Graduate Research Project

Survey of Powdery Mildew and Gray Mold Disease Management in Virginia and North Carolina Cut Flower Farms

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Abstract

Powdery mildew and gray mold diseases have potential to cause significant economic losses to cut flower growers. Information is needed on the effects of these diseases on growers' returns and the effectiveness of practices to control the diseases. A survey was conducted to examine powdery mildew and gray mold disease management practices on cut flower farms in North Carolina and Virginia. Twenty cut flower farmers completed an online survey and eight of those respondents also participated in an interview. The survey gathered information about the farms, such as its acreage and number of years growing cut flowers, flower genera affected by the diseases, fungicide use and efficiency, and cultural control use and efficiency. The survey and subsequent interviews provided several major findings. First, the floral genera most affected by powdery mildew in North Carolina and Virginia were *Zinnia,* followed by *Dahlia.* The genera most affected by gray mold were *Ranunculus,* followed by *Anemone* and *Dahlia.* Second, crop loss due to each disease was mostly at the 0 to 10% level, with one farm losing 91 to 100% of *Phlox* crops to powdery mildew and another losing 81 to 90% of *Tulipa* crops to gray mold. Third, 40% of respondents have not used any fungicides for disease management; and for those who have, neem oil was the product they used most frequently. Fourth, all respondents considered sustainability very important when making disease management decisions; this was supported by their extensive use of cultural practices for disease control, in addition to their preference of nonchemical approaches and biorational products over synthetic pesticides. The commonly used cultural controls included, crop rotation, proper watering, disease resistant cultivars, sanitation, proper spacing, and weeding. Findings from this survey will help cut flowers growers in the Mid-Atlantic region to better manage these two important diseases.

Introduction

The popularity of cut flower products and farming has grown in the last couple of decades. In a survey conducted by Granitz (2014), 67% of cut flower producers stated that they had an increase in demand for locally produced flowers. The Association of Specialty Cut Flower Growers members increased from 500 in 1996 to 1700 in 2014 (Loyola, et al., 2019). In the Floriculture Crops: 2018 Survey conducted by the USDA, the number of cut flower producers that made $100,000+ in sales increased from 444 in 2015 to 532 in 2018. Cut flower farms produce flowers and foliage, which are harvested by cutting and used to make bouquets and other decorations. Powdery mildew (Erysiphales) and gray mold (*Botrytis cinerea*) are two common fungal diseases found on many horticultural plants, including cut flowers.

Powdery mildews are caused by obligate pathogens; therefore, these pathogens need living hosts to reproduce and grow. The species of powdery mildew fungi are often host specific. For example, one species of powdery mildew may infect aster but not delphinium. Common disease symptoms and signs include white powdery looking mycelium and spores mostly seen on the upper side of leaves; leaves may also become distorted, wilted, and eventually blighted. Environmental conditions that favor this disease are high humidity at night, low humidity during the day, and temperatures around 70 to 80^{o}F. Spores are carried by wind to the leaves where they will germinate. Water on the leaves inhibits spore germination (Moorman, 2014).

Gray mold is a common disease that can affect many kinds of plants. Common disease symptoms include brown spots on petals that increase in size over time, leading to flower death and sometimes death of the entire plant, flower buds that do not open, irregularly shaped leaves with dead areas that form a bull's eye pattern, and stem cankers. *Bortytis cinerea* survives on dead plant tissue and the reproductive spores travel by wind or water onto living plants. High humidity or wet conditions are favorable for the disease; the spores quickly die in dry conditions (Hudson and Schraufnagel, 2004). The disease is usually most severe under cool temperatures and extended periods of wet conditions (ISU Extension Outreach, 2019).

Powdery mildew and gray mold can cause a great amount of damage if not controlled properly; therefore, learning what disease management practices are being used by local farmers and how effective they are could aid in management decisions made by other farmers. Cultural control practices, such as watering, soil management, and crop spacing, influence the environment of the plants. Those practices are used along with fungicides for disease control. For cut flower growers there is a lower threshold of tolerance for disease damage because of the need for the flowers to be attractive and almost aesthetically perfect for them to be profitable (Gullino et. al, 2015); therefore, implementing effective control practices is especially important. Specifically, this study focused on the following questions.

- What are the major cut flower crops affected by powdery mildew and gray mold in North Carolina and Virginia?
- During what stages of plant growth and which seasons are cut flowers affected by these diseases in North Carolina and Virginia?
- Which cultural management practices are used on farms to prevent these diseases and how effective are they?
- What fungicides are used on farms to control these diseases and how effective are they?

Literature Review

The USDA Floriculture Crops: 2018 Survey recorded information from producers of bedding and garden plants, potted plants, herbaceous perennials, indoor foliage, propagative materials, cut flowers, and cut cultivated greens. The data within that survey was separated into two groups; floriculture operations that produced $10,000 and greater in sales and operations that produced $100,000 and greater in sales. Data on cut flowers was only given for operations that had $100,000+ in sales. It was determined that the wholesale value for cut flowers produced domestically had increased by 3% from $294 million in 2014 to $374 million in 2018 (USDA, 2016, 2019). A survey conducted by Loyola et al. (2019), specifically looked at North American specialty cut flower production and post-harvest problems, and customer issues. For cut flower production, disease management was the third most important problem while insect management was the first, and crop timing was the second. Powdery mildew was a significant problem for phlox and zinnia and was one of the most serious issues for zinnia production. Around sixteen percent of respondents said gray mold was an issue for peony. Among post-harvest issues, gray mold was the least important issue while hydration, shattering, stripping leaves, temperature, and timing were some of the most important issues (Loyola et al., 2019).

The 2017 Southeastern U.S. Pest Control Guide for Nursery Crops and Landscape Plantings includes conventional fungicides that are recommended for these diseases. Fungicides recommended for gray mold include azoxystrobin, captan, chlorothalonil, copper compounds, cyprodinil + fludioxonil, dicloran, fenhexamind, fluoxastrobin, fludioxonil, iprodione, mancozeb, metconazole, potassium bicarbonate, thiophanate methyl, and triticonazole. Many fungicides recommended for gray mold can also be used for powdery mildew; in addition, piperalin, propiconazole, and tebuconalzole can be used for powdery mildew control. Most of the fungicides for gray mold control had an effectiveness rating of fair (relative control rating of 50-79%) to good (relative control rating of 80-100%). The copper fungicides only had a fair rating for gray mold and a good rating for powdery mildew. The control ratings were not species-specific (Chong, Neal, Springer, and Williams-Woodward, 2017).

There are alternate control methods associated with sustainable farming that do not include conventional fungicides but focus on organically approved fungicides and/or mostly cultural control methods. Alternative chemical controls for gray mold include baking soda solutions, copper sulfate, Bordeaux mixture, copper hydroxide, and horticulture oil. Recommended cultural controls include using resistant cultivars, proper air circulation, removing infected plant parts, proper watering, good drainage, avoiding overhead irrigation and avoiding crop shading. Alternative chemical controls for powdery mildew include insecticidal soap, neem oil, horticulture oil, and sulfur. Cultural controls include removing infected plant parts and weed hosts, proper watering, and avoiding over fertilization (Greer, 2000).

Existing floriculture surveys typically covered how many growers are producing different types of ornamentals, profits, diseases, and pests, and covered large areas, such as the entire United States. No surveys covered which practices and products are used for disease management in smaller areas such as North Carolina and Virginia. This survey will add to the

results of the Loyola et al. (2019) survey by providing more data on the flower genera impacted by powdery mildew and gray mold as well as the practices used to control those diseases in Virginia and North Carolina. Although information is available online and in print about recommended chemical and cultural control practices for these diseases, this survey provides data on which products and practices growers actually use.

