New Greenhouse Disease Management Recommendations

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Michigan State University carries out research on greenhouse diseases infecting ornamental crops yearly. Knowledge of the pathogen, the disease, the environmental conditions favorable for disease, and current effective control products are essential to an integrated approach to disease control.

The 'A' and 'B' Team tables listed under each disease show the results of many years of testing fungicide products and lists the product name, FRAC code, and active ingredient. The products listed in the 'A' Team are especially effective at disease control. The 'B' Team products also limit disease, but may not be as effective as the 'A' Team products and are recommended for use when disease pressure is not severe and for use in alternating programs. Always alternate among fungicide products with active ingredients that have different modes of action (FRAC codes) to delay the development of fungicide resistance in the pathogen.

***PYTHIUM* ROOT ROT.** A common and persistent disease in the greenhouse industry is crown and root rot caused by the water mold *Pythium*. This pathogen can "nibble" the feeding roots of plants, resulting in stunted growth. *Pythium* also causes severe symptoms, such as crown rot, that can result in plant death (Figure 1). Saturated, overwatered growing media favors the *Pythium* pathogen. *Pythium* can persist in the greenhouse and 'hibernate' on dirty plant containers, benches, hoses, and greenhouse walkways, ready to become activated by the right crop and weather conditions. Almost any greenhouse crop can be infected by *Pythium*, but the disease is most often found on geraniums, poinsettias, and snapdragons. Sanitation is especially important in limiting root rot. Minimizing stress on the crop by promoting good growth makes the plant less vulnerable to attack by a root rot. Use a pressure washer with soap and water when cleaning walkways, benches, etc. Follow with a disinfestant to remove any remaining *Pythium*. Choosing the right fungicide tools can help to minimize plant losses. If Pythium root rot is a recurring problem, growing cultivars that are less susceptible to the pathogen may be an option.

Figure 1. Closeup of poinsettia showing symptoms of Pythium root rot. In severe cases, stems become water-soaked and dieback occurs.

Scouting is an important first step in controlling Pythium root rot. If *Pythium* has a significant head start, the root system of some plants will be too rotted and the fungicides will not be able to rescue them. If *Pythium* continues to be an issue in your greenhouse and Subdue MAXX has been the only or primary fungicide used over years, it is possible that the *Pythium* has become resistant and is no longer

affected by this fungicide. Testing the *Pythium* present in your greenhouse by a diagnostic lab is the only way to know for sure if the pathogen is resistant.

If *Pythium* has been diagnosed as the problem, choosing an effective fungicide is important. Rotate among the different active ingredients (FRAC) available among fungicide products to avoid the development of resistance in *Pythium*. Subdue MAXX, Truban, Terrazole, and Segway (Figure 2B) are products proven effective against *Pythium*. If you have *Pythium* resistant to Subdue MAXX in your greenhouse it is recommended that Truban or Terrazole be used as they have been shown to be the most effective products in our greenhouse trials. Do not rotate between Truban and Terrazole as they have the same active ingredient (and FRAC code). If used early and if the disease is not severe, Captan, Empress Intrinsic, FenStop, and Heritage can be helpful for *Pythium* control. The phosphorous acid products can reduce infection (Figure 2A), however, results are not always consistent. Biocontrol products such as Actinovate and RootShield can also be helpful; however, they must be applied prior to *Pythium* symptoms being observed. For the best control, use drenches and not spray applications; apply fungicides at the minimum interval listed on the label. Although several new effective *Phytophthora* control products, such as Micora, Orvego, and Adorn, have recently been labeled for the greenhouse, studies have shown that the efficacy of these products does not always extend to *Pythium*.

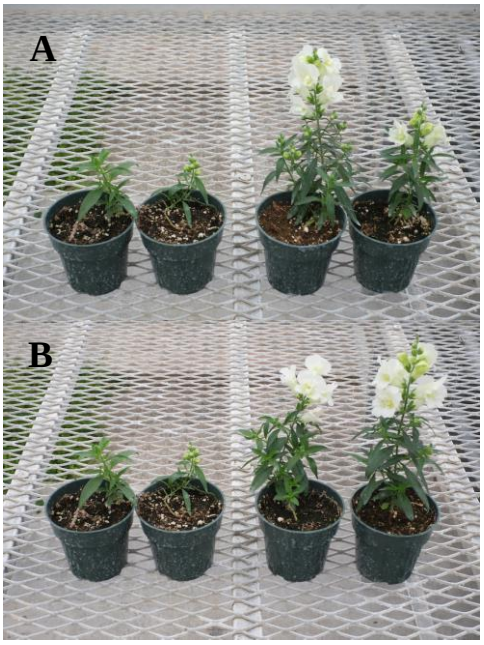

Figure 2. Pythium inoculated untreated snapdragons on left versus Alude (A) or Segway treated (B) on right.

