthetic fungicides azoxystrobin and boscalid for rose powdery mildew in greenhouses. [The phosphate salt is commercially available as Nutrol® Fungicide, see Resources]

Photo courtesy Charles Averre, North Carolina State, Bugwood.org

Cucumber powdery mildew caused by *Sphaerotheca fuliginea* can be prevented by least-toxic fungicides.

The mechanism of protection might be induced systemic resistance, or increased plant nutrition through foliar feeding (Quarles 2002). The salts seem to stimulate a systemic effect that causes resistance to a number of diseases. For example, such foliar sprays have suppressed rust on broad bean and maize, and northern leaf blight caused by *Exserohilum turcicum* on maize (Reuveni et al. 1993). Phosphate salts are ideal as foliar sprays due to their quick uptake and mobility, leading to improved growth. Other advantages are low cost, low toxicity, and environmental safety (Reuveni et al. 1995).

For roses, Pasini et al. (1997; 2007) found that sprays of 0.5% (w/w) KH_2PO_4 were just as effective as the fungicide dodemorph for control of powdery mildew. For the home garden, add 1 Tbsp of potassium dihydrogen phosphate to one gallon of water containing about 1/4 to 1/2 teaspoon of liquid soap or detergent (see Table 1). The phosphate salt can be obtained from a horticultural nursery or a garden supply store. Or it is commercially available as Nutrol® fungicide, which is a liquid (see Resources). Again, test a small portion of the foliage for phytotoxicity before you spray extensively.

Mixtures of mono and dipotassium salts of phosphorous acid (potassium phosphites) are also fungicidal. Potassium phosphites are just as effective as the fungicide dodemorph for rose powdery mildew (Dominguez-Serrano et al. 2016). There are 32 registered phosphite salt fungicides in California (DPR 2019). One of the first was Fosphite® (see Resources).

Silica and Silicate Salts

Researchers have shown that 100 ppm (0.01% w/w; 1/4 tsp/gallon water) of potassium silicate (commercial 30% solution), the salt of natural silica (silicic acid), will protect cucumber against damping off caused by *Pythium* sp. and powdery mildew caused by *Sphaerotheca fuliginea*. Cucumber powdery mildew is related to rose powdery mildew, and thus silica sprays should also work with roses. The mechanism of protection has not been fully determined, but at least in the case of cucumber, protection stems from soluble silica absorbed by the plant, not from mechanical protection afforded by deposits of insoluble silica (Chérif et al. 1994; Chérif et al. 1992; Menzies et al. 1991). Thus, induced systemic resistance is a possible mechanism (Quarles 2002). Aqueous foliar sprays of potassium silicate will reduce the number of powdery mildew colonies on grapes and squash (Menzies et al. 1992; Bowen et al. 1992). Sodium silicate will also protect plants against disease (Quarles 1995; Tayabi and Azizi 1984; Mathai et al. 1981). Potassium silicate is commercially available as Sil-MATRIX® fungicide, see Resources.

The silica can also be obtained from the horsetail plant, *Equisetum arvense*, which contains 15 to 40% natural silica. A recipe from *Rodale's Home Formula* book involves boiling about 1/4 cup of dried horsetail in 1 gallon of water for 20 minutes. The liquid is allowed to stand overnight, and the solid is removed by filtration with a coffee filter or cheese cloth. The solution that remains is saturated with silica. Since amorphous natural silica has a solubility of about 100 ppm in water of neutral pH, a saturated horsetail extract should contain silica in the proper concentration range for disease suppression (Quarles 1995).

Home gardener's recipes call for the horsetail extract to be sprayed on the plant. Apparently, the horsetail extract could also be used with success as a root drench, at least with cucumber. If horsetail extracts are not available, a similar saturated solution of soluble silica could be made by boiling diatomaceous earth or silica gel in water. Alternatively, add 1/4 tsp of 30% potassium silicate to a gallon of water. Be careful when mixing, as the concentrated solution is strongly alkaline. Spray small areas of your plants to check for phytotoxicity before general use.

Oils as Fungicides

Petroleum-based horticultural oils (mineral oils), essential plant oils, neem oil, jojoba oil, vegetable seed oils, and even fatty acids have been used to control pathogenic fungi. Before spraying, oils are emulsified with water using a liquid detergent or other surfactant. Commercial horticultural oils have emulsifier added as part of the formulation (see Resources). Mineral oils are less expensive but should have 0.5% liquid detergent added to the oil for application to deciduous foliage. This is about 1 Tbsp of liquid detergent per gallon of mineral oil, or 1/2 tsp per pint (Quarles 1992). Horticultural oils or mineral oils are sprayed at concentrations of 1 to 2% (v/v) in water (Flint et al. 1991; Baxendale and Johnson 1989). For roses, however, do not exceed 1% (Pasini et al. 1997). Add about 3 Tbsp of emulsified oil to 1 gallon of water (see Table 1).

Vegetable seed oils are the most readily available and are probably least disruptive to the environment. They are effective, as Yarwood (1939a) found that cottonseed oil had “considerable protective value” against powdery mildew, but only slight protective value against rust and downy mildew.

Emulsified vegetable oil sprays of sunflower, olive, canola, peanut, soybean, corn, grapeseed or safflower were able to control a form of powdery mildew, *Podosphaera leucotricha*, on apple trees (Northover and Schneider 1993), and are also effective on roses. For instance, emulsified soybean oil is just as effective as the fungicide dodemorph for controlling rose powdery mildew (Wurms et al. 2015). Emulsified canola oil was used by Pasini et al. (1997) to control powdery mildew on greenhouse roses. To prepare a 1% (v/v) spray add about 3 Tbsp of oil to 1 gallon of water containing 1/4 to 1/2 tsp of liquid soap or detergent (see Table 1). Check for phytotoxicity before general use, and be especially careful of blooms.

Neem Oil

Neem oil fungicides are commercially available. For preparation of commercial products, crude neem oil is extracted with ethanol, which removes azadirachtin and other insecticidal components (Quarles 1994b). The emulsified ethanol extract is sold as Bioneem®, Neemazad®, Neemix®, and Azatrol®, and probably has little fungicidal activity (see Resources). However, at least one study shows that an aqueous extract of neem seed can be fungicidal under greenhouse conditions (Rovesti et al. 1992).

