Identifying and Managing Powdery Mildew in Mirlitons (Chayote)

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Powdery mildew is one of two plant diseases that have the most damaging effects on mirlitons (scientific name Sechium edule and more popularly known as chayote). While anthracnose almost universally affects mirlitons in their first year, powdery mildew is less frequently a problem, but can kill a plant and make it susceptible to a more severe anthracnose infection later. Fortunately, unlike many plant diseases, preventative practices and organic fungicides can control and even eradicate powdery mildew on mirlitons. The same organic fungicide that effectively controls powdery mildew is equally effective for downy mildew.

Powdery mildew is a general disease description for a set of symptoms caused by specific toxic fungus. There are many different fungi strains that cause powdery mildew disease in different plants. When a fungus is "host specific," it means that the fungus causes powdery mildew disease only on specific "host" plant species. In mirlitons, which are in the cucurbit pant family (squash, pumpkins, cucumbers, etc.), a fungus with the scientific name *Podosphaera xanthii* is the primary cause of powdery mildew disease. It is an "airborne" fungus which means it is spread by wind, but it can also be transmitted by water splash and insects and humans can inadvertently transfer the fungal spores which are microscopic and can cling to skin or clothes.

Until a few years ago, scientists thought there were only a few "physiological races" of the Podosphaera xanthii (P. xanthii). But increasingly sophisticated techniques, including molecular marker analysis, have established that there are 28 physiological races of Podosphaera xanthii fungus and some of these are more virulent than others. The increase in the total number of races the byproduct of more accurate sophisticated analysis methods, better global reporting systems, and also a result of the repeated use of specific fungicides that resulted in the fungus adapting to fungicides and forming new resistant races.

Identification, Damage, and Fungus Life Cycle

There is no published research on the signs and symptoms of powdery mildew in fieldgrown mirlitons in North America. There is one laboratory study (of a plant I submitted for analysis) but that was conducted in greenhouse conditions where the plant was not exposed to heavy rains and wind. Most of what we know about the powdery mildew signs and symptoms in mirlitons comes from grower observations and from research literature on related plants in the cucurbit family—especially cucumbers. The problem is that the signs and symptoms of powdery mildew in mirlitons are quite

different than in other plants, so virtually everything you will find on the internet is misleading.

Powdery mildew normally infects mirlitons in the cool months of the spring. The most obvious sign of the disease are irregular round yellow blotches on the leaves—frequently leaves at the bottom and center of the plant where there is less light and air circulation.

Over a period of days, these yellow blotches grow and combine (coalesce) until the entire leaf turns yellow (chlorotic) and dies, withering into brown, papery leaf remnants. Since P. xanthii fungus on the leaves is constantly releasing new spores (conidial spores), the disease tends to move along the vine from leaf to leaf by way of wind or water splash. Although leaves provide the most obvious signs of powdery mildew in mirlitons, the fungus also affect leaf petioles, stems and tendrils.

Depending on the extent of the infection, the disease can reduce fruiting by damaging stems, or it can become severe enough to defoliate the entire plant until it wilts and dies in extreme heat. An early powdery mildew infection will weaken the plant's natural defenses and contribute to a later anthracnose infection. Powdery mildew also occurs at the same time as gummy blight, another fungal disease, and the symptoms are difficult to distinguish. Despite the damage to the plant, powdery mildew does not host on the mirliton fruit, so it cannot damage the fruit, nor can it be transferred through seed fruit, since any spores on the fruit surface will die within a few days of storage.

The confusion in making a field diagnosis of powdery mildew is that most plant disease books and articles specify that the principal sign of the disease is a white talc-like powder (a concentration of fungal colonies) visible only on the upper leaf surface. This is not the case with mirlitons in South Louisiana. Perhaps because of the heavier rains or perhaps because the mirliton upper leaf surface (adaxial surface) is different than other cucurbits, mirlitons infected with powdery mildew in the Deep South almost never exhibit this disease sign (water can wash off P. xanthii from leaf surfaces). In Louisiana, I have only seen this symptom on a few infected leaves in the spring during prolonged dry spells. It is more than likely that a mirliton plant will become infected with powdery mildew and lose most of its leaves without ever displaying the white powder on the upper leaf surface because the fungus is primarily growing on the underside of the leaf, and the top-yellowing is a byproduct of the fungus feeding off leaf tissue. Using a hand lens, the fungus is visible on the bottom of the leaf since the fungus spreads on the leaf surface by way of the cottony thread-like mycelia.
(see photograph on next page)

Healthy mirliton leaf.

