DIVISION OF AGRICULTURE
RESEARCH & EXTENSION
University of Arkansas System

Agriculture and Natural Resources

FSA6162

Developing a Sustainable Fungicide Spray Program to Prevent Fruit Rot in Strawberry for the Southeast

Taunya Ernst
Instructor - High Tunnel and Urban Agriculture Educator

Aaron Cato
Extension Specialist - Horticulture IPM

Amanda McWhirt
Extension Specialist - Horticulture

Ryan Keiffer
Program Associate - Horticulture IPM

Arkansas Is Our Campus

Visit our website at: http://www.uaex.uada.edu

Introduction

Strawberries are susceptible to infection from various pathogens such as fungi, bacteria, viruses and nematodes. Fungal pathogens, however, have the largest economic impact on strawberry production worldwide[1] with Botrytis (grey mold) and anthracnose fruit rots (Figure 1) being the most economically damaging[2]. Without proactive cultural practices and an effective spray program, more than 80% of strawberry flowers can be lost to Botrytis when environmental conditions are favorable[1]. While Botrytis is considered the most damaging disease of harvested strawberries, in recent years the incidence and impact of anthracnose fruit rot has increased[1,3]. In the Southeast, when warm and wet conditions are present during harvest, anthracnose fruit rot is commonly the most damaging fruit rot disease observed.

Preemptive measures are necessary to prevent significant yield losses from Botrytis and anthracnose fruit rot. While there are several practices that can help lower the incidence and spread of the causal pathogens, cultural practices used alongside fungicide applications will be needed to achieve sustainable management of these diseases. An effective and sustainable fungicide program should be based on an understanding of the life cycle of the targeted pathogen. This will enhance the effectiveness of a program's preventive control through improved application timing, selection of fungicides with high efficacy against the targeted pathogen, as well as improved cultural practices that can limit pathogen dispersal[4].

Figure 1. Strawberry fruit infected with Botrytis (grey or white mold) and anthracnose (brown sunken lesions).

Botrytis and Anthracnose Fruit Rot

The full life cycle of the pathogens that cause Botrytis and anthracnose fruit rot has been thoroughly explained in several forms of media. If you are interested in learning more you should watch the Phytographic Animated Disease Cycles videos developed by Clemson University at the following links: Botrytis (https://vimeo.com/509908236) and anthracnose (https://vimeo.com/509950986).

Botrytis fruit rot, commonly called grey mold or Botrytis, is caused by the fungus *Botrytis cinerea* (Figure 2). This fungus is known to infect several parts of the strawberry plant, including leaves and petioles, but ultimately the infection of flowers contributes to the most severe economic loss caused by this disease[5]. *Botrytis* spores primarily enter tissues through open wounds or natural openings, such as

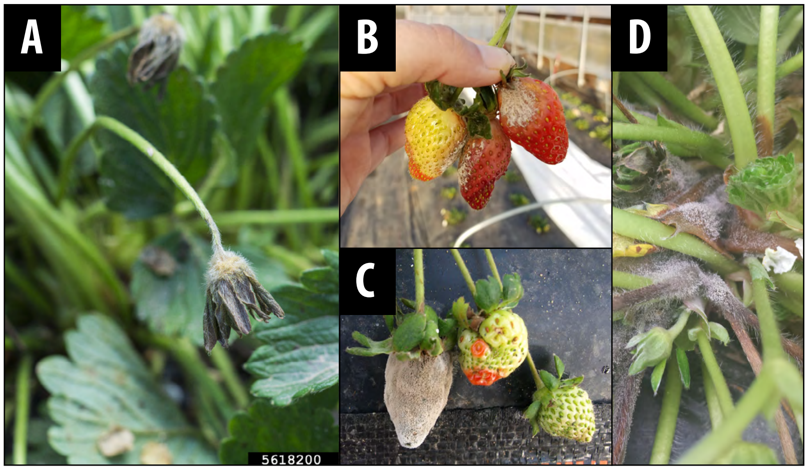

Figure 2. Botrytis fruiting bodies growing on a strawberry flower (A), fruit (B and C) and crowns (D). Photos by Taunya Ernst and Madeline Dowling, Clemson University, Bugwood.org

Figure 3. Anthracnose fruit rot lesions on strawberries.

flowers, and have limited impact on ripening or ripe, undamaged fruit[1]. Once the calyx of mature flowers become infected, direct infection can kill the flower, or symptoms can be delayed for several weeks as the infection slowly spreads through the calyx and then down into green or ripe fruit. Ripe fruit exposed to excessive water may also be infected by *Botrytis* spores, as water damage can create an entrance wound.

