Diseases – Angular Leaf Spot to Wilt and How to Manage Them

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Accurate diagnosis is step one in disease management since there is no fungicide or other management practice effective for all diseases. From Angular leaf spot to wilt, there are numerous diseases that can affect pumpkins in the Northeastern USA. Fortunately there are resources available to assist with diagnosis. The *Pumpkin Production Guide* from NRAES has a disease identification key plus several pictures (www.nraes.org/publications/nraes123.html). There is also information and photographs at vegetablemdonline.ppath.cornell.edu. These resources also have management guidelines.

Angular leaf spot occasionally occurs in the Northeast. Leaf spots are angular because the pathogen cannot move through major veins. Spots are initially water-soaked, then turn brown, become dry, and may crack. Spots on fruit are small and round. Symptoms can also develop on petioles and stems. A milky substance that becomes crusty can exude from affected tissue under high humidity.

Seed and infested crop debris can be the source of bacteria that cause this disease. Therefore use pathogen-free seed and rotate out of cucurbit crops for at least 2 years. Also do not work in infested fields when leaves are wet to avoid moving bacteria on workers or equipment. Copper fungicides can be effective used early in disease development when there are few symptoms.

Downy mildew is a potentially devastating disease that occurs sporadically in the Northeast. It was severe in some areas in 2003. Only leaves are affected. Leaf spots are angular being delineated by leaf veins. Initially they are pale green, then yellow before the tissue dies. Extensive defoliation can occur when conditions are favorable. Leaf petioles often remain green and upright after the leaf blade has died and drooped. In contrast with powdery mildew, a more common disease, spores of the downy mildew fungus are darker (purplish gray) and develop only on the underside of leaves.

This fungal pathogen does not survive winter here, thus it only occurs when conditions favor spore production, release, and movement from where the disease is occurring plus favorable conditions for disease development where the spores land. These factors are being used to forecast where downy mildew will occur in the eastern USA. Forecasts are posted at a North Carolina State University web site (www.ces.ncsu.edu/depts/pp/cucurbit/). Fortunately, downy mildew rarely starts developing early enough in the growing season in the Northeast to be a major disease. But its destructive potential warrants checking forecasts and scouting for symptoms.

Broad-spectrum contact protectant fungicides provide some control. Apply systemic fungicides beginning when downy mildew is forecast to occur in the area or symptoms have just started to develop. Fungicide resistance is a concern with this pathogen, therefore alternate among systemic fungicides in different chemical classes. Systemic fungicides currently registered include strobilurin or QoI fungicides (eg Amistar, Cabrio, Flint), mefenoxam (eg Ridomil Gold Bravo), and phosphoric acid (eg Aliette). Amistar is a new formulation of azoxystrobin replacing Quadris. Cabrio has controlled downy mildew better than Quadris in some efficacy experiments.

Fusarium fruit rot has recently re-emerged as a major problem, especially in fields where pumpkins are grown with minimal rotation. A major outbreak occurring in CT and NY during the 1940's led to a reduction in commercial production of all cucurbits for several years. It was not reported again as an important problem until 1996. Significant losses were observed in several fields in 2002 and 2003 in the Northeast as well as elsewhere in the USA.

Symptoms develop on the side of fruit contacting soil, beginning as round water-soaked spots. These spots become whitish when the fungal pathogen produces spores. Brown rotting tissue extends well into the flesh. Two races of the pathogen have been described. Race 2 only causes fruit rot while Race 1 also infects root and stem tissue causing a crown rot.

Seed and infested crop debris can be the source of the fungus causing this disease. Therefore use pathogen-free seed and rotate out of cucurbit crops and corn for at least 3 years. No fungicides have been found to be effective. Incidence of fruit with Fusarium fruit rot, and also incidence of black rot, was lower where pumpkins were planted into rye straw mulch than where grown on bare ground during a study conducted in Ohio. A research project is starting in the Northeast to evaluate straw and living mulches.

Plectosporium blight (previously named Microdochium blight) is another potentially devastating disease. It is a new disease having been first observed in the USA (TN) only in 1993. It was first seen in the Northeast in 1999. Severe losses occurred in 2003 probably because rainy weather provided favorable conditions.

Symptoms occur on leaf veins, stems, and fruit. Lesions are white and have a very distinctive diamond to spindle shape that is characteristic for this disease. They are small initially, but can expand and coalesce, causing the entire surface of stems, leaf veins or fruit handles to turn white. Leaf tissue between veins is not affected, thus early symptoms are not as apparent as with other foliar diseases. Leaves eventually die and collapse, often in a 10- to 25-ft diameter circle around the site of initial infection. Dead vines can be so brittle they shatter when stepped on. Spots are more circular on fruit, and they remain small and don't coalesce.