The neem oil remaining after ethanol extraction, which will be called NSO for the rest of this article, is fungicidal. Formulations include Trilogy™ for food crops, Triact™ and Rose Defense® for ornamentals (see Resources). Triact is labelled for control of powdery mildew, rust, blackspot, botrytis, downy mildew and other common ornamental diseases. For outdoor flowering plants 1% aqueous sprays (2.5 Tbsp/gallon water) every 7 to 14 days are recommended (OHP 2019).

Cold pressed, unextracted neem oil is also available. There are 16 registered products in CA. These products contain both oil and azadirachtin. An example is Debug Turbo® (see Resources). It is both insecticidal and fungicidal (DPR 2019).

Prevention Better than Cure

For rust, neem sprays may be better as a prevention than a cure. Locke (1990) found that 1% aqueous sprays of NSO were better than 90% effective in preventing bean rust, but were of little value after infection had occurred. Sprays every 14 days were also effective in preventing powdery mildew of hydrangea.

Other experiments showed that 1% aqueous NSO was only about 15% effective in suppressing rose rust caused by *Phragmidium americanum* on the susceptible cultivar ‘Mary de Vor’ (Raab 1991a). Better success was seen with rose powdery mildew control on this cultivar, as 1% NSO sprays were about 75% effective in suppressing visual signs of powdery mildew. For powdery mildew, the 1% NSO spray was as effective as the fungicide myclobutanil (Rally®) 40 W (Raabe 1991b).

Pasini et al. (1997) found that a neem extract commercially available in Germany “satisfactorily controlled rose powdery mildew.” They used weekly 0.5% aqueous sprays of the neem extract FU-3 (Trifolio-M).

Which Oil to Use?

Some essential oils including basil, foenigreek, cumin, clove, and eucalyptus are effective against a number of fungal pathogens (Quarles 1999a). Essential oils are classified Generally Recognized as Safe (GRAS) by the FDA, and many are 25b exempt EPA materials. They work by disrupting the cell membrane in fungi and in other ways (Jeliazkova 2012). For instance, cumin or clove oil at concentrations of 1% (v/v) completely inhibit the pathogen *Colletotrichum falcatum* on sugarcane. Use of essential oils on roses is a field of active research (Rao et al. 1992; Amrita et al. 1989; Dubey and Kishore 1987; Nazzaro et al. 2017). Jeliazkova (2012) showed that thyme and spearmint oils were effective against rose blackspot dis-

Table 1. Approximate Measurements for Rose Sprays

Material	% Aqueous	Amt. Material	Amt. Surfactant	Amt. Water
Antitranspirant	4% (v/v)	10 Tbsp	None	1 gallon
Antitranspirant	3% (v/v)	7.7 Tbsp	None	1 gallon
Baking soda	0.5% (w/w)	1 Tbsp	¼ to ½ teaspoon	1 gallon
Canola oil	1% (v/v)	2.5 Tbsp	¼ teaspoon	1 gallon
Canola oil	1% (w/w)	3 Tbsp	¼ teaspoon	1 gallon
Garlic	5% (v/v)	See text	See text	See text
Horticultural oil	1% (w/w)	3 Tbsp	None	1 gallon
Liquid soap	1% (w/w)	3 Tbsp	None	1 gallon
Mineral oil	1% (w/w)	3 Tbsp	½ tsp per pint of oil	1 gallon
Neem oil	1% (v/v)	2.5 Tbsp	None	1 gallon
Potassium phosphate	0.5% (w/w)	1 Tbsp	¼ to ½ teaspoon	1 gallon
Potassium silicate (30%)	0.01% (w/w)	1/4 teaspoon	None	1 gallon

1% by volume (v/v) means that one volume of active ingredient is mixed with 99 volumes of water. 1% by weight means that one weight unit (grams etc.) is mixed with 99 weight units (grams etc.) of water. When using a commercial product, follow the label instructions for amounts.

ease. Cinnamaldehyde, a major component of cinnamon oil, controlled rose powdery mildew in one study (Tjosvold and Koike 2001). It is commercially available as Cinnacure® (see Resources). Mint oil (Fungastop®) and rosemary oil (Sporan®) are being sold as fungicides.

Petroleum-based mineral oils have a long history of use, but negative effects might accumulate if they are repeatedly sprayed in the same area. Neem oil and essential oils are more expensive than mineral or vegetable oils. Vegetable oils are inexpensive, more biodegradable and should be less of a long-term problem when used in the garden. However, Pasini et al. (1997) found that emulsified canola oil left a greasy feeling on leaves, and this might be objectionable to some gardeners. There is also some evidence that jojoba (Eco-Erase®) or horticultural oils may be more effective (Wojdya 2002b; Tjosvold and Koike 2001). [Jojaba oil fungicide (Eco-Erase) is registered in CA]. Since some experimentation is involved, all of these formulations should be tested on a small amount of foliage for phytotoxic effects before committing valuable plants to a full treatment protocol. Rotations of different classes of oil might prove to be the best approach (see below).

Soaps

Potassium salts of fatty acids (soaps) can also reduce powdery mildew on roses. Sodium soaps are solids at room temperature and are sold as soap bars. Potassium soaps are liquids, and insecticidal soaps are usually potassium salts. Pasini et al. (1997) found that liquid soap applied at 1 to 1.5% (v/v) (see Resources) provided effective control of rose powdery mildew, but caused a moderate amount of phytotoxicity. Some soap formulations were more effective than others. If you want to try it, add 3 Tbsp of liquid soap per gallon of water, and check for phytotoxicity on a few leaves before general use.

Botanicals and Chitosan

Plants have been used for centuries in medicine and pest control. The German corporation BASF capitalized on this approach in 1993 by screening a large number of plant extracts as possible fungicides. The most promising result was a dried extract of the giant knotweed, *Reynoutria sachalinensis*. This fungicide was sold originally under the brand name Milsana™, and is currently available as Regalia® (Jespers and de Waard 1993; Su et al. 2012) (see Resources).

Daaf et. al. (1995) found that 2% sprays of *R. sachalinensis* extracts (Milsana®) reduced powdery mildew infection on cucumber by 50%. Other experiments found that efficacy can reach 90% (Quarles 2009). The botanical suppresses mildew, botrytis and other diseases through induced systemic resistance. Antibiotic phytoalexins are produced, and spore germination is suppressed (Petsikos et al. 2002; Schmitt 2002; Quarles 2002; Quarles 2009; Su et al. 2012). A 1% suspension of the dried leaves was also effective (Elad et al. 1996).