First signs of powdery mildeware irregular rounded yellow blotches.

Yellowing spots caused by fungal growth on underside of leaf are growing together in bottom leaf and have completely coalesced in top leaf to kill a section of the leaf. Eventually the entire leaf will resemble the brown dead section. Note also the tendency of the infection to follow a wedge formation from the leaf margins.

Top view of infected leaf with some living green tissue

The best way to make a preliminary diagnosis of powdery mildew (field identification) is to scout the plant daily and look for yellow-splotched leaves. If you find a leaf with yellow round blotches, remove a healthy leaf with no signs of disease, and then the diseased leaf (keeping in mind that handling a diseased leaf and then the touching rest of the plant can spread the fungal spores). Examine the bottom of the healthy leaf with 30x hand lens which can be purchased inexpensively on-line. Or you can use a digital camera

with a macro function to take a close-up photograph of the leaf underside. This will give you a good idea of what a healthy leaf looks like—normally the underside will look uniform and from a side view, looping the leaf over your finger, you will see a forest of clear cone-shaped growths that are leaf hairs. Now examine the underside of the leaf directly where there are yellow blotches. Powdery mildew will appear to be tiny white cottony strands—sometimes growing above the leaf surface, but also sometimes combined into small matted patches. The white cottony strands are called mycelia—they are branches of the fungus spreading throughout the plant and are a reliable sign of the disease.

Close-up photograph of underside of mirliton leaf infected with powdery mildew. The tiny white tufts and filaments are the mycelia of the Podosphaera xanthii fungus that causes powdery mildew. The bottom of a non-infected healthy leaf would not have these cottony growths. Note that they are colonized on tissue that is beginning to turn yellow or brown and beginning to die. To download this and two other photographs of infected plants, go to the photos section of the www.mirliton.org

It requires a compound microscope of 100x-400x to clearly view the main fungal structures that attach to the leaf surface and produce spores. Scouting plants daily in the

spring is important to detect powdery mildew and begin control practices at the first indication of plant disease. The existence of one leaf in 50 with clear signs of powdery mildew is a sign to start active disease control with organic fungicides.

If you don't have a hand lens, "chambering" a leaf is a useful way to test for powdery mildew. Remove a yellow-splotched leaf that still has at least 50% green surface and place it in a one-quart zip-lock plastic bag with a paper towel that has been wetted and then the water squeezed out. Place the bag outside but in the shade and covered to prevent light from reaching it. Mark the bag with the date the specimen was collected. Check the plant every few days: if the plant has powdery mildew fungus, the cottony growths on the leaf underside will become visible to the naked eye and the white talc-like powder may appear on the top surface. In a sense, you are using the live leaf as a petri dish to culture the fungus. To make a definitive analysis, send a freshly infected leaf to your local extension service according to their requirements.

Although the larger yellow circular blotches are an easy disease sign to detect, sometimes the first signs of powdery mildew are reddish-brown, small restrained spots on older leaves. This is because the more mature leaves have better defenses against infection and encircle the spores with protective tissue before they can germinate and grow. But the spots are a sign that spores are landing on the plant and are likely to fare better on interior younger leaves.

Occasional leaf yellowing is a normal for mirlitons. Mirlitons transplanted from containers almost always lose all the leaves and stems that existed in the container plant; they are quickly replaced by new shoots and are no cause for alarm. Leaf yellowing can also be caused by irregular rainfall and watering, insect damage, soil imbalances, and minor root problems. It is easy to distinguish powdery mildew from other causes of leaf yellowing if you understand the life cycle of the disease and invest in hand lens which can assist in making a tentative diagnosis. Plant disease tests through your local agricultural extension service are not expensive and enable you to test the accuracy of your own tests (hand lens observation and chambering) so that you don't always have to rely on laboratory tests.

Finally, it is crucial that you perform a basic soil test before you start growing mirlitons—or any vegetable. In urban areas, almost all yard soil had been brought in from commercial sources to elevate homes and level yards. The "fill dirt" and "garden soil" industry is completely unregulated; products sold as "top soils" "garden soils" and "raised beds soils" can contain elements that inhibit plant growth or improperly composted materials that are toxic when mirlitons require rapid water uptake in summer months. The first step in diagnosing plant problems is ruling out soil problems. While national brand potting mixes and growing media are regularly tested and safe to use without testing, we recommend that you don't purchase soils locally unless the vendor guarantees that the soil will meet extension service standards—and then get a test before you plant.