Botrytis can occur from previously formed sclerotia that survive in soil, through spores moving from infected weeds, or from nearby alternate crops. However, infected nursery plants are often cited as the main source of inoculum[6]. Plants are often received infected and remain asymptomatic until environmental conditions become favorable. The frequent rainstorms and cooler temperatures (between 60-70°F) that characterize much of the spring in the Southeast U.S. favor Botrytis growth and spread[6]. This makes strawberry flowers particularly susceptible to this disease and preventive fungicide sprays during bloom are essential for management of Botrytis fruit rot[7]. *Botrytis* spores can be spread by direct contact with infected tissue, by wind or on field equipment/workers[5]. Botrytis is also a destructive post-harvest fruit rot if post-harvest handling and storage conditions are not carefully monitored.

Anthracnose fruit rot can be caused by the infection of three different species of fungi *Colleotrichum acutatum, Colleotrichum gloeosporioides* and *Colleotrichum fragariae*, although most fruit rot infections observed in the Southeast were historically thought to be caused by *C. acutatum*[8,9]. Recent publications have revealed that *C. acutatum* is actually a species complex containing *C. nymphaeae* and *C. fioriniae* that impact strawberry, with *C. nymphaeae* being the main cause of disease we observe[10]. Spores from this fungus can infect any part of the strawberry plant but infection of fruit is largely responsible for the economic losses caused by this fungus (Figure 3). Anthracnose-causing fungal spores can directly infect and kill flowers, which results in direct yield loss as these flowers fail to develop. However, the largest impact from the anthracnose fruit rot disease is through the direct infection of green and red fruit. Unlike Botrytis fruit rot, anthracnose fruit rot is often the result of direct infection of *Colletotrichum* spores on developing fruit[8,9].

Fungal spores that cause anthracnose fruit rot can originate from several sources. These spores are known to survive in the soil for nine months and can infect new transplants in the fall. Spores can also move from weed species or from other susceptible crops. However, anthracnose is primarily introduced to strawberry plantings through infected nursery plants[3], which can look completely asymptomatic while the fungus continues to infect green plant material. Anthracnose is primarily dispersed through splashing water[8,9]. While plants are usually asymptomatic during bloom, it is during this time that spores spread rapidly throughout a field and protective fungicides are necessary to protect open flowers. When temperatures begin to warm (77-80°F), lesions (Figure 3) will begin to appear on developing fruit[11]. In the Southeast, it is important that growers aim to suppress anthracnose throughout bloom. Once favorable climatic conditions for anthracnose fruit rot development occur, it can be extremely difficult to stop rampant disease spread if a preventative program was not in place starting in the early spring.

Cultural Practices to Reduce Prevalence of Strawberry Fruit Rots

A sustainable fruit rot management program must include cultural practices that limit the presence, spread and likelihood of infection by plant pathogens. The predominate production system for strawberries in the Southeast, annual plasticulture, uses short-day plants (primarily, some day neutral cultivars are used) in an annual hill system[12] (Figure 4). In the annual

Figure 4. Strawberries growing in an annual plasticulture production system in the Southeast.

plasticulture system, new plants are transplanted every year in the fall. After spring harvest, plants are killed and removed from the field. This allows for crop rotation with crops that are non-hosts to strawberry diseases. This practice can cause a break in pest cycles and reduce the pathogen population in the field[12]. It is generally recommended to allow 1-3 years between planting of strawberries in the same field and to utilize non-related crops or cover crops when not growing strawberries in these areas. Growing plants on a raised bed, in full sun, with adequate spacing and weed control will help decrease the risk of infection as air circulation is increased, which helps to facilitate the drying of plant tissue. Additionally, plants and developing fruit are elevated above most standing water when grown on a raised bed, which helps reduce the risk of infection of fruit rot diseases.