Pasini et al. (1997) found similar powdery mildew reductions when Milsana was applied to greenhouse roses, but oils, soaps, biocontrol agents, salts and vinegar were more effective. Tjosvold and Koike (2001) confirmed that other non-toxic materials were more effective than Milsana for powdery mildew on roses. However, Milsana gives better protection than standard fungicides for powdery mildew on strawberries (Carlen et al. 2004). The Regalia formulation may be more effective than Milsana (Su et al. 2012).

Chitosan, which is produced from chitin sources such as shrimp shells, will induce resistance to powdery mildew and other diseases. It may work through the jasmonic acid pathway (Doares et al. 1995; Quarles 2002; Wojdya 2002a; Tjosvold and Koike 2001). Chitosan is now sold under the brandname Armour-Zen® (see Resources).

Another novel material from botanical sources is grapefruit extract. Grapefruit extract at a concentration of 0.066% was just as effective as the fungicide triforine in controlling rose powdery mildew. The extract is sold in Europe as Biosept® (Wojdya 2001).

Garlic

Aqueous garlic extracts will suppress a number of plant diseases when applied as a spray (Quarles 1999b). Qvarnstrom (1992) found that a 5% aqueous garlic emulsion controlled powdery mildew on greenhouse cucumber. Leaves were sprayed on both sides every 7 days. Qvarnstrom and Ramert (1992) applied 5% aqueous garlic sprays to roses for the control of blackspot. Three cultivars were tested, the susceptible Allotria and Super Star and the more resistant Peace. Garlic sprays gave satisfactory control only on Peace. Lower concentrations are needed to prevent germination than to inhibit growth (Tariq and Magee 1990). Activity may be due to sulfur-containing compounds such as ajoene or allicin (Wojdya 2002c; Quarles 1999b; Singh et al. 1995).

A stock solution of garlic spray can be made by homogenizing 2 bulbs of garlic (about 1/4 lb; 114 g) 5-10 minutes in a blender with a quart of water containing a few drops of liquid soap. The liquid is collected, then refrigerated, after squeezing through cheesecloth to remove solids. The stock solution is diluted 1:10 with water just before spraying, giving a solution containing about 25-50 ppm of the active compound allicin (Quarles 1999b). Higher concentrations are needed to cure mildew infestations. Reimers et al. (1993) found that 300-500 ppm of the related garlic compound ajoene could cure powdery mildew of rose.

Antitranspirants

Antitranspirants (AT's) are coatings sprayed onto plant foliage to prevent water loss. They have also been used to protect a number of different ornamental plants against diseases caused by fungi. For instance, antitranspirants are just as effective as systemic triazole fungicides against downy mildew, *Erysiphe* spp., on zinnia, hydrangea, and crapemyrtle (Kamp 1985; Ziv and Hagiladi 1984). Such products as Wilt Pruf and Vapor Gard protected garden roses from attack by powdery mildew for about 30 days (Hagiladi and Ziv 1986). These sprays have also provided protection against blackspot (Holcomb 1991ab). For protection against powdery mildew, 3% (v/v) solutions are used, approximately 7.7 Tbsp/gal water. Blackspot requires a slightly higher concentration: 4% (v/v), approximately 10 Tbsp/gal. Airborne spores of rust invade roses

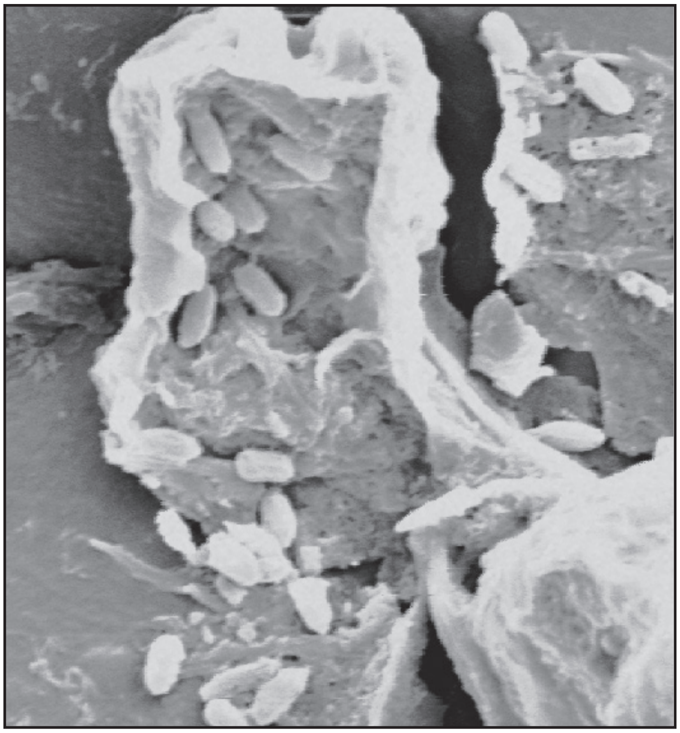


Photo courtesy of AgraQuest

Capsule-shaped *Bacillus subtilis*, shown here, can stop powdery mildew.

through leaf stomata. Thus, ATs that close stomata may give some relief (Quarles 1994a; Quarles 2000).

Antitranspirant coatings are non-toxic, biodegradable, and inexpensive compared to the increasing costs of fungicides, and are readily available at the local nursery (see Resources). Unlike fungicides, their action against pathogens is non-specific and therefore is not likely to result in a buildup of resistance (Quarles 2000; 1994a). Antitranspirants have the disadvantage, however, that new growth is not protected, and thus the coatings have to reapplied on a regular basis. Since leaf coatings reduce the rate of photosynthesis by about 5%, ATs are probably better suited for sunny climates (Ziv and Fredericksen 1983).

Fungal Antagonists

Biocontrol of fungal diseases can occur through competition for nutrients and space, production of antibiotics (antagonist), hyperparasitism, or induced resistance in the host plant (Elad et al. 1996). Antagonists have the advantage that they are biodegradable, do not persist in the environment, are non-toxic and are often just as effective as chemical fungicides. For instance, *Gliocladium catenulatum* is just as effective as myclobutanil for rose powdery mildew (Suthaparan et al. 2011). Fungal antagonists have the disadvantage that they work best under conditions of high humidity, usually 60-80%. The humidity requirement means that they must be restricted to greenhouse use, or to areas like Louisiana or other Gulf States where the humidity during the summer growing season is always very high.

The yeast-like fungus *Sporothrix flocculosa* has been tested on thousands of roses under greenhouse conditions, and has proved that it can increase both the yield and the quality of commercial roses compared to the use of chemical fungicides. However, it is not commercially available (Hajlaoui and Bélanger 1991; 1993; Hajlaoui et al. 1992; Elad et al. 1996).