Life Cycle:

Powdery mildew generally infects mirlitons in the spring when the conditions are ideal for fungal growth. Podosphaera xanthii fungal spores come from two sources; "ascospores" survive through the summer in "fruiting bodies" that are spherical sporeprotecting structures (cleistothecia)—which function like a seed coat in a plant seed. Spring rains followed by a dry spell cause these cleistothecia to open and release millions of spores into the air. If a plant had a long powdery mildew infection the previous year, the spores that infect it in the second year may come from this source in the soil beneath the vine. Although airborne spores can only survive 24 hours without living tissue to grow on, winds can spread them over several hundred miles (some studies have found that spores can last seven days airborne and can travel several hundred miles).

The other type of spore, and the most common, is called "conidial spores." These are spores released by the fungus as it grows on the plant. When a spore lands on the mirliton leaf, much like a seed putting down roots, it germinates by sending down an infection tube into the leaf epidermis and then developing a feeding structure (haustorium) that extracts nutrients from the leaf—at the leaf's expense. Within 3-7 days the plant is infected, and the first symptoms occur; yellow blotches on the top leaf surface caused by fungal colonies on the leaf underside that are destroying the chlorophyll producing process in cells. With the feeding structure (haustorium) providing the energy, the fungi expand by sending up microscopic cylindrical chain-like stalks (conidiophores). The tips of the conidiophores break off as spores and are carried off by wind or water to infect other leaves (sporelation). Simultaneously, the fungi spread out on the bottom leaf surface by way of the branching cottony mycelia. In this way, with thousands of conidiophores releasing countless spores, we can see how a small infection on one leaf can rapidly spread epidemically throughout the plant—and how other plants in a garden can also be the source of spores (inoculum). Since the spores can be transferred by hands or carried on cloth, it makes sense to minimize contact with infected plants and not move from infected plant to healthy plants. Washing hands after handling infected plants helps but spores are not affected by alcohol; garden implements used on mirlitons should be soaked in a 10% household bleach solution for 20 minutes (one-part bleach, 9 parts water) to kill spores.

Every plant fungal toxin has its own uniquely ideal germination conditions. For powdery mildew, ideal germination of the spore on the plant is during moderate temperatures between 60°F. and 80°F. with periods of 40% relative humidity (optimum is 61°F. at night and 81°F. during the day). The warning signs for a potential powdery mildew season are humid, overcast warm days and cool nights. If the spores originate with the cleistothecia, the optimal conditions are a rainstorms that opens and releases the ascospores, followed by several days of dry, warm weather that disperses the spores. Unlike anthracnose, powdery mildew does not flourish in standing water and, in fact, unattached spores can be washed off leaf surfaces by water, so an intermittently dry and cool spring is ideal for infection. Temperatures above 95°F. inhibit germination, so typically in our sub-tropical climate, summer temperatures in the mid 90s and heavy constant rain showers restrain powdery mildew growth, but only use of an eradicant fungicide and then preventative fungicide can stop the infection. Typically, if a mirliton makes it through August without an active infection, there is little likelihood that it will

develop a new infection September-December (which is the case with anthracnose as well).

It is rare to find the "fruiting bodies" cleistothecia containing spores at mirliton sites since these spore-carriers develop late in the season when the disease tends to abate. Since Podosphaera xanthii airborne spores can only live on living tissue, the question is what is the most likely source of spores between growing seasons? As we will see, the main culprit for spreading powdery mildew is probably humans themselves.

Disease Management:
There are no mirliton varieties known that are resistant to powdery mildew. But virtually all other garden-grown cucurbit seed sold has been hybridized or genetically altered to have some resistance to Podosphaera xanthii. That's not good for mirlitons. The powdery mildew fungus can still grow on resistant plants and produce spores (sporelator). The infection is reduced in the resistant plant so that it can fruit, even if production is reduced, but the plant still functions as a constant source of airborne spores that can easily infect a mirliton growing in the same area. I have seen this in gardens in which a resistant squash plant had clear signs of fungal growth (leaf-top white powder) which meant it was releasing thousands of spores into the air. In some cases, growers use the same trellis for mirlitons and other cucurbits such as cucuzza. At the bottom of this article is a link to a list of all plants that host the fungus that causes powdery mildew in mirlitons, including non-cucurbits such as sunflowers and verbena flowers. Not all powdery mildew is caused by Podosphaera xanthii fungus: for example, the fungus that causes powdery mildew in roses is a different species and cannot infect mirliton--nor will fungicides for powdery mildew in mirlitons work for roses.