Pythium* 'A' Team

Terrazole L/Truban WP	14	etridiazole
Subdue MAXX EC*	4	mefenoxam
Banol	28	propamocarb

*Watch for pathogen resistance.

***Pythium* 'B/B-' Team**

Captan WDG	M4	captan
Empress SC	11	pyraclostrobin
FenStop SC	11	fenamidone
Heritage WDG	11	azoxystrobin
Segway SC	21	cyazofamid
Alude	33	phosphorous acid

***PHYTOPHTHORA* ROOT ROT.** *Phytophthora* is a water mold and can be a particularly devastating and difficult-to-control problem in the greenhouse. The pathogen can spread quickly, especially in flood floor and hydroponic systems. Two species of *Phytophthora* (*P. nicotianae* and *P. drechsleri*) are usually found infecting floriculture crops and can cause root, crown, and foliar blights (Figure 3). *P. nicotianae* can infect snapdragon, fuchsia, verbena, vinca, African violet, and dusty miller to name a few. *P. drechsleri* may infect poinsettias, million bells/calibrachoa, and pansies. Warm temperatures and ample water favor disease epidemics and can cause especially severe losses. Symptoms include brown-black cankers at the soil line and diseased roots. In some cases, the crowns will be the first plant part to become infected, after which the infection will move up the stem into the foliage near the petiole. This type of symptom is especially noticeable on English ivy and African violets. Infection on some crops, such as rhododendrons, is more likely to be observed only on the foliage.

Figure 3. Although *Phytophthora* is often considered a root rot pathogen on ornamentals, foliar symptoms are observed on some hosts, such as on Rhododendrons (left), and Rehmannia (right).

Controlling the spread of *Phytophthora* can be difficult. *Phytophthora* must be kept out of the production site, and this can be particularly difficult with floriculture crops because of the widespread distribution of prefinished plants. Plants may not exhibit obvious symptoms until the infection is well established or the plant becomes stressed (e.g., over or underwatered). Infected plants treated with fungicides may appear healthy until the fungicide efficacy wears off, allowing *Phytophthora* to increase. Eradicating *Phytophthora* once it has been introduced is a challenge. Sanitation can limit disease and includes removing plant debris and disinfesting production surfaces. Power washing benches and replacing floor mats are important steps to take to reduce inoculum for future crops.

Figure 4. New products that are highly effective against Phytophthora root rot have been registered in recent years. In this photo, control of Phytophthora drechsleri is evident with the Segovis treated plants (right) vs. untreated plants (left).

It is important to choose effective products and rotate them among different modes of action (FRAC). Subdue MAXX has been the industry standard used to control *Phytophthora*, however, in recent years, the registration of products such as Adorn, Micora SC, and Segovis (Figure 4) have given growers more tools for controlling this devastating pathogen. Other fungicides listed in the 'B' Team may offer help if the disease pressure is not too severe. Some products have performed well controlling *Phytophthora* disease on one crop but failed on another, so care must be taken to use a fungicide program that effectively alternates products to maintain disease control and minimize the chance of fungicide resistance developing in *Phytophthora*.

***Phytophthora* 'A' Team**

Adorn SC	43	fluopicolide
Micora SC	40	mandipropamid
Segovis SC	49	oxathiapiprolin
Subdue MAXX EC	4	mefenoxam

***Phytophthora* 'B' Team**

Aliette WDG	33	fosetyl-al
Captan WDG	M4	captan
FenStop SC	11	fenamidone
Orvego SC	45/40	ametoctradin/dimethomorph
Segway SC	21	cyazofamid
Stature SC	40	dimethomorph
Terrazole L/Truban WP	14	etridiazole
Alude/Vital	33	phosphorous acid