Methods

The research pool for this study was farms that grew cut flowers for profit in Virginia and North Carolina. The survey was created online using Qualtrics (Qualtrics Software Company, Provo, UT). The questions were devised to gather information about the degree to which the two diseases have been present on the respondent's farm, which flower species have been affected, cultural control practices, and fungicides used to manage these diseases. Cut flower farmers were contacted through an email that explained the survey and included a link where they could complete the survey. Ninety-three farmers were contacted by email and 20 respondents took the survey. Each respondent was asked if s/he was willing to answer further questions in an in-person or phone interview. Two of the respondents agreed to an in-person interview and six agreed to a phone interview. Supplemental questions, such as reasons why they wanted to grow cut flowers and specifics on how the farmers approach disease management, were asked during the interviews. The data were collected from February 2019 through July 2019.

Background questions, including the age of the farm manager, acreage of the farm, number of years in flower farming, and annual sale range, were asked at the beginning of the survey. The importance of the diseases as a limiting factor and the importance of sustainability on the farm were ranked from very to not at all important. The respondents were provided with a list of flowers and asked to select those that have been affected by the diseases, powdery mildew and gray mold. If a flower was selected as impacted by the disease, then respondents were asked about the stages of plant growth at which the flower is affected, percentage of crop lost, season when the disease is seen, and if/when they use fungicides to control the disease. Fungicides were selected by respondents from a specified list and an option to enter another fungicide was available. Respondents ranked effectiveness from very to not all effective for each fungicide selected. Cultural controls were selected from a list of examples with the option to write in other practices and the effectiveness of each practice in slowing the disease progression was ranked from very effective to not at all effective. The importance of environmental sustainability to the respondent when making disease management decisions during flower production was ranked from very important to not at all important. Survey takers were asked if they have received assistance from any services for disease management and given the choices: state diagnostics laboratory, university or extension service, other, or none. The questions were generalized to the production of cut flowers on the entire farm and did not separate practices or impacts seen in greenhouses/hoop houses versus in the field (See Appendix A).

In the results section, the percentages of the number of reported flower genera affected by each disease are based on the number of respondents (=20). Respondents may select more than one answer, so the percentages may not add up to 100%. The tables and graphs were created using an Excel spreadsheet. The interview answers were compiled into a paragraph, showing the questions and the resulting answers.

Results

The survey results included 9 respondents form North Carolina and 11 respondents from Virginia. Farm manager ages ranged from 25 to 74, with the largest group in the range of 35 to 44. Most of the farms' acreages ranged from less than 1 acre to 15 acres, with 3 of the farms being more than 30 acres. Five of the farms were less than an acre and 7 of the farms were 1 to 5 acres. Fifteen of the survey takers have grown cut flowers for less than 5 years; 3 for 6 to10 years; and 2 for 21 to 25 years. The annual sales range included less than $5,000 for 4 of the participating farms, $5,001 to $10,000 for 3 of the farms, $10,001 to $25,000 for 3 of the farms, $25,001 to $50,000 for 4 of the farms, $50,001 to $75,000 for 2 of the farms, $75,001 to $90,000 for 1 of the farms, and greater than $105,000 for 2 farms. All respondents considered environmental sustainability very important when making decisions about disease management practices.

Disease Impact

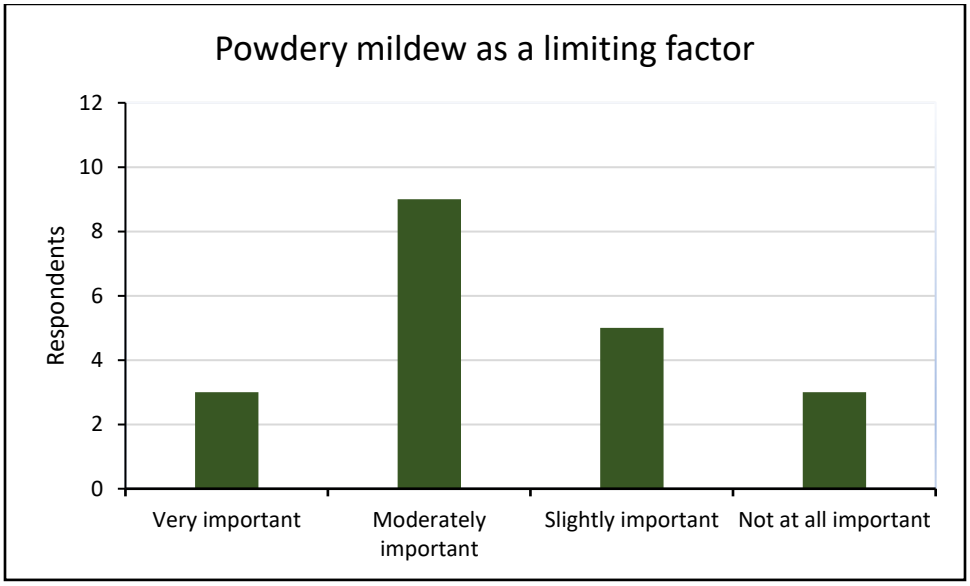

Figure 1. Respondents rated the importance of powdery mildew as a limiting factor to their cut flower production (n=20).

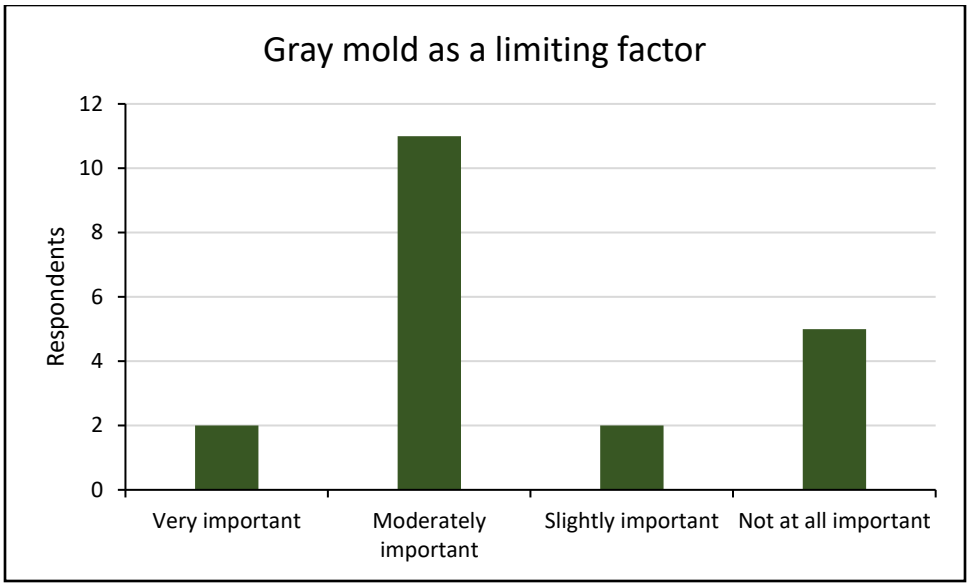

Figure 2. Respondents rated the importance of gray mold as a limiting factor to their cut flower production (n=20).

The two diseases appear to have similar importance in the surveyed area. About 55% of growers listed gray mold as being moderately important as a limiting factor while 45% respondents selected that option for powdery mildew. Likewise, 25% of growers rated gray mold as not at all important, while 10% selected that option for powdery mildew (Figures 1, 2).