The pathogen can survive in soil, therefore rotation is recommended for management. Chlorothalonil (Bravo, Equus, etc) applied regularly beginning at flowering or fruit set has provided effective control. Strobilurin fungicides are also effective, but their use should be limited to when they are needed most for overall disease control because of the high risk of selecting resistant strains of this or another pathogen that is also present. Restricted use will maximize the useful life of this important group of fungicides. Thus strobilurins are only recommended specifically for Plectosporium blight where this disease is a major concern. Strobilurins applications targeted for other diseases (e.g. powdery mildew, downy mildew, black rot) will also control Plectosporium blight.

Phytophthora blight continues to be a challenge to manage. Unfortunately it has been increasing in importance as it spreads into new areas. Symptoms include crown rot, tip blight, leaf spots, and fruit rot, the most common symptom occurring in pumpkin. Management focuses on preventing the pathogen from being moved into a new field and managing soil moisture to avoid saturated conditions that favor disease onset. Prevention is very important because Phytophthora blight is difficult to control once it starts, and after it has occurred on a farm it is challenging to continue growing susceptible crops without Phytophthora blight occurring, even in fields with no previous history. In addition, it is very difficult to suppress this disease once it starts to develop in a field.

It is important to use an integrated program with as many of the following practices as possible.

1. Avoid the pathogen if not already on a farm.
2. Long rotations (over 2 years) away from peppers, tomatoes, eggplants, lima beans, green beans and other cucurbits. This pathogen has recently been detected in roots of some weeds, including purslane, which means these plants will need to be controlled during rotation for this practice to be effective.
3. Select well-drained fields.
4. Plant cover crop in low areas.
5. Physically separate susceptible crops.
6. When growing small-fruited pumpkins, select varieties with hard rinds (eg Lil' Ironsides).
7. Subsoil between rows after planting to improve drainage. Also subsoil along driveways. Plant grass in driveways.
8. Don't move soil between fields on equipment or boots.
9. Irrigate as needed; not excessively.
10. Don't use pond or stream water draining from infested field for irrigation.
11. Fungicides have provided minimal control in efficacy trials and thus should not be relied on for managing Phytophthora blight. Currently available products include phosphoric acid (Aliette, Phostrol), dimethomorph (Acrobat), and zoxamide (Gavel). Chlorothalonil and copper fungicides, which are registered for other diseases, can also provide some control.
12. Scout routinely. Include any areas where water does not drain well or soil is compacted, such as driveways.
13. Disk affected areas plus border area if found early. Begin with border area.
14. Remove good fruit from affected field ASAP, especially if rain is forecast. Hold a few days then re-examine for symptoms before selling.
15. Don't display fruit in a field where blight occurred previously.

Powdery mildew is the most common foliar disease, occurring every year throughout the Northeast. White powdery fungal growth develops on both surfaces of leaves and on stems. Resistant varieties are available, but application of fungicides continues to be the main management practice.

<u>Powdery mildew needs to be controlled on both leaf surfaces</u> to avoid premature death of leaves. It is especially important to control powdery mildew on the underside of leaves where conditions are more favorable for disease development than on upper surfaces. <u>The best approach is to use systemic fungicides</u>. Advances are being made in sprayer technology to deliver more spray material to the underside of leaves. <u>Fungicide resistance is a major concern</u> with systemic fungicides. They generally have a high risk of resistance developing due to their specific mode of action. Powdery mildew fungi have a high potential for resistance development. In the USA, the cucurbit powdery mildew fungus has developed resistance to all chemical classes registered for controlling it: benzimidazole fungicides (Benlate, Topsin M), demethylation inhibiting or DMI fungicides (Bayleton, Nova, Procure), and strobilurin fungicides (Amistar, Quadris, Flint, Cabrio). Thus, <u>managing fungicide resistance is an essential component of effective powdery mildew control</u>.

General recommendations for managing powdery mildew and fungicide resistance are:

1. Reduce the need for systemic fungicides by selecting resistant varieties and not planting pumpkins next to spring cucurbit crops treated with systemic fungicides.