Improved Effectiveness

Fungal biocontrol agents of rose diseases have one big limitation—they require a large relative humidity. Or as the plant pathologists put it, "low vapor pressure deficit" (Elad et al. 1996). Combination of biocontrol agents with horticultural oil can make them more effective. Bélanger et al. (1994) got improved performance from *S. flocculosa* by mixing spores with 1% horticultural oil before spraying. Phillip et al. (1990) got similar improved results against powdery mildew by mixing *A. quisqualis* with 1% horticulural oil.

Bacterial Antagonists

A number of bacterial species have also been shown to work as antagonists to rose powdery mildew and other diseases. Bacterial antagonists are easier to produce and distribute than fungi or yeasts. These materials are commercially available and can provide effective protection against powdery mildew (Tjosvold and Koike 2001). Suthaparan et al. (2011) found *Bacillus subtilis* was just as effective as the synthetic myclobutanil for rose powdery mildew. It was also effective for *Botrytis cinerea* (Abbey et al. 2019; Percival et al. 2017). Commercially available microbes include *Bacillus amyloliquifaciens* D747 (Double Nickel®), *Bacillus subtilis* QST 713 (Serenade®, Rhapsody®, Cease®). These are approved for organic production by OMRI (OMRI 2019). Bayer also sells *Bacillus pumilus* QST2808 (Sonata®) for powdery mildew control in field grown roses (see Resources).

Hyperparasites

Ampelomyces quisqualis is a powdery mildew hyperparasite which was first described in the mid-nineteenth century. The organism attacks a wide range of powdery mildew species and genera. The *A. quisqualis* invades powdery mildew within 24 hours of contact. The biocontrol agent spreads naturally through an airborne route (Elad et al. 1996). Pasini et al. (1997) found that it controlled this disease on roses. However, other researchers have found it less effective than biocontrol bacteria and least-toxic materials for rose protection (Tjosvold and Koike 2001).

Compost Tea

Water extracts of compost, or "compost tea" have been show to suppress powdery mildew and botrytis on various crops (Singh et al. 2003). It is more effective than the fungicide Topaz® for rose powdery mildew (Stevic et al. 2014). Effectiveness is related to the bacterial content of the extract (Elad et al. 1996; Quarles 2001). One way to make compost tea is to mix 1 part finished compost with 6 parts of water, and let the mixture soak for a week. Then filter off solids with cheesecloth and collect the liquid. Dilute liquid until it has a tea-like color. Each batch should be tested for phytotoxicity before spraying (Quarles 2001; Smith 1994; Michalak and Gilkeson

1994). Other methods of preparation are described in Ingham (2001) and Quarles (2001).

Comparison Tests

A number of non-toxic sprays for powdery mildew control were tested on greenhouse roses by Pasini et al. (1997). Rose cultivars tested included Candia, Micol or Meibecka. Treatments were carried out at weekly intervals, starting immediately after the first symptoms appeared. Materials tested were the biocontrol agent, *A. quisqualis,* sodium bicarbonate, potassium dihydrogen phosphate, acetic acid, liquid soap, horticultural oil, emulsified vegetable oil, wine vinegar, neem extract, a concentrated extract of *R. sachalinenis*, the fungicide dodemorph (Milban®), and combinations. Aqueous solutions were sprayed at low pressure until runoff, resulting in use of about 200 liters per 1000 m^2 (3/4 cup per 11 ft^2 of foliage) (Pasini et al. 1997).

Materials were tested in a replicated trial of randomized plots, consisting of single rows containing 20 plants in each plot. Disease severity on each plot was rated on 200 leaflets chosen at random from new growth. Disease incidence was severe in untreated plots, with more than a 55% infection rate in 6 of 7 trials (Pasini et al. 1997).

Most of the tested materials were at least as effective as the fungicide dodemorph, which gave 75% average efficacy throughout all trials. The phosphate and bicarbonate salts at 0.5% (w/w), horticultural oil at 0.75% (w/w), soap at 1.5% (w/w) "satisfactorily and consistently controlled rose powdery mildew in the different trials."

However, the 1% (w/w) spray of bicarbonate caused phytotoxicity, and the horticultural oil sometimes left an unpleasant smell and produced some leaf scorching (Pasini et al. 1997). Satisfactory results were also obtained with *A. quisqualis*, neem extract, wine vinegar, acetic acid, and emulsified vegetable oil. The botanical *R. sachalinensis* and some of the soaps were less effective than other materials tested. However, the botanical was used only in one trial, and might need further study (Pasini et al. 1997). Regalia, the current formulation, might be more effective (Su et al. 2012).

Tjosvold and Koike (2001) compared a number of materials on Rosa x Fiesta Parade, which is highly susceptible to powdery mildew. Bicarbonate, oil, *Bacillus subtilis*, and Cinnamite® (now available as Cinnacure®) suppressed the disease (see Resources). Combination sprays of chitosan (Elexa®, now available as Armour-Zen®) and potassium dihydrogen phosphate (KH_2PO_4) were also effective (see Resources). Some phytotoxicity was noted after repeated applications.

Combination Treatments

Better results are obtained with combination treatments than with single control strategies in some cases. Combination treatments can be applied simultaneously, or sequentially in a planned rotation. For powdery mildew, Pasini et al. (1997) found that weekly rotation of 0.5% KH_2PO_4, the fungicide dodemorph, the biocontrol agent *A. quisqualis* and 0.75% horticultural oil gave an average efficacy of 82%, compared to 73% average effectiveness seen for dodemorph alone. Weekly rotation of 0.5% phosphate (KH_2PO_4) with 5% wine vinegar gave an impressive average efficacy of 83% (Pasini et al. 1997).