Powdery mildew – most affected flower species, growth stage and crop loss assessment

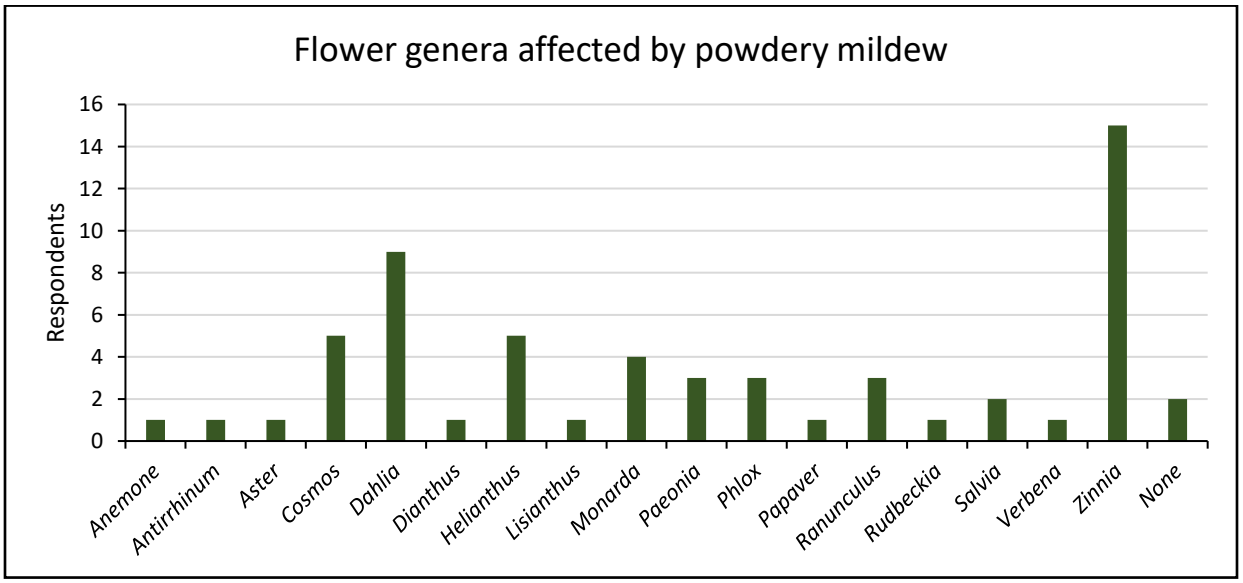

Figure 3. Respondents considered the flower genera being affected by powdery mildew (n=20).

Zinnia was the flower genus most impacted by powdery mildew as measured by the number of farms at 75% and the genus most affected by either disease. *Dahlia* was the second most impacted by powdery mildew at 45%, followed by *Cosmos* and *Helianthus* at 25% (Figure

3). The flower genera impacted by powdery mildew on surveyed farms in Virginia include *Antirrhinum, Cosmos, Dahlia, Helianthus, Lisianthus, Monarda, Paeonia, Phlox, Rudbeckia, Salvia,* and *Zinnia.* The reported flower genera affected in North Carolina include *Anemone, Aster, Cosmos, Dahlia, Dianthus, Helianthus, Monarda, Papaver, Ranunculus, Salvia, Verbena,* and *Zinnia.* All the surveyed farms in North Carolina reported that their crops have been affected by powdery mildew while two farms in Virginia reported no crops affected by powdery mildew. Loyola et al. (2019) reported that the flower genera (listed by common name), cosmos, dahlia, delphinium, larkspur, lily, phlox, ranunculus, sweet pea, and zinnia, encountered production challenges caused by powdery mildew.

Table 1.
Respondents selected the plant growth stages that have been impacted by powdery mildew

	Bulbs	Seedling	Immature	Mature/Flowering	Post-harvest	Total number of responses
Anemone				*1*		*1*
Antirrhinum				*1*		*1*
Aster				*1*		*1*
Cosmos			*1*	*4*		*5*
Dahlia		*1*		*8*		*9*
Dianthus				*1*		*1*
Helianthus				*5*	*1*	*6*
Lisianthus				*1*		*1*
Monarda				*3*	*1*	*4*
Paeonia				*3*	*1*	*4*
Phlox				*3*		*3*
Papaver			*1*	*1*		*2*
Ranunculus			*1*	*2*		*3*
Rudbeckia				*1*		*1*
Salvia				*2*		*2*
Verbena				*1*		*1*
Zinnia			*2*	*15*	*3*	*20*
Total		*1*	*5*	*53*	*6*	*65*

Note: Multiple plant stages could be selected for each flower genus (n=18).

For most flowers, powdery mildew was seen in the mature/flowering stage of plant growth, which is when the plant is likely the most susceptible to the disease and the environmental conditions are favorable for powdery mildew. While most flowers become affected by powdery mildew at the mature stage it is possible for plants to become infected at other growth stages; therefore, plants are typically monitored throughout growth and production (Table 1). The farmers in Virginia mostly reported powdery mildew in the mature growth stage, while one farmer reported it in the mature and post-harvest stages; another reported *Dahlia* having been impacted in the seedling stage. The impacted immature/vegetative growth stages and four of the six impacts in the post-harvest stage were reported in North Carolina.

Table 2.
Crop loss due to powdery mildew as rated by respondents

	0 - 10%	11 - 20%	21 - 30%	31 - 40%	41 - 50%	51 - 60%	61 - 70%	71 - 80%	81 - 90%	91 - 100%	Total number of responses
Anemone	*1*										*1*
Antirrhinum			*1*								*1*
Aster	*1*										*1*
Cosmos	*3*		*2*								*5*
Dahlia	*6*	*1*	*2*								*9*
Dianthus	*1*										*1*
Helianthus	*5*										*5*
Lisianthus		*1*									*1*
Monarda	*1*	*1*	*1*	*1*							*4*
Paeonia	*2*							*1*			*3*
Phlox					*2*					*1*	*3*
Papaver	*1*										*1*
Ranunculus	*2*	*1*									*3*
Rudbeckia						*1*					*1*
Salvia	*1*		*1*								*2*
Verbena	*1*										*1*
Zinnia	*3*	*4*	*4*	*2*	*2*						*15*
Total	*28*	*8*	*11*	*3*	*4*	*1*		*1*		*1*	*57*

Note: Percentage of crops loss on the farm as result of powdery mildew in the past 5 years (n=18).

Most growers surveyed reported crop losses of 0-10%, with *Helianthus* and *Dahlia* having the greatest number of growers reporting losses in that percentage group. For *Zinnia*, growers reported crop losses of 0-10% to 41-50% (Table 2). Most of the flower crops reported in North Carolina had a loss percentage of 0-10% except for *Cosmos* (up to 30%), *Ranunculus* (up to 20%), *Monarda* (up to 20%), and *Zinnia* (up to 40%). The Virginia flower crops had higher crop loss percentages than North Carolina. The largest percentages of crop loss of *Phlox* (91-100%), *Paeonia* (71-80%), *Rudbeckia* (51-60%), and *Zinnia* (41-50%) were reported in Virginia. The most severe crop loss reported in this study was *Phlox*, which encountered a crop loss of 91-100%. Powdery mildew does not typically result in the death of plants, unless the disease progresses until the leaves are completely covered with the mycelia. This coincides with the lower percentages of crop loss reported in the surveyed area.

Table 3.
Seasonal impact of powdery mildew typically seen by respondents

	Spring	Summer	Fall	Winter	Total number of responses
Anemone	*1*				*1*
Antirrhinum	*1*				*1*
Aster		*1*			*1*
Cosmos		*3*	*3*		*6*
Dahlia		*4*	*8*		*12*
Dianthus	*1*				*1*
Helianthus		*2*	*4*		*6*
Lisianthus		*1*			*1*
Monarda		*3*	*3*		*6*
Paeonia		*2*	*2*		*4*
Phlox		*3*	*1*		*4*
Papaver	*1*				*1*
Ranunculus	*2*			*1*	*3*
Rudbeckia		*1*			*1*
Salvia		*1*	*1*		*2*
Verbena	*1*				*1*
Zinnia		*11*	*12*		*23*
Total	*7*	*32*	*34*	*1*	*74*

Note: Multiple seasons could be selected for each flower genus (n=18).