2. Use systemic fungicides only when needed and not curatively; this can be accomplished by scouting to ensure applications are started very early in powdery mildew development, and using protectant fungicides alone late in the growing season. An action threshold has been developed to time the first application of systemic fungicides for powdery mildew. The scouting protocol entails weekly examining both leaf surfaces of 5 old, crown leaves in at least 10 locations through out a field. Start applying systemic fungicides when powdery mildew is found on at least 1 of the 50 leaves. It is critically important to examine the underside of leaves, especially where a protectant fungicide has been used for other diseases. Towards the end of the season it may be possible to obtain adequate control without sacrificing yield by using just protectant fungicides.

3. Alternate among systemic fungicides with different modes of action and mixing these with protectant fungicides. Specific recommendations often change as resistance develops to a new group of fungicides and new materials are developed. A protectant fungicide is needed because it has multi-site activity and thus low resistance risk. It will control pathogen strains resistant to systemic fungicides.

4. Maximize control obtained with protectant fungicides by selecting a product with good efficacy and ensuring good spray coverage.

5. Assess efficacy to determine if resistance may have developed. Any disease control problems should be reported promptly to local extension specialists so that the possible cause can be investigated.

Many protectant fungicides are available for powdery mildew. They vary considerably in efficacy (Table 1) and also price. This group includes products approved by OMRI for organic production: biofungicides (Serenade), potassium bicarbonate (Kaligreen), oil (JMS Stylet-oil), sulfur, and copper. Sulfur and oil are more effective than chlorothalonil because they provide better control on the lower surface of leaves. Sulfur is the least expensive fungicide available. Micronized formulations (eg Microthiol Disperss, Micro Sulf) are recommended over wettable powders. Powdery mildew is the only disease controlled by sulfur, therefore it is critical when using sulfur to inspect a crop regularly for symptoms of other diseases. Chlorothalonil and copper are effective for more additional diseases than the other protectants.

Resistance has developed quickly to strobilurins. This group of fungicides has been available for commercial use in the USA beginning in 1998 when Quadris received Section 18 registration in some states for cucurbit powdery mildew because systemic fungicides available then, Benlate and Bayleton, were no longer adequately effective due to resistance. Federal registration was granted in March 1999. Resistance to strobilurins was first detected in field and greenhouse crops of melon and cucumber in Japan, Taiwan, southern Spain, and southern France in 1999, after just 1 to 2 years of commercial use.

Reduced efficacy with strobilurins was first noted in the USA in 2002. Most reports were from research fields where one treatment was a strobilurin used alone on a 7-day schedule (use pattern not labeled). Detecting resistance based on reduced control can be harder to do in commercial production fields than in research fields where plants treated with other fungicides and non-treated plants provide comparisons for determining that efficacy is reduced and ruling out poor application timing as the cause. Additionally, other fungicides used with strobilurins in a program designed for managing resistance, as is done in commercial fields, might provide enough control of powdery mildew to mask the presence of strobilurin resistant strains, especially if they are at a low frequency. Resistance to strobilurins was confirmed by conducting laboratory assays on isolates of the powdery mildew fungus collected from fields with poor control in GA, NC, VA, and NY.

Development of resistance to strobilurins greatly challenges powdery mildew management. Cross resistance occurs among strobilurins, thus a resistant isolate is insensitive to all products in this group. Resistance was shown to be qualitative, which means isolates of the pathogen were either highly sensitive to strobilurins or highly resistant. Control cannot be regained with qualitative resistance by applying the fungicide more frequently and/or at a higher rate or by switching to a more active fungicide in the same chemical class, in contrast with quantitative resistance. Resistance to demethylation inhibiting fungicides (DMIs) is quantitative. Degree of resistance to DMIs in the cucurbit powdery mildew pathogen in the USA presently is such that the old DMI fungicide Bayleton is no longer effective while newer fungicides such as Nova are effective when applied at high rates. There continues to be concern that using DMI fungicides will eventually select for pathogen strains with greater resistance to this group of fungicides such that Nova is no longer effective. Strobilurins are needed to continue playing an important role in managing this resistance, therefore it is prudent to use them wisely in order to prolong their useful life. However, a further challenge to managing powdery mildew and resistance is that most of the 2002 strobilurin-resistant isolates tested also exhibited reduced sensitivity to DMI fungicides. Isolates collected in 2003 are being tested now.