Destruction of plants each year after harvest helps to reduce inoculum as infected plant material is turned in the soil or removed from the field. However, a main source of pathogen inoculum for both Botrytis and anthracnose is infected nursery plants[3,13]. Finding a reliable source of pathogen free plant material can be difficult due to asymptomatic infections. Removal of dead or visually injured leaves or blooms from the plants and fields at transplant, and again in the spring will help reduce the amount of inoculum[14]. However, this practice should be avoided during warm and wet weather, where fungal spores that cause anthracnose can be easily spread during leaf removal activity. Good sanitation practices should include the removal of any plant debris, weeds, and fruit with visible symptoms from the field[8]. Removal of all culled fruit, especially those clearly infected with disease, is a key practice that drastically reduces the amount of inoculum in fields. Areas where a pathogen is known to be present should be harvested or handled last in the day and workers and their equipment should be clean before entering other areas of the field[8]. Additionally, production practices that reduce splashing water around plants, such as using drip irrigation and having wheat straw or living mulches in row middles, will limit pathogen dispersal and is vital when trying to prevent anthracnose fruit rot[13,15]. Low tunnels can potentially decrease the occurrence of symptoms and growing in a high tunnel can potentially eliminate anthracnose symptoms altogether, even without the use of fungicides[13]. These systems can work well for low input or organic producers, however they can also increase the incidence of other pest issues like powdery mildew and spider mites.

No strawberry cultivars that are currently grown are known to be resistant to Botrytis fruit rot. A few strawberry cultivars acceptable for the Southeast growing region have some resistance to anthracnose, and more are expected to be developed in the future as many breeding programs have made breeding for disease resistance a priority. The following cultivars are commonly grown in the Southeast and have some level of anthracnose resistance: *'Sweet Charlie'* and *'Florida Brilliance'* are known to have medium resistance, *'Florida Radiance'* has medium resistance to full resistance, and *'Flavorfest'* has full resistance (Flavorfest is not recommended to be grown in Arkansas and may not be acceptable for other southeastern states). For more information about resistant cultivars see the Southeast Regional Strawberry Integrated Pest Management Guide. Always consult your local extension specialists for information about what cultivars will work in your region.

Fungicide Applications

In addition to several forms of cultural control, a preventative fungicide spray program is necessary for sustainable production of strawberries in the Southeast. A preventive fungicide spray program should begin in the early spring and continue until harvest is completed. Because fungal spores that cause Botry-

Table 1. Summary of common fungicides used for Botrytis and anthracnose fruit rot management in strawberries.
For a complete list see the Southeast Regional Strawberry IPM Guide

Product	FRAC Group	Efficacy		Contact or Systemic***	Botrytis Resistance
		Botrytis Fruit Rot	Anthracnose Fruit Rot		
Captan	M04	G	G	Contact	None
Thiram	M03	G	F	Contact	None
Topsin M	1	Not effective	Not effective	Systemic	Widespread
Rovral	2	G	Not effective	Systemic	Prevalent
Tilt; generics	3	Not effective	F	Systemic	Not applicable
Fontelis	7	E	F	Systemic	Prevalent
Kenja	7	E	Not effective	Systemic	NOT prevalent
Scala	9	G	Not effective	Systemic	Prevalent
Pristine	7 + 11	G	E*	Systemic	Prevalent
Merivon	7 + 11	E	E*	Systemic	Prevalent
Luna Sensation	7 + 11	E	E*	Systemic	NOT prevalent
Quadris Top, Quilt Xcel	3 + 11	F	E*	Systemic	Widespread
Cabrio, Abound, Flint Extra	11	F	E*	Systemic	Widespread
Miravis Prime	12 + 7	E**	E**	Systemic	NOT Prevalent
Switch	12 + 9	E	G	Systemic	NOT prevalent
Elevate	17	E	Not effective	Contact	Prevalent
Ph-D, OSO	19	G	F	Systemic	NOT prevalent