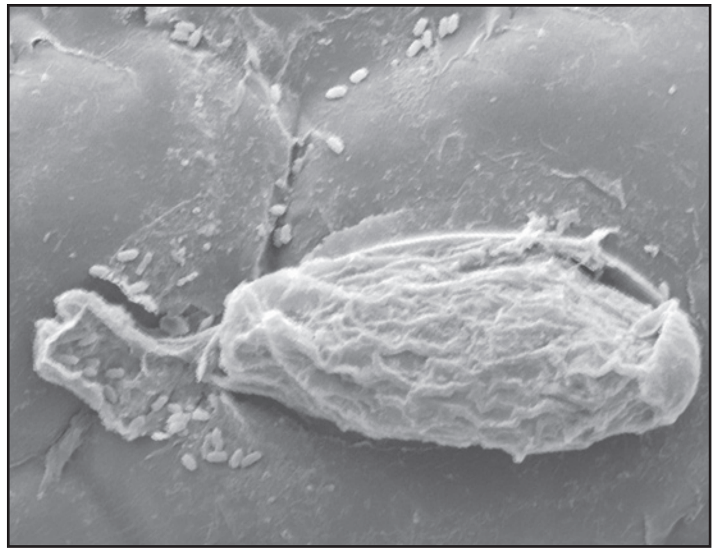


Photo courtesy of AgraQuest

Bacillus subtilis **has destroyed this powdery mildew spore.**

Mixtures of oil and bicarbonate are more effective than each one used separately. Roses sprayed weekly with aqueous solutions containing about 1 level tablespoon/gallon (0.5% w/v) of baking soda and 2.5 tablespoons/gal (1% v/v) of horticultural oil were protected against powdery mildew (Horst et al. 1992), and combination sprays were also effective on other plant species (Ziv and Zitter 1992; Ziv and Hagiladi 1993).

Conclusion

Since weekly sprays may be necessary to control fungal diseases, especially in areas of high rainfall, rotations of active ingredients will help reduce resistance. The least expensive and most available rotation for preventing powdery mildew would be vinegar, baking soda, and vegetable oil. Phosphate salts are inexpensive and have the advantage of suppressing active infestations and fertilizing the plant.

Silica treatments have drawn the interest of plant pathologists, and organic gardeners believe that it helps prevent plant disease. Knotweed extract could be an effective component in the rotation. Effectiveness of compost tea for disease prevention is supported by anecdotal evidence, and has a lot of enthusiastic support among organic gardeners.

Blackspot and rust require preventive sprays. Neem oil sprays in rotation with antitranspirants or garlic might prevent these diseases, especially on resistant species. The systemic effect of the phosphate salts could be useful.

Since diseases and severity vary with location, the home gardener must experiment to find the most effective combination. With all these options, there is no longer any need to use toxic sprays, especially when resistant species and good cultural practices can be used to help prevent the problem.

References

Abbey, J.A., D. Percival, L. Abbey et al. 2019. Biofungicides as alternative to synthetic fungicide control of grey mould (*Botrytis cinerea*)—prospects and challenges. *Biocontrol Sci. Technol.* 29(3):207-228. [CAB Abstracts]

Amrita, A., K. Dixit, N.N. Tripathi and S.N. Dixit. 1989. Efficacy of ocimum oil against fungi attacking chilli seed during storage. *Trop. Sci.* 29:15-20.

Barger, W.R. 1928. Sodium bicarbonate as a citrus fruit disinfectant. *Calif. Citrograph* 13:164-174.

Baxendale, R.W. and W.T. Johnson. 1989. Update note concerning horticultural oil concentrations for verdant use. *J. Arboriculture* 15(2):51-52.

Bélanger, R.R., C. Labbé and W.R. Jarvis. 1994. Commercial-scale control of rose powdery mildew with a fungal antagonist. *Plant Dis.* 78:420-424.

Bender, C.L. and D.L. Coyer. 1984. Isolation and identification of races of *Sphaerotheca pannosa* var. *rosae. Phytopathol.* 74:100-103.

Bender, C.L. and D.L. Coyer. 1986. Pathogenic variation in Oregon populations of *Sphaerotheca pannosa* var. *rosae. Plant Dis.* 70:383-385.

Bowen, P., J. Menzies, D. Ehret, L. Samuels and A.D.M. Glass. 1992. Soluble silicon sprays inhibit powdery mildew development on grape leaves. *J. American Soc. Hort. Sci.* 117:906-912. [cited in Reuveni et al. 1995]

Bowen, K.L., B. Young and B.K. Behe. 1995. Management of blackspot of rose in the landscape in Alabama. *Plant Dis.* 79:250-253.

Carlen, C. R. Faby, R. Karjalainen, J.J. Pommier and R. Steffek. 2004. Control of airborne diseases in strawberries with natural and synthetic elicitors. *Acta Hort.* 649:237-240.

Chaplin, L.T. 1994. Grow the right rose for your region. *Organic Gardening* April:56-64.

Chérif, M. N. Benhamou, J.G. Menzies and R.R. Bélanger. 1992. Silicon induced resistance in cucumber plants against *Pythium ultimum. Phys. Molecular Plant Pathol.* 41:411-425.

Chérif, M., J.G. Menzies, D.L. Ehret, C. Bogdanoff, and R.R. Bélanger. 1994. Yield of cucumber infected with *Pythium aphanidermatum* when grown with soluble silicon. *HortScience* 29(8); 896-897.

Corral, L.G., L.S. Post and T.J. Montville. 1988. Antimicrobial activity of sodium carbonate. *J. Food Sci.* 53(3):981-982.

Daayf, F., A. Schmitt, and R.R. Bélanger. 1995. The effects of plant extracts of *Reynoutria sachalinensis* on powdery mildew development and leaf physiology of long English cucumber. *Plant Dis.* 79:577-580.

Depasquale, D.A., A. El-Nabarawy, J.D. Rosen and T.J. Montville. 1990. Ammonium bicarbonate inhibition of mycotoxigenic fungi and spoilage yeasts. *J. Food Prot.* 53(4):324-328.

Dik, A.J., D.J. van der Gaag and M.A. van Slooten. 2003. Efficacy of salts against fungal diseases in glasshouse crops. *Comm. Agric. Appl. Biol. Sci.* 68(4b):475-485. [CAB Abstracts]

Doares, S.H., T. Syrovets, E.W. Weiler and C.A. Ryan. 1995. Oligogalacturonides and chitosan activate plant defensive genes through the octadecanoid pathway. *Proc. Natl. Acad. Sci.* 92(10):4095-4098.

Dominguez-Serrano, D., R.G.-Velasco, M.E. Mora-Herrera et al. 2016. Identification and management alternatives of powdery mildew of rosebush. *Revista Mex. Fitopatol.* 34(1):22-42. [CAB Abstracts]

DPR (CA Department of Pesticide Regulation). 2019. Database of registered pesticides. December 9, 2019.

Dubey, N.K. and N. Kishore. 1987. Fungitoxicity of some higher plants and synergistic activity of their essential oils. *Trop. Sci.* 27:23-27.