To develop recommendations for managing powdery mildew with strobilurins, information is needed on occurrence of strobilurin resistant pathogen strains before these fungicides are applied and information is needed on impact of applying strobilurins on frequency of resistant strains. Obtaining this information was the goal of a project conducted on Long Island, NY, during the 2003 growing season. Fungicide resistance was monitored using a seedling bioassay. Squash seedlings were treated with fungicide, then placed with non-treated seedlings in a production field for a day. Afterwards seedlings were kept in a greenhouse until symptoms appeared. For the first assay, seedlings were placed during late July in spring plantings of squash that had not been sprayed with systemic fungicides. Powdery mildew starts to develop in spring squash before main season plantings of pumpkin, melon, etc. Resistance to strobilurins was detected at a low level in one of five fields. A second assay was conducted at the end of August in pumpkin fields where systemic fungicides had been used. DMI and protectant fungicides had been used in all 7 fields; strobilurins in 6 fields. Resistance to strobilurins was detected in all fields. Several strobilurin-treated seedlings had as much powdery mildew as non-treated plants indicating a very high frequency of resistance. Seedlings treated with a DMI fungicide had less powdery mildew, indicating a lower percentage of isolates with reduced sensitivity to this fungicide group. Powdery mildew did not appear to be suppressed very well on the underside of leaves in these fields. Resistant strains were also detected during a third assay conducted in organic and conventionally-managed fields that had not been sprayed with systemic fungicides. Widespread distribution on Long Island of strobilurin-resistant powdery mildew strains is alarming. Poor control possibly due to resistance has been reported elsewhere in the USA in 2003. Fortunately, there were also areas where strobilurin fungicides appeared to be effective, especially where disease pressure was not very high and good fungicide programs were used. Thus strobilurin fungicides may continue to be important tools for managing cucurbit powdery mildew in some areas.

Several fungicide programs were evaluated in 2003 on Long Island where strobilurin-resistant strains occurred. On September 8 after 5 weekly applications (August 7 – September 6), the strobilurin fungicide Flint (2 oz/A) applied in alternation with sulfur (4 lb/A Microthiol Disperss) was providing poor control (37% on upper leaf surfaces and 0% on lower surfaces). Control was improved by applying sulfur every week and applying on alternate weeks a DMI fungicide: using Nova (5 oz/A) provided 84% and 48% control on upper and lower leaf surfaces, respectively;

Procure (6 oz/A) provided a similar level of control (89% and 34%). Applying a DMI fungicide every week in this program with Flint and sulfur by alternating between Nova and Procure did not improve control significantly (86% and 52%). Control was not improved by applying Flint and Procure more than once in a fungicide program with weekly applications of sulfur, most likely due to high frequency of resistant strains; Flint plus sulfur applied week 1 followed by Procure plus sulfur week 2 then sulfur alone weeks 3 – 5 provided 68% and 24% control. Sulfur applied alone weeks 3 – 5 did contribute to control; where only the week 1 and 2 applications of Flint, Procure and sulfur were made, powdery mildew on September 8, 25 days after the last application, was as severe as where no fungicides were applied. There was also no significant differences in amount of defoliation on September 22: 66% where the two applications were made and 76% where there were none, versus 21% where there was an additional 3 applications of sulfur. Flint used with sulfur as the protectant fungicide was more effective than Quadris used with Bravo (Procure included in both programs), which provided 45% and 19% control. In comparison, 95% and 91% control was obtained with an experimental fungicide.

When selecting powdery mildew resistant (PMR) varieties, it is important to know the degree of resistance and the potential for other diseases to occur when less fungicide is used for powdery mildew. Some fungicides have broad-spectrum activity and thus will control additional diseases. Resistant varieties should be scouted weekly for powdery mildew, as well as other diseases, regardless of the variety. Resistance is not immunity, and new races can arise at any time. Resistant varieties differ in the degree of resistance depending on the number of resistance genes they have. There are at least two genes for resistance plus several modifier genes. Varieties with genes for resistance from both parents (eg PMR Aladdin) will be less severely affected by powdery mildew than those with a single resistant parent (eg Merlin and Magic Lantern). A reduced fungicide program is recommended with PMR varieties to improve control of powdery mildew and lower selection pressure for new races of the pathogen able to overcome genetic resistance. Fewer applications will be needed compared to a susceptible variety because disease onset generally is delayed and a 14-day spray interval can be as effective as a 7-day interval. Additionally, biocompatible fungicides (eg potassium bicarbonate, biofungicides) can be as effective for controlling powdery mildew as conventional fungicides when combined with genetic resistance. Some PMR varieties are more susceptible to bacterial wilt.

Wilt caused by bacteria (bacterial wilt) has recently become a greater problem on pumpkin, which was previously considered a minor host compared to cucumber and melon. This may be partly due to presence of new strains of the pathogen and greater susceptibility of some new varieties.