Powdery mildew was mostly reported in the summer and fall with a couple of sightings in the spring (Table 3). All the responses from Virginia indicated fall and summer occurrences, except for one (spring). The responses from North Carolina had a similar number of summer, spring, and fall seasonal impacts. The pathogen prefers moderate temperatures which occur in fall. The pathogen does not prefer long intervals of high humidity or wet conditions; in the summer the temperatures become warm enough to allow the surface of the plants to dry and create optimal conditions for disease development when the temperatures are not too high.

Gray Mold – most affected flower species, growth stage and crop loss assessment

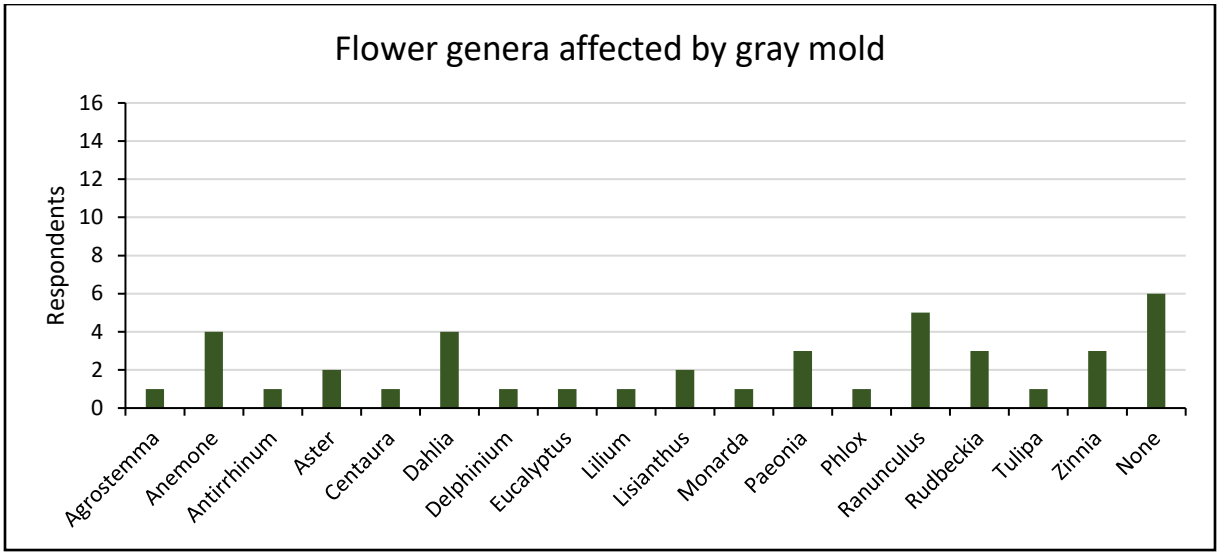

Figure 4. Respondents selected the flower genera that have been affected by gray mold (n=20).

The impact of gray mold was relatively evenly spread among the species listed in the survey, with *Ranunculus* being the most frequently reported at 25% and *Anemone* and *Dahlia* the second highest at 20% (Figure 4). The same number of genera (=17) were reported to have been impacted by both diseases. The flower genera reported to have been impacted by gray mold in Virginia include *Anemones, Aster, Dahlia, Eucalyptus, Lilium, Lisianthus, Monarda, Phlox, Paeonia, Ranunculus, Rudbeckia, Tulipa,* and *Zinnia.* The affected flower genera in North Carolina include *Agrostemma, Anemones, Antirrhinum, Aster, Centaura, Dahlia, Delphinium, Lisianthus, Paeonia, Ranunculus, Rudbeckia,* and *Zinnia.* Two of the surveyed farms in North Carolina reported that none of their crops have been affected by gray mold while four reported none in Virginia. Loyola et al. (2019) reported that the flower genera (listed by common name) anemone, cockscomb, delphinium, lily, lisianthus, marigold, peony, ranunculus, statice, sweet william, tulip, and zinnia encountered production challenges caused by gray mold.

Table 4.
Respondents selected the plant growth stages that have been impacted by gray mold

	Bulbs	Seedling	Immature	Mature/Flowering	Post-harvest	Total number responses
Agrostemma			*1*			*1*
Anemone			*2*	*3*		*5*
Antirrhinum			*1*			*1*
Aster				*2*		*2*
Centaurea			*1*	*1*		*2*
Dahlia			*1*	*3*		*4*
Delphinium			*1*	*1*		*2*
Eucalyptus		*1*				*1*
Lilium				*1*		*1*
Lisianthus		*1*	*2*			*3*
Monarda				*1*		*1*
Paeonia			*2*	*3*		*5*
Phlox				*1*		*1*
Ranunculus		*1*	*3*	*4*		*8*
Rudbeckia				*3*		*3*
Tulipa	*1*	*1*	*1*	*1*	*1*	*5*
Zinnia			*1*	*3*	*1*	*5*
Total	*1*	*4*	*16*	*27*	*2*	*50*

Note: Multiple plant stages could be selected for each flower genus (n=14).

Gray mold is seen mostly in the immature and mature stages of plant development, compared to the bulb, seedling, and post-harvest stages. More impacts were reported in the mature/flowering stage as the fungus will typically infect the flower petals (Table 4). Leaf spots are also very common with gray mold; leaf spots would occur in the immature and mature stages. Only a small percentage of respondents reported gray mold as a post-harvest issue, which is consistent with the results of Loyola et al. (2019). In Virginia, farmers reported gray mold affecting each of the plant growth stages with most of the reports being in the mature stage. One farm in Virginia reported the genus *Tulipa* had been affected at every growth stage. Ten of the sixteen reports of immature/vegetative growth stage impacts were from farms in North Carolina.

Table 5.
Crop loss due to gray mold as rated by respondents

	0 - 10%	11 - 20%	21 - 30%	31 - 40%	41 - 50%	51 - 60%	61 - 70%	71 - 80%	81 - 90%	91 - 100%	Total number of responses
Agrostemma		*1*									*1*
Anemone	*1*	*3*									*4*
Antirrhinum	*1*										*1*
Aster	*1*										*1*
Centaurea		*1*									*1*
Dahlia	*3*	*1*									*4*
Delphinium			*1*								*1*
Eucalyptus	*1*										*1*
Lilium		*1*									*1*
Lisianthus	*2*										*2*
Monarda		*1*									*1*
Paeonia		*1*	*2*								*3*
Phlox		*1*									*1*
Ranunculus	*2*	*1*	*2*								*4*
Rudbeckia	*2*	*1*									*3*
Tulipa									*1*		*1*
Zinnia	*1*	*1*		*1*							*3*
Total	*13*	*13*	*5*	*1*					*1*		*33*

Note: Percentage of crops loss on the farm as result of gray mold in the past 5 years (n=14).

Most growers report crop loss from gray mold in the 0-20% range with a few reporting losses of 21-30% (Table 5). The crop loss percentage reported from North Carolina go up to 30% for *Ranunculus, Paeonia,* and *Delphinium*. Responses from Virginia included the higher percentages of 31-40%, and 81-90%; thus, for the surveyed farms, crop loss was higher in Virginia than North Carolina. Many plants can recover quickly once dry conditions return (Grabowski, 2019). The reported loss in *Tulipa* that resulted in 81-90% crop loss was from the farm where the crop was impacted by gray mold in every growth stage.