Fungicide efficacy ratings and Botrytis resistance risk ratings as reported in the 2024 Southeast Regional Strawberry Integrated Pest Management Guide Focused on Plasticulture.
*Resistance issues to FRAC 11 fungicides in the AFR pathogen have been reported in multiple states. Problems tend to be plant-source-associated.
**Efficacy ratings are tentative based on the performance of similar products and laboratory studies.
***Systemic indicates that some level of movement occurs into plant tissue, but the degree of movement varies.
Key: F: Fair; G: Good and E: Excellent

tis enter and infect flowers in the early spring, early fungicide sprays should have a high efficacy against this fungus (Table 1). The first fungicide application to prevent fruit rot should occur when most plants are at 5% bloom[13]. Subsequent applications should continue at least every seven days to maintain protection. Delaying the start of a fungicide program will result in an increased incidence of Botrytis. Applications will need to be more frequent during periods of persistent moist conditions, such as repeated rain showers or heavy dew. An earlier spring fungicide application (about 10 days before bloom is expected to begin) may be necessary if plants were exposed to a hard frost followed by warm weather. These conditions could lead to a high incidence of Botrytis crown rot[16].

While Botrytis is the primary fungal concern in the early spring and during bloom, anthracnose spores are also actively spreading during this time and can infect and kill flowers during periods of warm weather[13]. Fungicide sprays applied during bloom need to have some efficacy against anthracnose to prevent bloom infection and suppress spores prior to warm and wet conditions when spores will easily infect fruit. As temperatures begin to warm, environmental conditions become more favorable for anthracnose development and symptoms will begin to appear[11]. Like Botrytis, anthracnose can infect open blooms, however, it can also infect undamaged green and red fruit. This means fungicides should be applied at seven-day intervals throughout fruit ripening and harvest to protect fruit from anthracnose fruit rot. Prolonged periods of wet and warm weather, such as prolonged rain showers and wind-blown rain, will require more frequent fungicide applications. When selecting what fungicides to use during harvest, products with a high efficacy against anthracnose should take precedence over products with high efficacy against Botrytis, especially when weather becomes hot and warm rains are frequent (Table 1). Fungicide applications should continue within 7-10 days of the projected last harvest.

In addition to fungicide application timing, adequate spray coverage and correct fungicide rate are key to effective disease management. Growers should calibrate sprayers each year to ensure that thorough coverage of the full plant canopy is obtained and to ensure that the fungicide rate being applied per acre is accurate. In addition to leaf coverage to prevent the production of excess fungal spores from infected plant material, flowers and fruit must also be covered with spray material to be protected from moving spores. This level of coverage to a short and crowded canopy generally involves a boom design that uses drop nozzles where spray material is forced into the center and sides of the plant canopy. A minimum spray output/carrier volume of 80 GPA (gallons per acre) is recommended to achieve adequate coverage. Little to no research has been done on air blast sprayers and their effectiveness in annual plasticulture strawberry growing systems. Growers should be wary of using any spray system that relies on spray material crossing multiple strawberry rows, as the likelihood of even and thorough spray coverage across all rows is low.

Fungicide Selection

Before selecting and applying a fungicide for fruit rot control, ensure the product is labeled for use on strawberries in your state and for use in the spring when blooms and fruit are present. Follow all label directions and safety instructions, the label is the law. For help in selecting fungicides that are effective in treating strawberries for anthracnose and Botrytis see the Southeast Regional Strawberry Integrated Pest Management Guide.

When developing a fungicide program, choose fungicides that are known to prevent both Botrytis and anthracnose fruit rot. Fungicides with high efficacy for Botrytis should take precedence during prebloom and bloom while fungicides with high efficacy for anthracnose should be prioritized during harvest (Table 1). Although the risk for anthracnose is low early in the season, all fungicide applications made in the Southeast should be rated at least 'good' in their effectiveness for both Botrytis and anthracnose fruit rot to prevent excess disease buildup. Products such as Kenja (FRAC 7) and Elevate (FRAC 17) work well for Botrytis but are not effective in preventing anthracnose and should be accompanied with captan during bloom. Luna Sensation (FRAC 7+11) and Miravis Prime (FRAC 12+7) are great products to use as climate conditions shift to favor anthracnose growth. When disease pressure is high consider adding captan to applications for enhanced effectiveness.