BLACK ROOT ROT. Black root rot is caused by the fungus *Thielaviopsis basicola*. It is a serious threat to pansies, petunias and vinca, and may also infect cyclamen, calibrachoa, poinsettia, primula, impatiens, snapdragon, verbena, phlox, begonia and nicotiana. Black root rot symptoms are often mistaken for nutrient deficiencies (Figure 5). Leaves may turn yellow and the youngest leaves become stunted and tinged with red. In mild infections, older leaves are yellow-green with the veins remaining green. *Thielaviopsis* produces a spore that can persist on floor mats, greenhouse benches, or flats/pots. It is not recommended to reuse plug trays for crops that are susceptible to black root rot. University studies have shown that fungus gnats and shore flies can move *Thielaviopsis* around a greenhouse by eating the spores and excreting them into nearby pots. Based on MSU studies, fungicides with thiophanate-methyl as the primary active ingredient (3336 F is an example) should be used frequently for black root rot. Terraguard has also shown to be effective in MSU studies against black root

Figure 5. Symptoms of black root rot are often misdiagnosed as a nutrient deficency (left). Underdevoloped root symptoms on crops such as pansy and petunia are often a result of *Thieliaviopsis* infection (right).

rot and is a good choice as a rotational product since it has a different mode of action (FRAC). Due to the virulence of this pathogen, biocontrol products are not recommended as a primary method of control. A misstep early in the disease epidemic may result in an unsalable crop; therefore, choosing an effective fungicide to control black root rot is critical. Using the highest labeled rate of each treatment with close reapplication intervals is also recommended.

***Thielaviopsis* 'A' Team**

3336 F/OHP 6672	1	t-methyl
Terraguard SC	3	triflumizole

POWDERY MILDEW. The white talcum-like colonies of powdery mildew start small but can rapidly blight the leaves, stems, and flowers of susceptible crops (Figure 6). Some powdery mildews can infect many different annual and perennial flowers and vegetables while others can be specific to one plant type. The abundant conidia (spores) give a white, powdery or fluffy appearance. Sometimes the disease only causes yellowing and withering of leaves and stunted plant growth and the characteristic white powdery spores are not produced, making identification of the disease difficult. High relative humidity can prompt epidemics. Gerbera daisy, calibrachoa, zinnia, asters, and verbena are very susceptible and may need to be protected with frequent applications of effective fungicides. Other crops may not need frequent fungicide treatments but should be scouted regularly for signs of the disease. Research has found that certain cultivars of a plant crop may be more susceptible than others. For instance, verbena cultivars were tested in earlier studies and determined to have differences in their response to powdery mildew.

Fungicides have typically played a key role in meeting the challenge of growing crops susceptible to powdery mildew. If a crop is especially susceptible or plants have early powdery mildew symptoms then beginning a fungicide spray program with one of the most effective products such as Eagle and Terraguard is recommended (Figure 7). Since these fungicides have a similar mode of action, they should be used in alternation with products from a different FRAC group from the 'A-/B+' team. Powdery mildew pathogens are tricky and have been known to genetically adapt to overcome some of the most effective fungicides. Biocontrol products, such as the natural oil product Proud 3F, can be used in instances when disease pressure is low or on a host that is less susceptible to powdery mildew.

Figure 6. Powdery mildew on zinnia has been noted more frequently in recent years. This disease can easily be diagnosed when sporulation is observed on the foliage (left) and flowers (right).

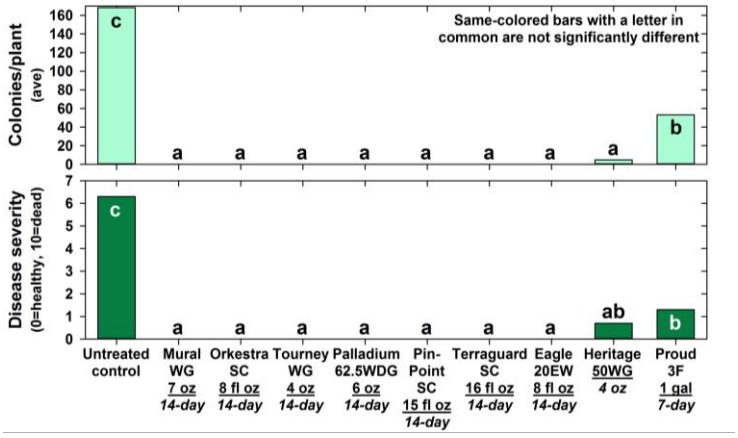

Figure 7. Evaluation of registered and non-registered fungicides against powdery mildew on zinnia.