Table 6.
Seasonal impact of gray mold typically seen by respondents

	Spring	Summer	Fall	Winter	Total number of responses
Agrostemma				*1*	*1*
Anemone	*3*			*2*	*5*
Antirrhinum				*1*	*1*
Aster		*2*			*2*
Centaurea	*1*				*1*
Dahlia		*3*	*3*		*6*
Delphinium	*1*				*1*
Eucalyptus				*1*	*1*
Lilium		*1*			*1*
Lisianthus		*1*	*1*	*1*	*3*
Monarda		*1*			*1*
Paeonia	*2*	*2*			*4*
Phlox		*1*			*1*
Ranunculus	*3*	*1*		*2*	*6*
Rudbeckia		*3*			*3*
Tulipa	*1*				*1*
Zinnia		*3*			*3*
Total	*11*	*18*	*4*	*8*	*41*

Note: Multiple seasons could be selected for each flower genus (n=14).

The seasonal impact of gray mold is distributed more evenly across the seasons than powdery mildew. The highest impact was seen in the summer and the second highest impact was seen in the spring. Gray mold was seen more frequently in the winter (Table 6) than powdery mildew (Table 3). Most reports from Virginia were in spring and summer, while responses from North Carolina included 6 of the reported winter impacts and 6 of the reported summer impacts. Although gray mold is most severe in cool temperatures, disease impact may be lower in the winter because few crops are typically grown in the winter. Even though the pathogen prefers cool temperatures, it can affect plants whenever there is wet weather (Grabowski, 2019).

Fungicides

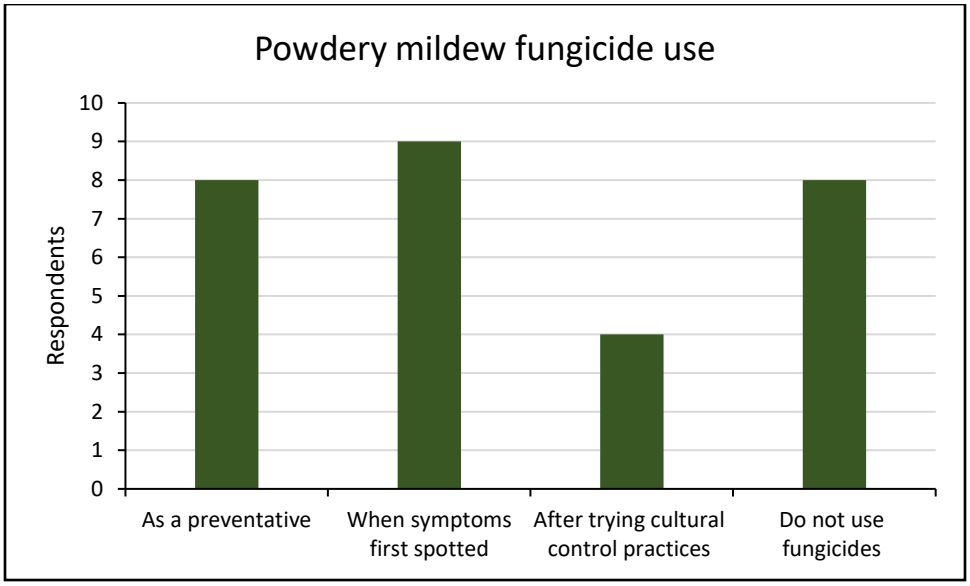

Figure 5. When respondents used fungicides in their management of powdery mildew. More than one answer could be selected (n=20).

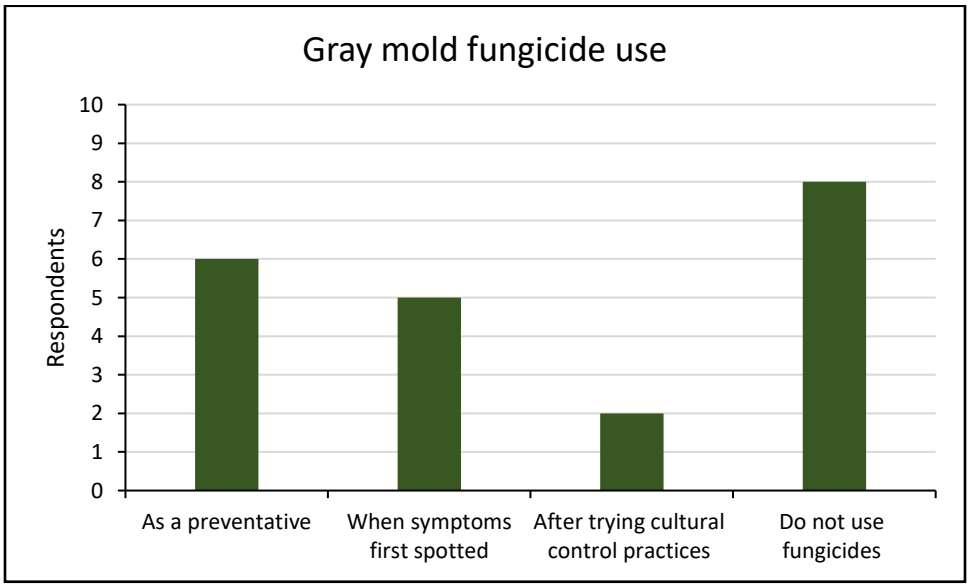

Figure 6. When respondents used fungicides in their management of gray mold. More than one answer could be selected (n=20).

Fungicides have been used more for powdery mildew than gray mold control. Twenty-one selections were made for powdery mildew usage and 13 selections were made for gray mold usage. For both diseases, fungicides are mostly used as a preventative or when symptoms are first seen. Forty percent of respondents did not use fungicides at all (Figures 5, 6). This demonstrates the respondents' commitment to the use of nonchemical alternatives, instead of fungicides, to control diseases.

Table 7.
Powdery mildew fungicide effectiveness rated by respondents

	Very effective	Moderately effective	Slightly effective	Not at all effective	Total number of responses
Daconil	*1*				*1*
Kaligreen		*1*			*1*
Trinity		*1*			*1*
Green Cure	*1*				*1*
Safer Copper Fungicide		*1*			*1*
Neem oil	*2*	*1*	*3*	*1*	*7*
Total	*3*	*4*	*3*	*1*	*11*

Note: Only the fungicides selected by the respondents are included (n=8).

Table 8.
Gray mold fungicide effectiveness rated by respondents

	Very effective	Moderately effective	Slightly effective	Not at all effective	Total number of responses
3336-WP Turf & Ornamental		*1*			*1*
Exotherm Termil			*1*		*1*
Neem Oil		*1*	*1*		*2*
Contans		*1*			*1*
Total		*3*	*2*		*5*

Note: Only the fungicides selected by the respondents are included (n=5).

It was difficult to compare fungicide effectiveness because most of the fungicides were used by only one to two respondents while neem oil for powdery mildew was used by seven respondents. None of the fungicides were reported as very effective for gray mold, suggesting that it is important to focus on prevention for this disease (Table 8). The fungicides that would be recommended for powdery mildew include Daconil, Green Cure, and neem oil, based on the effectiveness reported (Table 7). However, neem oil's effectiveness is inconsistent as it ranged from very to not at all effective. The grower who used Contans had low crop loss (in the 0-10%) range for all the flower crops affected. However, Contans is registered for the control of *Sclerotinia sclerotiorum* and *Sclerotinia minor* and not for the control of gray mold. The crop loss from powdery mildew ranged from 0-10% to 51-60% on farms that used neem oil. It is not known which crops the neem oil was used on. Only one of the farmers who reported no plants affected by one or both diseases used fungicides. That farmer experienced no gray mold impacts but has experienced low to moderate (0-60%) crop loss from powdery mildew. Daconil and neem oil was used to control the disease on that farm, combined with all the control practices listed in the next section. The farmers who have used fungicides have experienced low to moderate crop loss – a result that is similar to farms that have not used fungicides.