When selecting fungicides, precautions should be taken to avoid the development of pesticide resistance. Selecting effective fungicides that use different methods to target and kill an organism, known as the mode of action (MoA), can greatly slow the development of pesticide resistance. Most fungicide labels will clearly display the FRAC group, which indicates MoA (Figure 5). Rotating between using fungicides with different FRAC groups will help delay the development of resistance to any one MoA. Chemicals in FRAC groups 3, 7, 11, 12 and 17 are considered at-risk for pathogen resistance, and the number of times they are used should be limited in a single season[17]. Using fungicides containing active ingredients with multiple MoAs, such as Luna Sensation (FRAC groups 7 + 11), or tank mixing compatible fungicides from different FRAC groups will not only slow down the development of pesticide resistance but also greatly increase the efficacy of a spray program[14]. Growers should be wary of active ingredient season use limits when using products with multiple modes

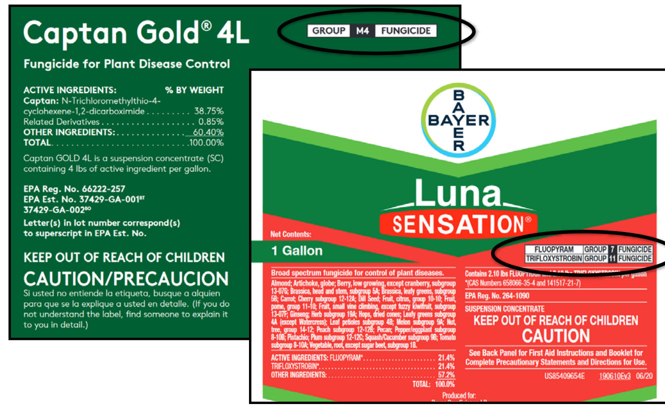

Figure 5. FRAC groups stated on fungicide labels.

of action. Uses of Miravis Prime may limit uses of other fludioxonil containing products, such as Switch. Additionally, consider the effectiveness of each active ingredient when using fungicides with several MoA, not all will be effective in controlling anthracnose or Botrytis. Products in an M FRAC group, such as captan and thiram, are multi-site fungicides and are at low risk to develop pesticide resistance. For this reason, they should be used as the backbone for any season-long fungicide program and should be paired with single site fungicides that may be affected by pathogen resistance[17]. Growers can seek assistance in determining what resistance may be present on their farms. Contact local extension agents for help in sending disease samples to appropriate plant pathology labs for Botrytis and anthracnose fruit rot resistance screening. This information can be vital in building an effective spray program, as products with known resistance should not be used.

Organic Fungicides

There are several organic fungicide products that list anthracnose and Botrytis fruit rot control for strawberries (Table 2). Many organic fungicides are biocontrol agents or living organisms (or parts of organisms) that can interfere with the development and productivity of a pathogen[18]. It should be noted that many organic products achieve inconsistent results in efficacy trails and more research is needed to provide organic pest control recommendations that are effective[19]. In efficacy studies performed at the University of Arkansas and several other areas, OSO (Polyoxin D zinc salt – FRAC 19) has exhibited the best and most consistent management of both Botrytis and anthracnose among the organic fungicides we have tested. Based on these results, OSO should be the backbone fungicide in an organic spray program, with other products used in conjunction to increase disease control. Although OSO is the most effective organic fungicide for fruit rot protection, other effective control measures should be integrated into an organic spray schedule to prevent the potential for resistance formation to this product. Integration of

Table 2. Summary of common organic fungicides listed for management of Botrytis and anthracnose fruit rot in strawberries. *For a complete list see the Cornell Organic Production and IPM Guide for Strawberries.*

Product	Resistance Risk	FRAC Group	Mode of Action	*Efficacy*	
				Botrytis	Anthracnose
Actinovate AG (Streptomyces Lydicus WYEC 108)	Low	BM 02	Kills spores	0	NL
Double Nickel 55 (Bacillus amyloliquefaciens str. D747)	Low	BM 02	Out competes pathogens	0	0
Serenade (Bacillus subtilis str QST 713)	Low	BM 02	Disrupts spore cell membranes	2	0
OSO 5% SC Fungicide (Polyoxin D zinc salt)	Medium	19	Inhibits cell wall growth	3	3
Bee Vectored Biocontrol Agent					
Vectorite (Clonostachys rosea)	Low	BM 02	Outcompetes and degrades cell walls	2	NL

Key: 5 = excellent and consistent, 4 = good and reliable, 3 = moderate and variable, 2 = limited and/or erratic, 1 = minimal and often ineffective, 0 = ineffective, NL = not on label[24,25]

several effective cultural practices, such as high tunnels, can help improve the effectiveness of an organic fungicide program[13,19].