Powdery Mildew 'A+' Team		
Eagle 20EW	3	myclobutanil
Terraguard SC	3	triflumizole

Powdery Mildew 'A/A-' Team Cont.		
Mural WG	11/7	azoxystrobin/benzovindiflupyr
Broadform SC	11/7	trifloxystrobin/fluopyram

Powdery Mildew 'A/A-' Team		
Pageant 38WG	11/7	pyraclostrobin/boscalid
Palladium WDG	9/12	cyprodinil/fludioxonil
Orkestra	7/11	fluxapyroxad/pyraclostrobin

Powdery Mildew 'B' Team		
Heritage WDG	11	azoxystrobin
Compass O WDG	11	trifloxystrobin
Insignia WG	11	pyraclostrobin

DOWNY MILDEW. Downy mildew is an important pathogen on several important annual crops in Michigan. In recent years, the host range has expanded and includes crops such as viburnum and basil. The specific pathogens that cause the various downy mildew diseases differ based on the host, meaning that it will not likely spread to other nearby, unrelated crops in greenhouses or in the landscape. For example, the downy mildew pathogen that infects rose (Figure 8B) will not cause disease on other

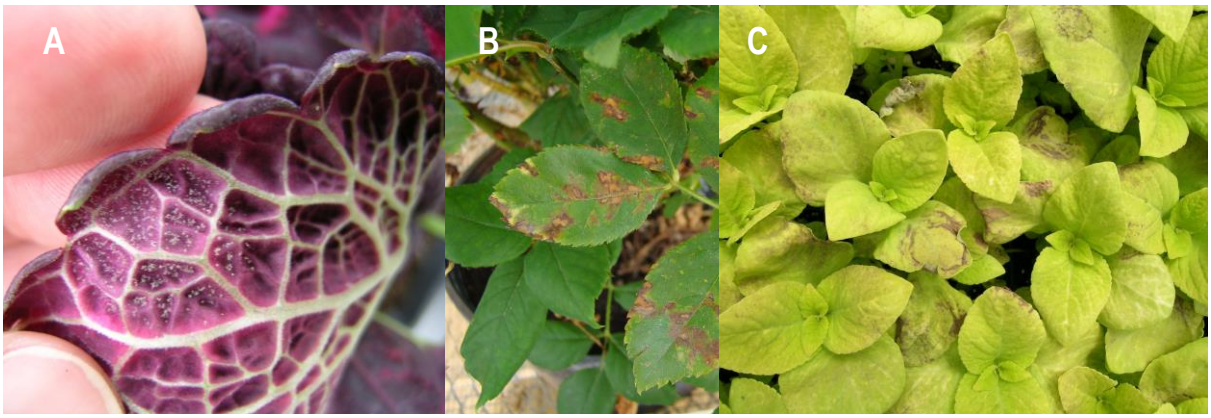

Figure 8. Visible downy mildew sporulation on coleus (A). Downy mildew infection on rose (B) and coleus (C) can result in visible lesions on leaves.

ornamentals such as coleus (Figure 8C), snapdragon or impatiens. Downy mildew can occur on all aboveground plant parts, blighting the leaves and stems. Sometimes the first symptoms of downy mildew are confused with a nutrient deficiency or spray injury. Leaf spots may be purplish or brown and appear square since they may be limited by the larger veins. Some downy mildews, such as the one that infects roses, do not always produce a fuzzy mat of spores on the underside of the leaf that is noticeable without magnification. On other crops, such as impatiens and coleus, sporulation may be easily observed on the underside of infected leaves (Figure 8A). When the infection becomes severe, leaves may drop from the plant, leaving the plant nearly devoid of foliage. By the time the disease is defoliating the plant, the downy mildew is advanced and stopping it becomes difficult. The downy mildew pathogen can infect a plant and lay quiet in tissue without noticeable blighting; it is possible to receive plants that appear healthy only to have symptoms develop later (Figure 9).

Figure 9. Symptoms of impatiens downy mildew can be subtle and include stunting and chlorosis.

Downy mildew is very responsive to environmental cues; when the greenhouse environment is favorable, downy mildew symptoms can seem to explode

overnight. Wetness, high relative humidity, and overcast conditions are triggers to downy mildew disease. In outdoor growing facilities, fog provides nearly the perfect weather for an outbreak. During wet weather, a fuzzy mat of fungal-like threads can coat the underside of the leaf. This is where the downy mildew pathogen reproduces via a spore type called a sporangium. Sporangia develop and ripen during the night as long as there is darkness and at least 6 hours of continuous moisture. When the environment begins to dry in the early to mid-morning hours, air currents or splashing water pluck the sporangia from their spore stalks and carry them to nearby healthy foliage. Downy mildew is most favored at temperatures around 60 to 65°F. Temperatures that are too warm (80°F and above) or too cold (40°F and below) may slow the disease. If the weather becomes hot and dry, the downy mildew pathogen will be halted at least for a while, but it is possible for it to lay quiet in infected tissue and wait for cooler weather. MSU research tested the effect of temperature on the ability of *Peronospora* sp. to infect coleus at different temperatures. Infection was greatly reduced when temperature reached 77°F and did not occur at 86°F. A similar study was conducted to determine temperature effect on sporulation of *Peronospora* sp. Again, when temperatures reached 77 to 86°F sporulation was significantly reduced.