Cultural control practices

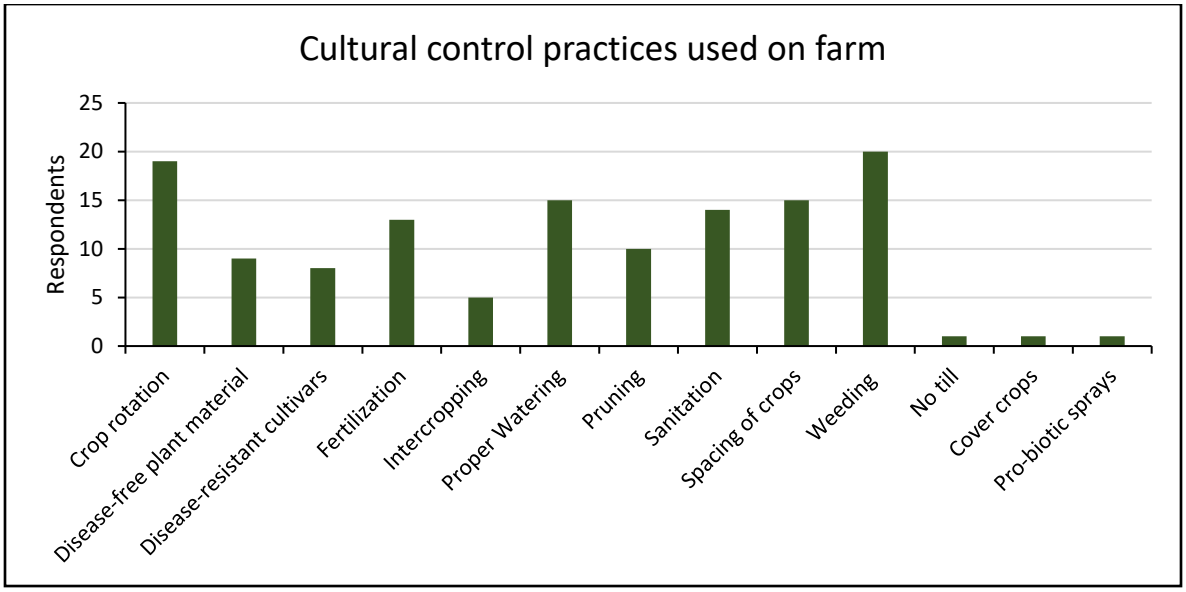

Figure 7. Cultural control practices used by respondents on their farms. More than one may be selected if applicable. Cover crops and preventative pro-biotic sprays were added by respondents (n=20).

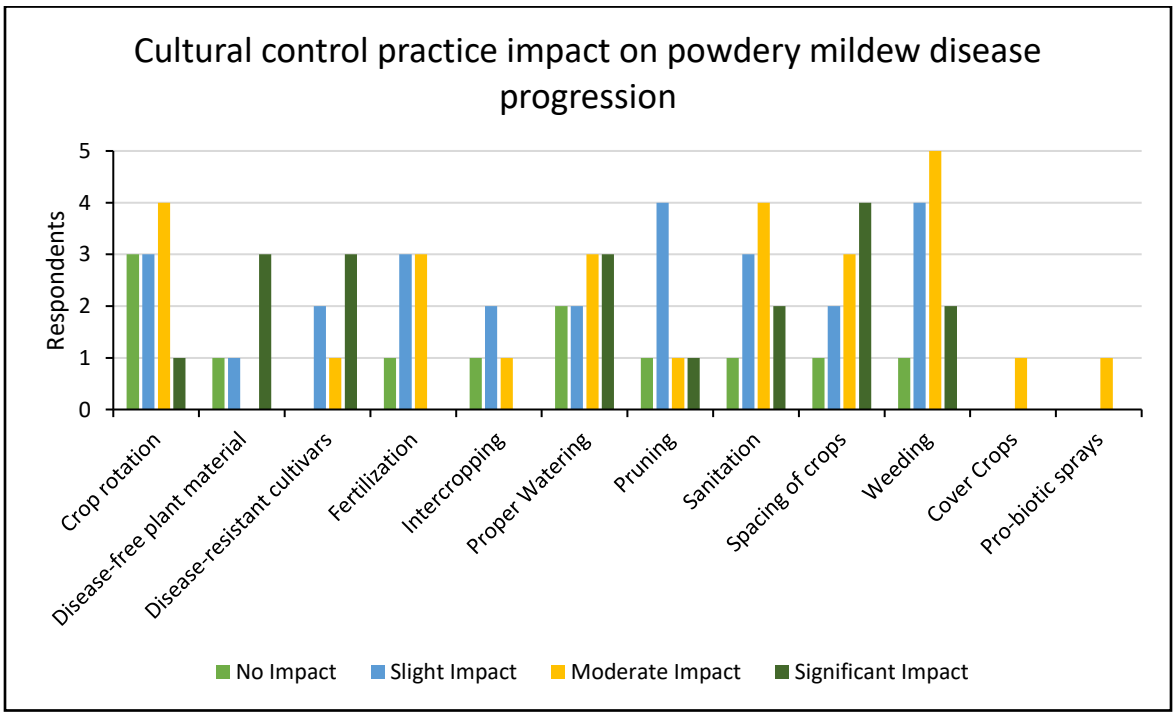

Figure 8. Respondents rated each practice on how much impact it has as a disease mitigation tool for powdery mildew (n=20).

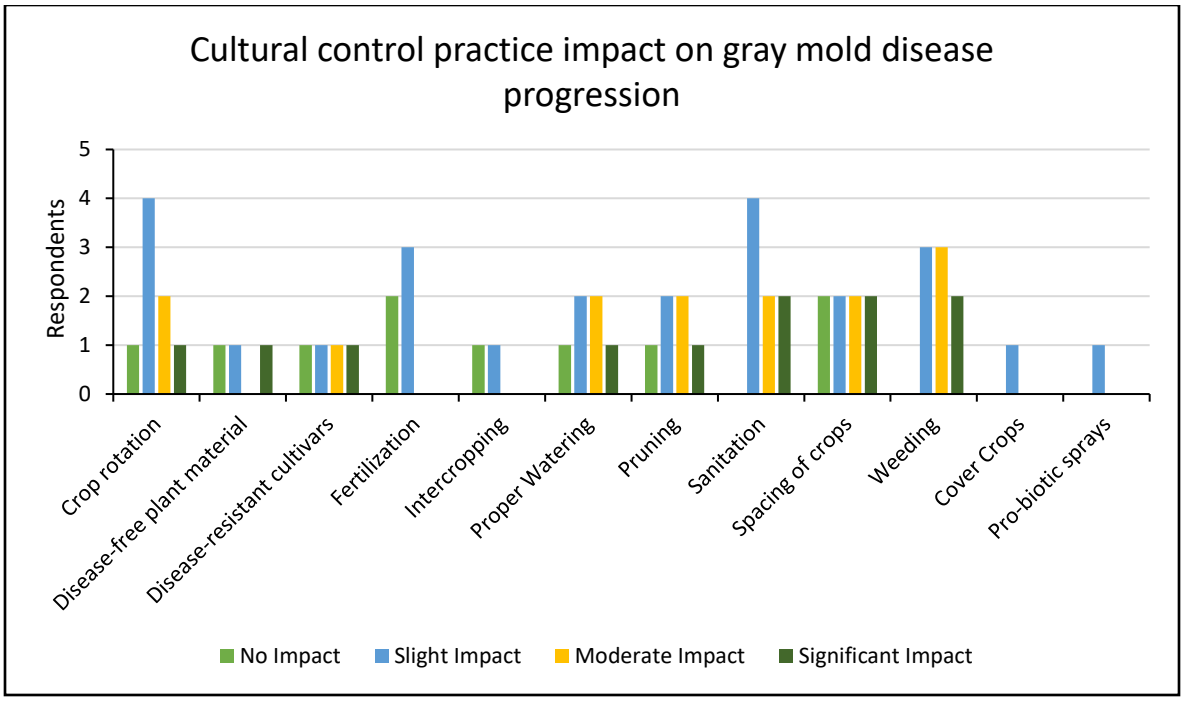

Figure 9. Respondents rated each practice on how much impact it has as a disease mitigation tool for gray mold (n=20).