Resources

Antitranspirants

Wilt Pruf Products, PO Box 469, Essex, CT 06426; 860-767-7033; www.wilt-pruf.com

Vapor Gard, Miller Chemical, PO Box 333, Hanover, PA 17331; 800-233-2040.

Oils and Soap

Horticultural Oil—JMS Stylet Oil, JMS Flower Farms, 4423 5th Pl. SW, Vero Beach, FL 32968; 772-562-8770; www.stylet-oil.com. Harmony Farm Supply, PO Box 460 Graton, CA 95444; 707-823-9125, www.harmonyfarm.com

Jojoba Oil (Erase®)—IJO Products, 4672 W. Jennifer, Suite 103, Fresno, CA 93722; 559-221-6048. Harmony Farm Supply, see above

Neem Oil, clarified (70%)—Triact®—OHP, 5145 Forest Run Trace, Alpharetta, GA 30022; www.ohp.com. Harmony Farm Supply, see above

Neem Oil, cold pressed—Debug Turbo®, Agro Logistic Systems, 555 W. Lambert Rd., Brea, CA 92821; 714-990-9220; www.agrologistic.com

Vegetable Oil—Grocery Store

Safer Insecticidal Soap—Woodstream Corporation, 69N Locust St., Lititz, PA 17543; 800-800-1819; www.woodstreampro.com

Salts

Potassium Dihydrogen Phosphate —Nutrol® Fungicide, Lidochem, 20 Village Ct., Hazlet, NJ 07730; 732-888-8000; www.lidochem.com

Potassium salts of phosphorous acid—Fosphite®, JH Biotech, 4951 Olivas Park Drive, Ventura, CA 93003; 805-650-8933; www.jhbiotech.com

Sodium Bicarbonate (Baking Soda)—Grocery Store

Potassium Bicarbonate (85%)—(Milstop®), BioWorks, 100 Rawson Road, Victor, NY 14564; 585-924-4362; www.bioworksinc.com. (Greencure®), H and I Agritech, 5529 Glades Cutoff, Fort Pierce, FL 34981; 772-286-5581. Harmony Farm Supply, see above

Silica—Diatomaceous Earth, Permaguard®, 115 Rio Bravo SE, Albuquerque, NM 87105; 505-873-3061. Harmony Farm Supply, see above.

Silicates—Potassium silicate (29%)—Sil-MATRIX®, Certis, 9145 Guilford Rd., Suite 175, Columbia, MD 21046; 800/250-5020; www.certisusa.com

Botanicals and Chitosan

Chitosan, 30% (Armour-Zen®)—Botry-Zen, 901 H St., Suite 610, Sacramento, CA 95814; 530-574-5768; www.botryzen.co.nz

Cinnamon oil (30% cinnamaldehyde, Cinnacure®)—Progard, PO Box 550, Suisun, CA 94585; 707-426-2500.

Giant Knotweed (Regalia®)—Marrone Bio Innovations, 1540 Drew Avenue, Davis, CA 95618; 530-750-2800; https://marronebio.com

Mint Oil (Fungastop®)—Soil Technologies, 2103 185th St., Fairfield, IA 52556; 800/221-7645, 515/472-3963; www.soiltechnologies.com

Rosemary oil (Sporan®)—Keyplex, PO Box 2525, Winter Park, FL 32790; 407-682-6500, www.keyplex.com. Harmony Farm Supply, see above

Biocontrol

Bacillus amyloliquifaciens D747 (Double Nickel®)—Certis, see above

Bacillus subtilis (Serenade®) (powdery mildew in home garden)—Bayer Crop Science, 2 TW Alexander Drive, Research Triangle Park, NC 27700; 919-549-5361. Harmony Farm Supply, see above

Bacillus subtilis (Cease®)—BioWorks, 100 Rawson Road, Victor, NY 14564; 585-924-4362.

Bacillus pumilis (Sonata®) (powdery mildew commercial field grown roses)—Bayer, see above.

Elad, Y., N. Ayish, O. Ziv and J. Katan. 1990. Control of grey mould (*Botrytis cinerea*) with film-forming polymers. *Plant Pathol.* 39:249-254.

Elad, Y., N.E. Malathrakis and A.J. Dik. 1996. Biological control of Botrytis-incited diseases and powdery mildews in greenhouse crops. *Crop Prot.* 15:229-240.

Fernández-Falcón, M., C.E. Alvarez-González, V. Garcia and J. Báez. 1986. The effect of chloride and bicarbonate levels in irrigation water on nutrition content, production and quality of cut roses 'Mercedes'. *Sci. Horticulturae* 29:373-385.

Flint, M.L., N.A. Davidson, J.E. Dibble, P.J. Marer and A. Guye. 1991. *Managing Insects and Mites with Spray Oils.* University of California Division of Agriculture and Natural Resources, Pub. No. 3347, 6701 San Pablo Avenue, Oakland, CA. 47 pp.

Garg, B.K. and O.P. Garg. 1986. Influence of sodium bicarbonate on growth, nutrient uptake and metabolism of pea. *Annals of Arid Zone* 25(1):69-72.

Gullino, M.L. and A. Garibaldi. 1996. Diseases of roses: evolution of problems and new approaches for their control. *Acta Hort.* 424:195-201.

Hagiladi, A. and O. Ziv. 1986. Use of antitranspirants for control of powdery mildew on field grown roses. *J. Environ. Hort.* 4(2):65-68.

Hajlaoui, M.R. and R.R. Bélanger. 1991. Comparative effects of temperature and humidity on the activity of three potential antagonists of rose powdery mildew. *Netherland J. Plant Pathol.* 97:203-208.

Hajlaoui, M.R., N. Benhamou and R.R. Bélanger. 1992. Cytochemical study of the antagonistic activity of *Sporothrix flocculosa* on rose powdery mildew, *Sphaerotheca pannosa* var. *rosae. Phytopathol.* 82:583-589.

Hajlaoui, M.R. and R.R. Bélanger. 1993. Antagonism of the yeast-like phylloplane fungus *Sporothrix flocculosa* against *Erysiphe graminis* var *tritici. Biocontrol Sci. Technol.* 3:427-434.

Holcomb, G.E. 1991a. Experimental control of rose blackspot with antitranspirants. *American Rose Magazine* August:6-7.

Holcomb, G.E. 1991b. Experimental control of rose blackspot with antitranspirants. *American Rose Magazine* October:11.

Homma, Y., Y. Arimoto and T. Misato. 1981. Effect of sodium bicarbonate on each growth stage of cucumber powdery mildew fungus (*Sphaerotheca fuliginea*) in its life cycle. *J. Pesticide Sci.* 6:201-209.