Figure 6. Hives equipped with a biocontrol agent dispenser.

Insect vectored fungicides (entomovector technologies) are a hot topic in organic and conventional management of fruit diseases and may offer benefit for growers. Entomovector technologies is a term first coined in 2007 to describe the use of pollinators, such as honeybees or bumblebees, as vectors (or means) to disseminate biocontrol agents (BCA) directly to open flowers[20]. This is accomplished by equipping hives with dispensers that coat bees with a BCA as they exit the hive (Figure 6). Bees then carry these living organisms to open flowers as they pollinate them. As bees pollinate daily, a flower may be visited more than once and newly opened flowers may be visited quickly as they open, potentially offering continual targeted protection[18,20]. Because blooms are the primary site of infection for many fungal pathogens, including Botrytis and anthracnose, this method of dispersal not only targets the most susceptible plant tissue, but it also uses less product per acre.

Strawberry fields treated using bee vectored fungicides have exhibited a reduction in the incidence of Botrytis compared to untreated fields and achieved a similar level of protection as conventionally treated fields when paired with a fungicide spray program[18,20]. In these trials, a single hive evenly disperses a BCA up to 330 feet around the hive. Disease suppression using these methods is weather dependent, with very limited suppression occurring in high disease pressure years with high rainfall. Fungicides may also impact the potential effectiveness of any fungal biocontrol agents. The effectiveness of these techniques in the Southeast region where disease pressure is high is still relatively unknown, although testing is taking place in Arkansas and Florida. It is unlikely that entomovector systems can be used alone for organic or conventional management of fruit rots, and should be considered in addition to weekly fungicide spray programs.

Weather Considerations in Fungicide Selection

Frequent or heavy rain showers during strawberry production in the Southeastern U.S. can greatly increase the crop losses caused by fruit rots. To achieve adequate protection a fungicide program must consider forecasted weather conditions in the selection and application timing of a fungicide. The rainfastness of a fungicide product, or how a fungicide is affected by rain events, should influence the selection of a fungicide and the timing of an application. A product's rainfastness is influenced by several factors, most notable:

1. The type of fungicide used. Contact fungicides (Table 1) have fungicidal activity only on the surface of plant tissue and their protective residue can be washed off by rain or degraded by environmental conditions, such as sunlight[7,21]. A general rule of thumb is an inch of rainfall will wash off 50% of a contact fungicide's residue, with some studies indicating as little as 1/25 inch of rain can wash off about 50% of captan residue[7,22,23]. A systemic fungicide (Table 1), on the other hand, is absorbed into plant tissue (to varying degrees) and can continue to protect from within the plant after fungicide residue has been washed off plant surfaces.

2. Time between application and rain event. If a rain event occurs within 2 hours of a fungicide application, it is likely most residue was washed off[7]. Some level of protection will exist if the application occurs 3-6 hours before a storm, but to work properly, systemic fungicides should be applied at least 12 hours prior to rain events to give fungicides adequate time to absorb into plant tissue. Adjuvants may facilitate penetration of plant tissue.

3. Intensity of the rainfall event. While some level of wash/removal can occur during a light drizzle, a heavy downpour (1-2" of rain) will result in the complete loss of a contact fungicide residue[7,21]. Additionally, intensity of the rainfall event will decrease the effectiveness of systemic fungicides applied less than 12 hours prior to the rainfall.

A pre-rain application of a contact fungicide will limit the number of spores that can spread during a rain event and the amount of infection that occurs when plants will be wet for an extended period of time, but only if the fungicide is given adequate time to dry before the rainfall event. The protection provided by these fungicide applications lessens in the days following the rain event. Always be sure that strawberry plants and fruit are protected prior to a rainfall event, and reapply fungicides on tighter intervals (within what is allowed by the label) after rains if the forecast projects that scheduled applications will be prohibited.