Spacing had the most impact on slowing the disease progression of powdery mildew, followed by weeding, sanitation, proper watering, and crop rotation (Figure 8). Sanitation, weeding, spacing, and crop rotation also had the most impact for gray mold (Figure 9). Less impact was seen on the progression of gray mold than powdery mildew when using these practices, as 72 slight to significant impacts were reported for powdery mildew and 50 slight to significant impacts were reported for gray mold (Figures 8, 9). Several respondents did not answer the question of cultural control impact completely, likely because they haven't kept track of how the practices impact the diseases, the disease has not impacted enough of their crop to see a difference in the progression of the disease, or they have not used the practice.

The farms with no reports of flowers affected by powdery mildew (=2) all used the following the cultural controls: crop rotation, weeding, proper watering, sanitation, and fertilization. The farms with no reports of flowers affected by gray mold (=6) all used the following cultural controls: crop rotation, proper watering, sanitation, weeding, pruning, spacing, and intercropping. These farms also focused mostly on using cultural controls instead of fungicides to control diseases. Farms that reported only 0-20% crop loss did not use fungicides and used a combination of cultural controls that included crop rotation, disease resistant cultivars, sanitation, proper watering, spacing of crops, and weeding. The two farms that had the highest crop loss used four to five cultural controls and did not use fungicides for the disease causing the high crop loss. These farms used similar practices to farms that reported low to moderate crop losses. Those practices included crop rotation, spacing of crops, sanitation, and weeding. Low to moderate crop loss occurred when fungicides and five to nine cultural controls were used.

Services

About 66% of the respondents have not used any services for assistance in disease management, 24% have used a university or extension service and 9.5% have used a state diagnostic laboratory.

Interviews

Eight survey respondents also participated in an interview. The growers started flower farming because there was an interest in farming overall and they liked flowers, had the resources and land, and were interested in the creative aspect of cut flower farming. The major thought process or philosophy when it came to disease management was being proactive in preventing the disease and focusing on the health of the plant. Two respondents stated that they are reactive by focusing on treating the disease when it is seen or simply getting rid of the plants that become affected. The diseases were monitored by scouting the plants to make sure they look healthy and keeping an eye out when walking around the farm while performing other tasks. The respondents implemented sustainability into their farming practices by using organic practices, natural products, crop rotation, cover crops, and whole farm planning. Sanitation practices used on the respondents' farms included keeping all equipment clean, washing/bleaching buckets, keeping beds clean by removing diseased or dead plants, and weeding. Seeds were obtained from Geo, Gloeckner, New Country Organics, Floret's Farm, and the most common source was Johnny's Seeds. Fertilizers used on the farm include composted manure, granulated fertilizer, fish emulsion, pro-mix starter, mushroom mulch, organic fertilizers, feather meal, potassium sulfate, rock phosphate magnesium, harmony, bone meal, calcium carbonate, high-cal lime, and azmite. When asked about areas for needed self-improvements the answers were different for each grower and included focusing more on prevention, improving management protocol, improving the growing environment by building up the beds, soil structure, improving spacing, and increasing knowledge. The last question asked was if the grower thought there are=o any weaknesses in available products or treatment options overall. The answers included the fact that a lot of information is available, so it can sometimes be difficult to find what is needed, and some information is more difficult to find, such as business or organic weed treatment information. One grower in a small community has difficulty accessing organic seeds and certain products and must drive three hours to obtain certain products.

Discussion and Conclusions

Powdery mildew appears to be a large problem for *Zinnia,* as 75% of the respondents reported it affecting this genus with a crop loss percentage up to 50%. This is congruent with the Loyola et al. (2019) survey which stated that powdery mildew is one of the most serious issues for *Zinnia* production. The range of crop loss reported for powdery mildew for all the flower genera was broad, with most occurring in the 0-10% range. This can be attributed to the fact that if powdery mildew is seen relatively early during infection and effective controls are used, then it is rarely fatal to the plant. It does affect the appearance of the leaves, which is important in cut flower production, but if the plants are treated, only a small percentage of the crop may be lost. If enough of the plant is affected by the disease, the crop can be lost because it is no longer profitable even if the plant does not die. If the environmental conditions favor the growth of

powdery mildew, treatment may be less effective as the disease progresses quickly and high crop loss could occur on a farm that has an otherwise effective management plan.

Overall, the crop losses from powdery mildew and gray mold were mostly low for cut flowers crops in the farms surveyed in North Carolina and Virginia. Cut flower farms in these states have been doing well in managing these diseases by keeping crop losses low to moderate. There were several severe crop losses, including instances in the genera *Paeonia, Phlox,* and *Tulipa,* which suggests that there is potential for these diseases to be a large problem on cut flower farms in these states. Two of the farmers interviewed stated that they do not have much of a disease management plan and do not keep track of diseases. These small farms may have encountered these diseases but do not record the impacts and therefore have no affected crops to report. Some of the flower genera reported to be affected by these diseases were different in this survey compared to the Loyola et al. (2019) survey. Surveys from different locations provide valuable information about which flowers could be susceptible to the diseases in each environment.

Among the Virginia and North Carolina growers surveyed, it appears that powdery mildew is a bigger problem than gray mold. While the number of flower genera (=17) affected was the same for each disease, powdery mildew had a higher number of disease impacts overall at 57 reports of affected plants, while gray mold had 35 reports of affected plants (Figures 3, 4). The crop loss range for gray mold was smaller than powdery mildew, with most occurring between 0 and 20% for gray mold and between 0 and 50% for powdery mildew. While the higher percentages of crop loss occurred in Virginia, this may be due to factors on the specific farms as the climates are very similar between the two states.

There appeared to be little correlation between crop loss and cultural controls on the farms surveyed. In comparison of two farms that used the same cultural control practices, one had a high percentage of crop loss and was in Virginia, and the other had low percentages of crop loss and was in North Carolina. The crop loss differences on these farms likely resulted from other factors besides the cultural practices used on the farm, such as environment and susceptibility of the flower species. To have an effective disease management plan, it would be important to determine which practices and products are effective in controlling these diseases on the flower crops on each farm.

When monitoring for powdery mildew it is important to scout the flowers during the flowering stage in the summer and fall. For gray mold it is also important to monitor the plants in the flowering and vegetative stages during the spring, summer, and winter. As part of a proactive disease management program a grower should scout plants through the entire growing season, as impact was seen in all seasons for gray mold and powdery mildew. Being proactive in disease management is a method that most of the interviewed growers use and is something that several growers are looking to improve upon as they develop their disease management program.

The farming and disease management practices performed on the participating farms appeared to be consistent with the fact that every respondent selected environmental sustainability as very important when making decisions about disease management. Forty percent of respondents do not use fungicides, and neem oil, an organically approved fungicide, was used by the greatest number of respondents. Cultural controls were also used by more respondents than fungicides: 60% of respondents used fungicides and every respondent selected

at least four of the cultural control practices. Cultural control practices are often used for disease prevention and most respondents focus on maintaining the health of the plant, which is how several of the growers reported their approach to disease management in the interviews. Natural fertilizers were also preferred by the respondents who participated in the interview. Whole farm planning was also mentioned in the interviews. This involves growers taking into consideration how the disease management practices used will impact the rest of the farm, including the land, other crops, insects, and other animals.