Horst, R.K. 1983. *Compendium of Rose Diseases.* American Phytopathological Society, St. Paul, MN. 50 pp.

Horst, R.K., S.O. Kawamoto and L.L. Porter. 1992. Effect of sodium bicarbonate and oils on the control of powdery mildew and black spot of roses. *Plant Dis.* 76:247-251.

Horst, R.K. and R.A. Cloyd. 2007. *Compendium of Rose Diseases and Pests*, 2nd ed. American Phytopathological Society, St. Paul, MN. 83 pp.

Hsieh, T.F., J.H. Huang and L.J. Hsieh. 2005. Control of powdery mildew with potassium bicarbonate and polyelectrolyte. *Plant Pathol. Bull.* 14(2):125-132.

Ingham, E.R. 2001. *The Compost Tea Brewing Manual,* 2nd ed. Soil Foodweb, 1128 NE 2nd St., Suite 120, Corvallis, OR 97330.

Jeliazkova, E.A. 2012. Evaluating natural products for black spot disease on roses. *J. Medicinally Active Plants* 1(1):13-18.

Jespers, A.B.K. and M.A. De Waard. 1993. Natural products in plant protection. *Netherland J. Plant Pathol.* 99(Suppl. 3):109-117.

Kamp, M. 1985. Control of *Erysiphe cichoracearum* on *Zinnia elegans*, with a polymer-based antitranspirant. *HortScience* 20(5):879-881.

Liu, H.L. 2001. Management of rose powdery mildew with automatic water sprays. *Plant Prot. Bull. Taipei* 43(1):7-16. [CAB Abstracts]

Locke, J. 1990. Activity of extracted neem seed oil against fungal plant pathogens. Paper presented at the USDA Neem Workshop, April 16-17, 1990. Beltsville, MD, pp. 132-136.

Marloth, R.H. 1930. The influence of hydrogen ion concentration, and of sodium bicarbonate and related substances on *Penicillium italicum* and *P. digitatum.* Ph.D. thesis University of California, Berkeley, California. 88 pp.

Mathai, G., P.V. Paily and M.R. Menon. 1981. Effect of fungicides and silica in the control of sheath blight disease of rice caused by *Corticium sasakii* (Shiriai). *Agric. Res. J. Kerala* 19(1):79-83.

Menzies, J.G., D.L. Ehret, A.D.M. Glass and A.L. Samuels. 1991. The influence of silicon on cytological interactions between *Sphaerotheca fuliginea* and *Cucumis sativus. Phys. Molecular Plant Pathol.* 39:403-414.

Menzies, J., P. Bowen, D. Ehret, and A.D.M. Glass. 1992. Foliar applications of potassium silicate reduce severity of powdery mildew on cucumber, muskmelon, and zucchini squash. *J. American Soc. Hort. Sci.* 117:902-905. [cited in Reuveni et al. 1995]

Michalak, P.S. and L.A. Gilkeson. 1994. *Rodale's Successful Organic Gardening: Controlling Pests and Diseases.* Rodale Press, Emmaus, PA. 160 pp.

Nazzaro, F., F. Fratianni, R. Coppola et al. 2017. Essential oils and antifungal activity. *Pharmaceuticals* (Basil) 10(4):86.

Northover, J. and K.E. Schneider. 1993. Activity of plant oils on diseases caused by *Podosphaera leucotricha*, *Venturia inaequalis*, and *Albugo occidentalis. Plant Dis.* 77(2):152-157.

OHP. 2019. Label for Triact. OHP, 5145 Forest Run Trace, Alpharetta, GA 30022; www.ohp.com.

OMRI (Organic Materials Review Institute). 2019. OMRI Products List. OMRI, PO Box 11558. Eugene, OR 97440.

Pace, H., H. Vrapi and B. Gixhari. 2016. Evaluation of some reduced-risk products for management of powdery mildew in greenhouse tomatoes. *Intl. J. Ecosys. Ecol. Sci.* 6(4):505-508.

Pasini, C., F. D'Aquila, P. Curir and M.L. Gullino. 1997. Effectiveness of antifungal compounds against rose powdery mildew (*Sphaerotheca pannosa* var. *rosae*) in glasshouses. *Crop Prot.* 16(3):251-256.

Pasini, C., F. D'Aquila, M. Amoretti et al. 2007. Control of powdery mildew of roses in greenhouse conditions. *Acta Hort.* 751: 246-249.

Percival, D.C., J. Abbey, H. Lu et al. 2017. Use of biofungicides to address conventional botrytis blight control challenges in wild blueberry production. *Acta Hort.* 1180:241-247.

Petsikos-P., N., A Schmitt, E. Markellow, A.E. Kalmarkakis, K. Tzempelikou, E. Siranidow and S. Konstantinidou-D. 2002. Management of curcumber powdery mildew by new formulations of *Reynoutria sachalinensis. Z. Pflanzenkrank. Pflanzenschutz* 109(5):478-490. [CAB Abstracts]

Philipp, W.D., E. Beuther, D. Hermann, F. Klinkert, C. Oberwalder, M. Schmidtke and B. Straub. 1990. Zur Formulierung des Mehltauhyperparasitin *Ampelomyces quisqualis* Ces. *Z. Pflanzenkrank. Pflanzenpathol. Pflanzenschutz* 97:120-132.

Quarles, W. 1992. USP Mineral oil versus horticultural oil. *IPM Practitioner* 14(8):18.

Quarles, W. 1994a. Antitranspirants as non-toxic fungicides. *American Rose Annual* 1994:83-86.

Quarles, W. 1994b. Neem tree pesticides protect ornamental plants. *IPM Practitioner* 16(10):1-13.

Quarles, W. 1995. The truth about horsetails or natural plant disease protection from silica. *Common Sense Pest Control Quarterly* 11(2):18.

Quarles, W. 1999a. Grow pesto for your pests! *Common Sense Pest Control Quarterly* 15(4):13-19.

Quarles, W. 1999b. Garlic as a pesticide. *Common Sense Pest Control Quarterly* 15(4):4-12.

Quarles, W. 2000. Antitranspirants as least-toxic fungicides. *IPM Practitioner* 22(1):1-9.

Quarles, W. 2001. Compost tea for organic farming and gardening. *IPM Practitioner* 23(9):1-9.

Quarles, W. 2002. Aspirin, composts, talking plants, and induced systemic resistance. *IPM Practitioner* 24(5/6):1-9.