Once a plant is infected with downy mildew, the best course of action is the removal and destruction of the plant. Fungicides should be used preventively to protect crops that are susceptible to downy mildew. Plants that are highly susceptible to downy mildew, such as basil, coleus and impatiens, should be treated every 14 to 21 days with the most effective fungicides. Greenhouse and landscape studies conducted in recent years have greatly increased our knowledge of efficacy and residual control of the various fungicides available for use against downy mildew. Systemic products that can be applied as a drench offer the best control and the longest residual. In particular, drenches of Adorn, Subdue MAXX and the new product Segovis have provided control against downy mildew for >150 post-treatment days in greenhouse and landscape studies (Figure 10). Due to pathogen resistance concerns associated with systemic products, it is important to tank-mix and rotate with other products that can be applied as a drench, such as Alude and Heritage. Greenhouse studies have shown that preventive foliar applications of Micora, Orvego, Segway, FenStop, and Stature offer protection against downy mildew. These foliar applications, however, do not provide disease control for an extended period and should only be part of an overall management program.

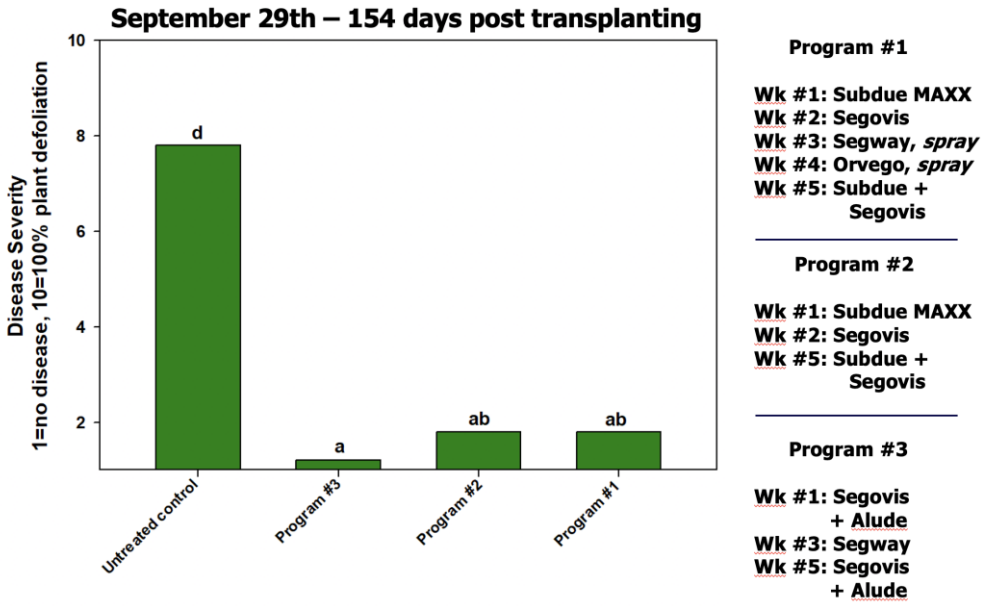

Figure 10. Applications of effective fungicides applied to bedding impatiens in the greenhouse prior to transplanting can help reduce downy mildew infection for >150 days post transplanting.

Downy Mildew 'A' Team

Segovis	49	oxathiapiprolin
Subdue MAXX	4	mefenoxam
Adorn SC	43	fluopicolide

Downy Mildew 'A-' Team

FenStop SC	11	fenamidone
Micora SC	40	mandipropamid
Orvego SC	45/40	ametotoctradin/dimethomorph
Segway SC	21	cyazofamid
Stature SC	40	dimethomorph

Downy Mildew 'B' Team

Compass O WDG	11	trifloxystrobin
Alude	33	phosphorous acid
Heritage WDG	11	azoxystrobin
Insignia WG	11	pyraclostrobin
Protect DF	M3	mancozeb
Pageant Intrinsic 38WG	11/7	pyraclostrobin/boscalid