Conclusion

Anthracnose and Botrytis fruit rot are serious fungal diseases that can severely limit strawberry production in the Southeastern U.S. The integration of effective cultural practices and a thorough and properly timed fungicide spray program can effectively protect strawberry plants from infection and prevent significant yield losses from either pathogen. While cultural practices will enhance the positive effect of any sustainable fungicide spray program, they are essential for the success of an organic pest management program.

References

[1] Petrashch, S., Knapp, S. J., van Kan, J. A. V. and Blanco-Ulate B. 2019. Grey mould of strawberry, a devastating disease caused by the ubiquitous necrotrophic fungal pathogen *Botrytis* cinerea. Molecular Plant Pathology. 20(6): 877-892.

[2] Samtani, J. B., Rome, C. R., Friedrich, H., Fennimore, S. A., Finn, C. E., Petran, A., Wallace, R. W., Pritts, M. P., Fernandez, G., Chase, C. A., Kubota, C. and B. Bergefurd. 2019. The Status and Future of the Strawberry Industry in the United States. HortTechnology. 29(1), 11-24.

[3] Poling, B. E. 2008. Anthracnose on Strawberry: Its Etiology, Epidemiology, and Pathology, Together with Management Strategies for Strawberry Nurseries: Introduction to the Workshop. American Society for Horticultural Science. 43(1): 59-65.

[4] Wycoff, S. B. and D. Frank. 2020. An Introduction to Integrated Pest Management. Virginia Cooperative Extension Publication: ENTO-365NP. https://vtechworks.lib.vt.edu/bitstream/handle/10919/98323/ENTO-365.pdf?sequence=1

[5] Koike, S. T., Browne, G. T., Gordon, T. R., Bolda, M. P., Gubler, W. D. and W. M. Wintermantel. 2018. Botrytis Fruit Rot: Botrytis cinerea. UC IPM Pest Management Guidelines: Strawberry. UC ANR Publication 3468. https://ipm.ucanr.edu/agriculture/strawberry/botrytis-fruit-rot/.

[6] Louws, F. 2018. Botrytis Fruit Rot/Gray Mold on Strawberry. NC State Extension Publications. https://content.ces.ncsu.edu/botrytis-cinerea-botrytis-fruit-rot-and-blight-on-strawberry

[7] Cato, A. 2020. Rainfastness of Fungicides in Strawberry: What factors should be considered when using Contact or Systemic Fungicides. U of A Division of Agriculture Research and Extension. https://www.uaex.uada.edu/farm-ranch/crops-commercial-horticulture/horticulture/ar-fruit-veg-nut-update-blog/posts/2020rainfastnessinstrawberries.aspx

[8] Smith, B. J. 2008. Epidemiology and Pathology of Strawberry Anthracnose: A North American Perspective, HortScience, 43(1), 69-73.

[9] Plaza, E. G. 2020. Strawberries: Production, Post-harvest Management and Protection. International Journal of Food and Fermentation Technology, 10(1), 28-28.

[10] Wang, N., Forcelini, B., and N. Peres. 2019. Anthracnose Fruit and Root Necrosis of Strawberry Are Caused by a Dominant Species Within the *Colletotrichum acutatum* Species Complex in the United States. Phytopathology 109: 1293-1301.

[11] Schilder, A. 2016. Warm weather favors anthracnose fruit rot in strawberries. Michigan State University Extension, Department of Plant, Soil and Microbial Science. https://www.canr.msu.edu/news/warm_weather_favors_anthracnose_fruit_rot_in_strawberries#:~:text=Anthracnose%20fruit%20rot%20is%20favored,wetting%20is%20required%20for%20infection.