Most of the respondents have not used assistant services for disease management, such as university or extension services or state diagnostic laboratories. This could result from several factors such as growers not being aware of these services, or not thinking they need to use these services due to the amount of information available online. Educating growers through surveys and/or social media to make more of them aware of the resources available to them, may enable cut flower farmers to further reduce crop losses due to these two diseases while promoting environmental sustainability.

Further Research

The results of this study provide cut flower farmers with information about the practices that other growers have used in powdery mildew and gray mold disease management. Future research and experiments should be completed on organically approved and conventional fungicide effectiveness on cut flowers, and how different practices can be used in combination to control powdery mildew and gray mold. Research on sustainable and organic practices specifically would be helpful as all the cut flower farms surveyed focus on those practices. Species-specific data would be very helpful for growers, as different species within a genus may react differently to a disease. Surveys conducted with a larger participant pool would lead to more accurate results and statistical analysis. This would add detailed information about the effectiveness of disease management practices and products and provide better recommendations to cut flower growers.

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Appendix A

Survey Questions

Q1. In which state do you currently reside?

Q2. How old is the manager of the farm?

- 18-24
- 25-34
- 35-44
- 45-54
- 55-64
- 65-74
- 75 or older

Q3. How long have you been growing cut flowers?

- Less than 5 years
- 6 to 10 years
- 11 to 15 years
- 16 to 20 years
- 21 to 25 years
- More than 25 years

Q4. What is the annual sale range for your cut flower production?

- Less than $5,000
- $5,001 to $10,000
- $10,001 to $25,000
- $25,001 to $50,000
- $50,001 to $75,000
- $75,001 to $90,000
- $90,001 to $105,000
- More than $105,000

Q5. What is the acreage of your farm?

- Less than 1 acre
- 1 to 5 acres
- 6 to 10 acres
- 11 to 15 acres
- 16 to 20 acres
- 21 to 25 acres
- 26 to 30 acres
- More than 30 acres

Q6. How important is powdery mildew as a limiting factor to your cut flower production compared to all other diseases?

- Very important
- Moderately important
- Slightly important
- Not at all important

Q7. Which flowers have been affected by powdery mildew?

- None
- Abelia
- Ageratum
- Anemone
- Antirrhinum
- Aster
- Baptisia
- Campanula
- Calycanthus
- Columbine
- Cosmos
- Dahlia
- Delphinium
- Dianthus
- Gerbera
- Helianthus
- Helleborus
- Lilium
- Lisianthus
- Monarda
- Narcissus
- Nigella
- Paeonia
- Phlox
- Papaver
- Ranunculus
- Rosa
- Rudbeckia
- Salvia
- Scabiosa
- Syringa
- Tagetes

- Tulipa
- Zinnia
- Other

Q8. For the following crops, in which growth stage do you usually see powdery mildew?

*Answers selected in Q7 carried over into this question

- Bulbs
- Seedling
- Immature plants
- Mature/flowering plants
- Post-harvest

Q9. What percentage of the following crops has been lost as a result of powdery mildew in the past 5 years?

*Answers selected in Q7 carried over into this question

- 0-10%
- 11-20%
- 21-30%
- 31-40%
- 41-50%
- 51-60%
- 61-70%
- 71-80%
- 81-90%
- 91-100%

Q10. In which seasons do the following crops typically get affected by powdery mildew?

*Answers selected in Q7 carried over into this question

- Spring
- Summer
- Fall
- Winter

Q11. How important is gray mold (Botrytis) as a limiting factor to your cut flower production compared to all other diseases?

- Very important
- Moderately important
- Slightly important
- Not at all important

Q12. Which flowers have been affected by gray mold?

- None
- Abelia
- Ageratum
- Anemone
- Antirrhinum
- Aster
- Baptisia
- Campanula
- Calycanthus
- Columbine
- Cosmos
- Dahlia
- Delphinium
- Dianthus
- Gerbera
- Helianthus
- Helleborus
- Lilium
- Lisianthus
- Monarda
- Narcissus
- Nigella
- Paeonia
- Phlox
- Papaver
- Ranunculus
- Rosa
- Rudbeckia
- Salvia
- Scabiosa
- Syringa
- Tagetes
- Tulipa
- Zinnia
- Other

Q13. For the following crops, in which growth stages do you usually see gray mold?

*Answers selected in Q12 carried over into this question

- Bulbs

- Seedling
- Immature plants
- Mature/flowering plants
- Post-harvest

Q14. What percentage of the following crops has been lost as a result of gray mold in the past 5 years?

*Answers selected in Q12 carried over into this question

- 0-10%
- 11-20%
- 21-30%
- 31-40%
- 41-50%
- 51-60%
- 61-70%
- 71-80%
- 81-90%
- 91-100%

Q15. In which seasons do the following crops typically get affected by gray mold?

*Answers selected in Q12 carried over into this question

- Spring
- Summer
- Fall
- Winter

Q16. How important is environmental sustainability to you when making disease management decisions during flower production?

- Very important
- Moderately important
- Slightly important
- Not at all important

Q17. When do you use fungicides in your management of powdery mildew?

- As a preventative
- When symptoms are first spotted
- After trying cultural practices
- We have not used fungicides
- Not applicable
- Other

Q18. Select the effectiveness of the following fungicides if you have used them for control of powdery mildew.

- Banner Maxx (propiconazole)
- Bayleton (triadimefon)
- Cygnus (kresoxim-methyl)
- Daconil (chlorothalonil)
- Eagle (myclobutanil)
- Kaligreen, First Step (Potassium bicarbonate)
- Neem Oil
- Ortho Funginex (triforine)
- Rubigan (fenarimol)
- Sulfur
- Strike (trifloxystrobin and triadmefon)
- Trinity (triticonazole)
- Tourney (metconazole)
- Zyban (thiophanate-methyl and mancozeb)
- Other

*For each fungicide respondent has potential to select effectiveness

- Very effective
- Moderately effective
- Slightly effective
- Not effective at all

Q19. When do you use fungicides in your management of gray mold?

- As a preventative
- When symptoms are first spotted
- After trying cultural practices
- We have not used fungicides
- Not applicable
- Other

Q20. Select the effectiveness of the following fungicides if you have used them for control of gray mold.

- 3336-WP Turf & Ornamental Fungicide (thiophanate-methyl)
- Camelot
- Captan
- Chipco 26019 (iprodione)
- Decree (fenhexamid)

- Exotherm Termil (chlorothalonil)
- Neem Oil
- Pageant (pyraclostrobin and boscalid)
- Other

Q21. Which of the following cultural control practices do you use on your farm?

- Crop rotation
- Disease free lining, plugs, and seedlings
- Disease resistant cultivars
- Fertilization
- Intercropping
- Proper watering
- Pruning
- Sanitation
- Spacing of crops
- Weeding
- Other

Q22. When using each of the following practices, how much does it slow the progression of powdery mildew?

*Answer selected in Q21 carried over into this question

- No impact
- Slightly
- Moderately
- Significantly
- I don’t know

Q23. When using each of the following practices, how much does it slow the progression of gray mold?

*Answer selected in Q21 carried over into this question

- No impact
- Slightly
- Moderately
- Significantly
- I don’t know

Q24. Have you received assistance from any services for disease management?

- State diagnostic laboratory
- University or extension service: Please specify
- Other

- None

Q25. Do you have any additional thoughts or questions on overall disease management in cut-flower farming? If so, please share below.

Q26. Will you be willing to be contacted by the researcher to answer a few follow-up questions? If Yes, please enter your farm name and email address. The researcher will contact you by email from rshana5@vt.edu.

- Yes
- No