***BOTRYTIS* BLIGHT (Gray mold).** The fungus *Botrytis cinerea* infects many greenhouse ornamental and vegetable crops. Disease symptoms include leaf spots, blighting, stem cankers, and damping-off. *Botrytis* blight is also called gray mold due to the large masses of gray conidia or spores ('seeds' of the *Botrytis* pathogen) that are produced (Figure 11). Spores are carried on air currents to healthy plants where new infections can become established. An infection that started as a small leaf spot can quickly coalesce into a large necrotic area. Infection of the cut stem surface of a stock plant can progress downward, causing a dieback of the entire plant. *Botrytis* typically becomes established and produces conidia on older lower leaves that are near the moist soil surface and under the plant canopy of bedding and stock plants. *Botrytis* can also infect dead plant tissue in the pot or on the greenhouse bench or floor, which can be a source of future infections.

Figure 11. Once established, Botrytis cinerea often produce a large amount of conidia which can result in an epidemic under favorable environmental conditions.

Water allows the *Botrytis* conidia to germinate and penetrate the plant. A moist and humid environment favors *Botrytis* infection, including wetting of plants due to water dripping from overhead, dew, or condensation. Cuttings propagated under mist should be scouted daily for signs of *Botrytis* infection. Minimize *Botrytis* by watering in the morning so that the foliage can dry rapidly. Space plants further apart and provide good air circulation to reduce relative humidity. Reduce the relative humidity for a minimum of 24 hours immediately following the harvesting of cuttings to help 'dry' the wounded stems and thereby limit stem blight. Scout for disease by looking for the beginning of the brown/gray fuzziness on lower leaves that signal the need for disease control measures. Sanitation is an important first step to reduce *Botrytis* in your greenhouse. Remove dead plant tissue from greenhouse benches to prevent it from supporting sporulating *Botrytis*!

Fungicides can be an effective tool against Botrytis blight in the greenhouse and there are a plethora or treatments available to choose from. Industry standards that have been available for many years include Daconil WeatherStik, Affirm, and Decree DF. Newly registered products Pageant Intrinsic 38WG, Orkestra (Figure 5), Insignia WG, Broadform, Astun, Mural, and Palladium WDG are also excellent choices and should be included in a Botrytis blight control program. Due to the pathogens ability to reproduce and spread quickly, reapplication intervals should be shortened when environmental conditions favor disease development (Figure 12).

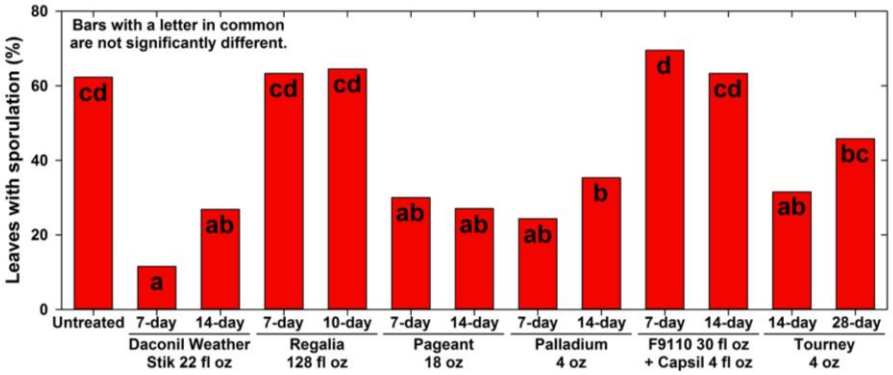

Figure 12. Evaluation of registered and non-registered products against Botrytis blight at various application intervals based on label instructions.

***Botrytis* 'A' Team**

Affirm WDG	19	polyoxin D zinc salt
Daconil Weatherstik SC	M5	chlorothalonil
Decree 50DF	17	fenhexamid
Broadform SC	11/7	trifloxystrobin/fluopyram
Pageant Intrinsic 38WG	11/7	pyraclostrobin/boscalid
Astun	7	isofetamid
Orkestra	7/11	fluxapyroxad/pyraclostrobin
Palladium	9/12	cyprodinil/fludioxonil
Mural	7/11	benzovindiflupyr/azoxystrobin
Medallion/Spirato	12	fludioxinil

Botrytis* 'B' Team

Compass O WDG	11	trifloxystrobin
Heritage WDG	11	azoxystrobin
Insignia WG	11	pyraclostrobin
Iprodione Pro/Chipco	2	iprodione

*Not recommended when disease pressure is high.

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