[12] McWhirt, A., Fernandez, G., Schroeder-Moreno, M. and M. Hoffmann. 2020. Sustainable Practices for Plasticuture Strawberry Production in the South. NC State Extension Publications: AG-796. https://content.ces.ncsu.edu/sustainable-practices-for-plasticulture-strawberry-production-in-the-south

[13] Demchak, K., Elkner, T. and M. Hu. 2023. Anthracnose on Strawberry Fruit. Penn State Extension. https://extension.psu.edu/anthracnose-on-strawberry-fruit

[14] Hu, M. and K. Demchack. 2022. Strategies for Effective Management of Botrytis and Anthracnose Fruit Rot in Strawberries. Penn State University Extension. https://extension.psu.edu/strategies-for-effective-management-of-botrytis-and-anthracnose-fruit-rot-in-strawberries

[15] Madeiras, A. and S. Schloemann. 2015. Strawberry IPM-Gray Mold. UMass Extension Fruit Program. https://ag.umass.edu/fruit/fact-sheets/strawberry-ipm-gray-mold

[16] Louws, F. and B. Cline. 2019. Gray Mold / Crown Rot of Strawberry. NC State Extension Publications: https://content.ces.ncsu.edu/gray-moldcrown-rot-of-strawberry

[17] Melanson, R. A., Brannen, P. and B. Cline Eds. 2023. Southeast Regional Strawberry Integrated Pest Management Guide Focused on Plasticulture Production. Southern Region Small Fruit Consortium. https://secure.caes.uga.edu/extension/publications/files/pdf/AP%20119-4_1.PDF

[18] Karise, R., Dreyersdorff, G., Jahani, M., Veromann, E., Runno-Paurson, E., Kaart, T., Smagghe, G. and M. Mand. 2016. Reliability of the entomovector technology using Prestop-Mix and Bombus terrestris L. as a fungal disease biocontrol method in open field. Scientific Reports: 6(1). DOI: 10.1038/srep31650

[19] Carroll, J. and M. P. Pritts, eds. 2022. Production and IPM Guide for Organic Strawberries. New York State Integrated Pest Management Program. Ithaca, NY. 69 pages. https://ecommons.cornell.edu/bitstream/handle/1813/42890.3/2022-org-strawberries-NYSIPM.pdf?sequence=7&isAllowed=y

[20] Hokkanen, H. M. T., Menzler-Hokkanen, I., and M. L. Lahdenpera. 2015. Managing Bees for Delivering Biological Control Agents and Improved Pollination in Berry and Fruit Cultivation. Sustainable Agriculture Research: 4(3). doi:10.5539/sar.v4n3p89

[21] Mueller, D. 2006. Fungicides: Terminology. Iowa State University, Integrated Crop Management p. 122-123. https://dr.lib.iastate.edu/server/api/core/bitstreams/dfe14fe3-cb16-4284-aff4-0957910e1f12/content

[22] Schilder, A. 2010. Fungicide properties and weather conditions. Michigan State University Extension. https://www.canr.msu.edu/news/fungicide_properties_and_weather_conditions

[23] Schilder, A. 2015. The challenges of disease control during rainy spells. Michigan State University Extension. https://www.canr.msu.edu/news/the_challenges_of_disease_control_during_rainy_spells_1

[24] Carroll, J. and M. P. Pritts, eds. 2022. Production and IPM Guide for Organic Strawberries. New York State Integrated Pest Management Program. Ithaca, NY. 69 pages. https://ecommons.cornell.edu/bitstream/handle/1813/42890.3/2022-org-strawberries-NYSIPM.pdf?sequence=7&isAllowed=y

[25] Bolda, M. P., Dara, S. K., Daugovish, O., Koike, S. T., Ploeg, A. T., Browne, G. T., Fennimore, S. A., Gordon, T. R., Joseph, S. V., Westerdahl, B. B. and F. G. Zalom. Retrieved 2023 (Revised continuously). *UC IPM Pest Management Guidelines: Strawberry*. UC ANR Publication 3468. Davis, CA. https://ipm.ucanr.edu/agriculture/strawberry/fungicide-efficacybiocontrols-and-natural-products/

Acknowledgements: This factsheet was produced with funding support from the Southern Sustainable Agriculture Research & Education Program (SSARE).

Printed by University of Arkansas Cooperative Extension Service Printing Services.

TAUNYA ERNST is a Instructor - High Tunnel and Urban Agriculture Educator. **DR. AARON CATO** is a extension specialist - horticulture IPM. **DR. AMANDA MCWHIRT** is a extension specialist - horticulture. **RYAN KEIFFER** is a program associate - horticulture IPM. All are with the University of Arkansas System Division of Agriculture, Little Rock.

FSA6162-PD-03-2024N