Initial symptoms of wilt are pale, wilted sections of leaves that are often associated with feeding injury. Leaf tissue between veins becomes yellow while main veins often remain green even after the rest of the leaf tissue dies. Plants may have shortened internodes causing branches to have a "tufted" appearance. Symptoms of bacterial wilt progress from localized leaf symptoms to collapse of individual vines and eventually to plant death. When plants are affected young they often die quickly. Older plants may continue to grow, but fruit will be small and/or soft.

A common diagnostic test for bacterial wilt involves cutting a wilted vine close to the crown of the plant, rejoining the cut surfaces for a moment, then slowly drawing apart the cut ends. Only with this disease will there be strands of a sticky clear substance between the cut surfaces. The strands are masses of bacteria streaming from xylem tissues. The procedure may need to be repeated several times to obtain these strands.

Bacteria that cause wilt survive overwinter in cucumber beetles. There is no evidence for transmission in seed or survival in soil. Bacteria do not survive long in dried plant debris.

The bacterium causing this disease cannot be controlled directly with pesticides, therefore, management practices have targeted the insects that harbor and vector the pathogen, which are the striped and spotted cucumber beetles. Control is complicated because the presence of beetles alone is not indicative of an impending wilt epidemic. In the absence of the pathogen, a much higher beetle density can be tolerated by the crop. However, if growers wait until disease symptoms occur to treat the beetle vectors, subsequent control of wilt is erratic. Neonicitinoid insecticides (eg Admire) are a valuable tool for managing bacterial wilt because they are systemic and can be applied in furrow when direct seeding or to seedlings before transplanting, thus control is provided to young plants which are very attractive to beetles and susceptible to wilt.

Perimeter trap cropping is an alternative management strategy recently demonstrated to be effective under conditions in the Northeast by Jude Boucher in CT. It entails planting 'Blue Hubbard' squash, or another cucurbit crop that is highly attractive to cucumber beetles, around the edge of a cucurbit crop and targeting insecticide applications to this trap crop.

Two PMR pumpkin varieties, 'Merlin' and 'Magic Lantern', are more susceptible to wilt than other pumpkin cultivars. Therefore wilt needs to be controlled more aggressively when these varieties are grown. 'Merlin' is the most susceptible. This is not due to greater attractiveness to beetles based on beetle density or feeding damage. These varieties were developed in an area where bacterial wilt does not occur. Fortunately wilt susceptibility does not appear to be linked to PMR genes. An experimental pumpkin line closely related to 'Magic Lantern' that has resistance from both parents was not more susceptible to wilt than 'Magic Lantern' as would be the case if these two traits were linked

Table 1. Percent control of powdery mildew achieved on upper and lower surfaces of pumpkin leaves with fungicides and health-promoting fertilizers applied weekly in experiments conducted in Riverhead, NY, in 1997 to 2002.

	Upper leaf surface						Lower leaf surface					
Fungicide and rate/A	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
Serenade 6 lb					36 b	23 ab					8 abc	10 bc
Milsana 1%			45 b	85 b	59 c				21 ab	26 b	10 a-d	
Armicarb 100 4 lb				23 a	62 c					23 b	16 bcd	
Kaligreen 2.2-5 lb	65 ab				62 c	47 cd	45 bc				5 ab	6 bc
Prudent Plus 1.4-2.5 qt					40 b	47 cd					17 bcd	0 ab
Nutrol 20 lb	60 ab	66 cd			68 c	50 cd	29 b	24 b			21 d	16 c
Prudent Plus 2 qt + Nutrol 10 lb						61 de						18 c
Kocide 2000 2-2.25 lb	98 f-h	72 de	64 b		84 d	60 de	60 c-e	20 b	26 ab		19 cd	0 a
JMS Stylet-oil 1.5%					93 e	59 de					55 f	4 abc
Microthiol Disperss 4 lb	99 g-j	96 i	69 b		93 e	76 e	72 d-f	63 efg	31 ab		53 f	10 bc
Bravo Ultrex 2.7 lb				97 cd	98 e	78 e				14 ab	37 e	10 bc
Quadris 15.4 oz alternated with Nova 5 oz + Armicarb				100 efg						100 g		
Quadris 15.4 oz alternated with Nova 5 oz + Bravo		93 i	100 d	100 e	95 e	45 bcd		58 ef	84 de	98 fg	72 g	18 c

Numbers in a column with a letter in common are not significantly different according to statistical analysis using Fisher's Protected LSD. Numbers with an 'a' are not significantly different from nontreated, thus control is really 0% ('a' or ‘b’ for lower leaf surface in 2002).