Growers have one of two options to decrease the chance of spore spread to their mirliton from other plants. (1) Don't grow other cucurbits in your garden or (2) start a preventative organic fungicide treatment before the disease appears and as soon as the mirliton sends up shoots and be prepared to increase to eradicant levels if the disease establishes itself (more on fungicides later).

Preventative (Cultural) Practices:
In addition to limiting exposure to other sources of Podosphaera xanthii spores (this is called "reducing the inoculum load"), there are many methods that growers can use to reduce the likelihood of infection. Sun is a natural fungicide, so exposing the plant to the most sun possible helps: it is one of the main reasons that we recommend a horizontal trellis which provides direct sunlight to most of the leaves. Good air circulation helps as well. Using a wire barrel trellis as a ladder for the vine to move from the ground to the horizontal trellis prevents bunching in the middle of the plant and reduces having to physically string-up stems to the overhead trellis, which can spread spores (see link below). Powdery mildew tends to start in the middle of the plant where there is the least sun and circulation and the most leaf-to-leaf contact.

Above all, if you container plant mirlitons to over-winter them outside, make sure that you don't create an ideal "micro-climate" for powdery mildew. I have seen infections in

plants because they were bunched together against a wooden fence which blocked full sun, limited air circulation, and also created a fog-trap. These conditions were ideal for powdery mildew and all the plants—which were also crowded together and stressed by irregular watering, contracted the disease.

Once leaves are infected, if you are not using a fungicide that stops the spread of the disease to other leaves, then prune off the infected leaves and dispose of them away from the plant so they cannot spread spores. Monitoring the spread of the disease can be done by placing a twist-tie around the base of a healthy "control" leaf that is adjacent to an infected leaf and then monitoring for yellowing on the control leaf (the same technique can be used to monitor the effectiveness of fungicides). Practice standard garden sanitation and be careful not to transfer spores from leaf to leaf or from one plant to another. If you hand-pollinate your mirliton, be careful not to touch leaves—a small artist paint brush works well.

Fungicides:
There's a good deal of bad advice floating around the internet about fungicides—and most of it is bad for mirlitons. First, yes there are very effective synthetic fungicides that can ensure 100% eradication of powdery mildew. We don't recommend synthetics, especially since some are a danger to humans during application and most are systemic—meaning the fungicide enters the entire plant system. The imported mirliton sold in grocery stores are treated heavily with synthetic fungicides and pesticides. Podosphaera xanthii is a particularly resourceful fungus that adapts to synthetic fungicides about as fast as the agro-companies can produce them. The downside of that is that synthetic fungicides help create new strains of the fungus as they adapt to new fungicides. I have included a link below to an article on the adaptability of the powdery mildew fungus.

Fungicides can function as protectants, eradicants, or both. Protectants simply prevent the spores from germinating and infecting the plant; eradicants kill the fungus. The problem with most organic fungicides is that they are lethal to mirlitons (phytotoxic) if used during temperatures above 85°F. In South Louisiana and along the Gulf Coast, it is common to experience temperatures at or above this level as early as April. This means that these potentially phytotoxic fungicides can only be used for a few weeks during the Spring growing season, or used in cooler latitudes. These phytotoxic fungicides include sulfur, Bordeaux mix, and horticultural oils. It is recommended that you research any organic fungicide thoroughly before applying.

There are protectant and eradicant organic fungicides that can be used at any temperature and are more effective than some synthetic fungicides, though the science is newer on these and, again, there are no controlled studies of their effect specifically on mirlitons. I have experimented with potassium bicarbonate (KHCO3) which kills the fungus quickly by dehydrating it (P. xanthii's principal structures are exposed on the surface of the plant and are susceptible to desiccation). I found it an effective eradicant, but it did cause damage in temperatures above 90° to the tendrils and young meristem leaves. Since tendrils stimulate stem growth, this means the plant does not grow much while being

treated at the eradicant level solution (two tablespoons per gallon, applied in the evening once a week for at least three weeks, both top and bottom of leaves.

To find the product, Google for "potassium bicarbonate" and “LD Carlson.” The company sells certified 99% pure potassium bicarbonate.

Conclusion:
Powdery mildew can be a fatal disease for mirlitons; but the good news is that it can be controlled and managed with vigilance, knowledge of the disease’s life cycle, signs, and symptoms, and preventative actions and prudent use of environmentally safe fungicides.

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