Quarles, W. 2009. Giant knotweed, plant disease protection, and immortality. *IPM Practitioner* 31(3/4):1-6.

Quarles, W. 2013. New biopesticides for IPM and organic production. *IPM Practitioner* 33(7/8):1-10.

Qvarnstrom, K. 1992. [Treatment of powdery mildew, *Erysiphe cichoracearum*, on cucumber plants with very low toxic measures.] *Vaxtskyddsnotiser* 56(1):17-20. [CAB Abstracts]

Qvarnstrom, K. and B. Ramert. 1992. [Control of blackspot, *Marssonina rosae*, on garden roses.] *Vaxtskyddsnotiser* 56(4):83-85. [CAB Abstracts]

Raabe, R.D. 1991a. Control of rose rust. *F&N Tests* 48:401.

Raabe, R.D. 1991b. Control of rose powdery mildew. *F&N Tests* 48:399.

Rao, G.F., M. Singh and H.N. Singh. 1992. Fungitoxic evaluation of essential oils extracted from higher plants against some sugarcane pathogens. *Trop. Sci.* 32:377-382.

Reimers, F., S.E. Smolka, S. Werres, K. Plank-Schumacher and G. Wagner. 1993. Effect of ajoene, a compound derived from *Allium sativum*, on pathogenic and epiphytic microorganisms. *Z. Pflanzenkrank. Pflanzenschutz* 100:622-633.

Reuveni, M., V. Agapov and R. Reuveni. 1993. Induction of systemic resistance to powdery mildew and growth increase in cucumber by phosphates. *Biol. Agric. Hort.* 9:303-315.

Reuveni, R., V. Agapov, M. Reuveni et al. 1994. Effects of foliar sprays of phosphates on powdery mildew of roses. *J. Phytopathol.* 142(3/4):331-337.

Reuveni, M., V. Agapov and R. Reuveni. 1995. Suppression of cucumber powdery mildew, *Sphaerotheca fuliginea*, by foliar sprays of phosphate and potassium salts. *Plant Pathol.* 44:31-39.

Rovesti, L., S. DiMarco and D. Pancaldi. 1992. Effect of neem kernel extract on some phytopathogenic fungi under greenhouse conditions. *Z. Pflazenkrank. Pflanzenschutz* 99:293-296.

Schmitt, A. 2002. Induced responses by plant extracts from *Reynoutria sachalinensis*: a case study. *Bull. OILB/SROP* 25(6):83-88. [CAB Abstracts]

Schulman, G. 1996. Chlorothalonil versus horticultural oil: phytotoxicity to rose foliage. *Plant Dis.* April:347.

Singh, U.P., P. Prithivairaj, K.G. Wagner and K. Plank-Schumacher. 1995. Effect of ajoene, a constituent of garlic, *Allium sativum*, on powdery mildew, *Ersiphe pisi*, of pea, *Pisum sativum. Z. Pflanzenkrank. Pflanzenschutz* 102(2):399-406.

Singh, U.P., S. Maurya and D.P. Singh. 2003. Antifungal activity and induced resistance in pea by aqueous extract of vermicompost for control of powdery mildew of pea and balsam. *Z. Pflanzenkrank. Pflanzenschutz* 110(6):544-553.

Smith, M., ed. 1994. *The Real Dirt.* Northeast SARE, Hills Building, University of Vermont, Burlington, VT 05405. 264 pp.

Stevic, T., T. Beric and K. Savikin. 2014. Using aerated compost tea in comparison with a chemical pesticide for controlling rose powdery mildew. *Arch. Phytopathol. Plant Prot.* 47(6):658-664.

Su, H., R. Blair, T. Johnson and P. Marrone. 2012. Regalia bioprotectant in plant disease management. *Outlooks Pest Manag.* February:30-34.

Suthaparan, A., S. Torre, L.M. Mortensen et al. 2011. Evaluation of biological control agents for control of botrytis of geranium and powdery mildew of rose. *Can. J. Plant Pathol.* 33(4):499-505.

Tariq, V.N. and A.C. Magee. 1990. Effect of volatiles from garlic bulb extract on *Fusarium oxysporum* f.sp. *lycopersici. Mycological Res.* 94(5):617-620.

Tayabi, K. and P. Azizi. 1984. Influence of silica on rice yield and stem borer (*Chilo supremain*) in Rasht/Iran 1979-1980. *Pesticides* 18(5):20-22.

Tjosvold, S.A. and S.T. Koike. 2001. Evaluation of reduced risk and other biorational fungicides on the control of powdery mildew on greenhouse roses. *Acta Hort.* 547:59-67.

Wojdya, A.T. 2001. Grapefruit extract activity in the control of rose powdery mildew and blackspot. *Med. Fac. Landbouww. Univ. Gent.* 66(2a):167-177.

Wojdya, A.T. 2002a. Chitosan in the control of rose powdery mildew and downy mildew. *Plant Prot. Sci.* 38(Special 2):494-496.

Wojdya, A.T. 2002b. Oils activity in the control of rose powdery mildew. *Med. Fac. Landbouww. Univ. Gent.* 67(2):369-376.

Wojdya, A.T. 2002c. Influence of some biotic and abiotic factors on the development of powdery mildew (*Sphaerotheca pannosa* var *rosae*) on roses. *Phytopath. Polonica* 24:77-80. [CAB Abstracts]

Wurms, K.V. and J.D. H.-Zijlstra. 2015. Control of powdery mildew on glasshouse grown roses and tomatoes in the Netherlands using anhydrous milk fat and soybean oil emulsions. *New Zealand Plant Prot.* 68:380-388.

Yarwood, C.E. 1939a. The fungicidal value of cottonseed oil and some other spray supplements. *Phytopathol.* 29:24.

Yarwood, C.E. 1939b. Control of powdery mildews with a water spray. *Phytopathol.* 29:288-290.

Ziv, O. and R.A. Frederiksen. 1983. Control of foliar diseases with epidermal coating materials. *Plant Dis.* 67(2):212-214.

Ziv, O. and A. Hagiladi. 1984. Control of powdery mildew on hydrangea and crapemyrtle with antitranspirants. *HortScience* 19(5):708-709.

Ziv, O. and T.A. Zitter. 1992. Effects of bicarbonates and film-forming polymers on curcurbit foliar diseases. *Plant Dis.* 76:513-517.

Ziv, O. and A. Hagiladi. 1993. Controlling powdery mildew in euonymus with polymer coatings and bicarbonate solutions. *HortScience* 28(2):124-126.

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