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MANAGING FUNGICIDE RESISTANCE IN VINE CROP DISEASES

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Best management program for several important diseases of vine crops is based on knowledge of occurrence of resistance in the pathogen, knowledge of resistance management strategies, and knowledge of new fungicides. Fungicides are the main tool for managing diseases due to their efficacy and the importance of managing diseases of foliage as well as fruit to obtain high yield of good quality fruit. Modern fungicides that are the foundation of conventional fungicide programs due to their inherent activity, have risk of pathogens developing resistance to them due to their single site mode of action. Some targeted fungicides have narrow activity necessitating applying multiple products when more than one disease is occurring. This is especially true with the most common diseases, powdery mildew (caused by a fungus) and downy mildew and Phytophthora blight (caused by oomycetes). Fungicides recommended routinely change as new products are registered and pathogens develop resistance to fungicides that have been in use for several years. Resistance to fungicides has been documented in pathogens causing powdery mildew, downy mildew, gummy stem blight/black rot, and Phytophthora blight affecting vine crops. Resistance is a concern with other pathogens being managed with fungicides that are considered to be at risk for resistance development.

Fungicide resistance management. The basic strategy to manage resistance is minimizing use of each fungicide chemistry in the management program that has resistance risk while striving for good control. This is achieved by using resistant varieties and other cultural management practices to reduce the need for fungicides and alternating among fungicides in different chemical groups based on FRAC code. Incorporate new, effective fungicides into the program. Rarely new fungicides are not as effective as older ones. Look for recommendations and information about efficacy from applied pathologists doing fungicide evaluations. Starting applications promptly at appearance of first symptoms or before disease onset (especially important with Phytophthora blight) and maintaining good control are important for managing resistance to keep the pathogen population small so there are fewer individuals being subjected to selection for resistance. Use high rate with fungicides labeled over a rate range. This is recommended to avoid selecting for isolates with intermediate resistance (able to tolerate low dose) when the type of resistance is quantitative as with FRAC code 3 (DMI) fungicides, but typically the type of resistance (quantitative versus qualitative) is not known until resistance develops. Strict alternation of fungicides with different FRAC codes often is recommended; this is based on the assumption that if a resistant isolate is selected by applying the first fungicide, the next fungicide applied will control it. Another idea for managing resistance is to apply each chemistry consecutively before alternating (block alternation); rationale is the dose of this chemistry will remain high on plant tissue for a longer period of time and there will be only once after the second application that the dose decreases to a level that could allow selection of any isolates with intermediate resistance. Many fungicides can be applied consecutively; twice is typically the label limit. Label use restrictions pertaining to alternations are to compel resistance management. Another common recommendation for managing resistance is tank mixing

fungicides at risk for resistance with contact, protectant fungicides that have low inherent risk for resistance development (e.g. chlorothalonil and mancozeb). Whether it is better to apply the most effective fungicide in an alternation program primarily early or late in disease development is an important question. Better control of cucumber downy mildew was achieved when the most effective fungicide was applied later when disease pressure was increasing rather than in an early application soon after disease onset. Testing strategies to manage resistance is difficult, and it cannot be done until the pathogen has already developed resistance.

Powdery mildew is the most common disease of cucurbit crops because the pathogen produces an abundance of spores widely dispersed by wind and the pathogen doesn't require leaf wetness or high humidity to infect as others do. Only cultural management practice is resistant varieties, which are available in most crop groups. Resistance in cucumber is standard in modern varieties and is so strong it is easy to forget this cucurbit type is susceptible until an Heirloom type is grown. Resistance in other cucurbits is not adequate used alone (without fungicides) to prevent impact of powdery mildew on yield. An integrated program with both resistant varieties and fungicides is recommended to maximize likelihood of effective control and to manage resistance as well as reduce selection pressure for isolates able to overcome resistant varieties.

Resistance has developed in this pathogen to six fungicide chemical groups: FRAC Code 1 (MBC fungicides; Topsin M), Code 11 (QoI fungicides; Quadris, Cabrio and Flint), Code U6 (Torino), Code 13 (Quintec), and to some fungicides in Code 3 (DMIs) and Code 7 (SDHIs). Fungicide resistance and efficacy have been studied at LIHREC for 30 years. This work documented control failure due to resistance to these chemistries by testing pathogen isolates from field plots where the fungicide was ineffective. Pathogen isolates collected every year from commercial and research fields are tested. Seedling bioassays are conducted in field plantings to assess resistance in pathogen populations. Recent results revealed that resistance in the pathogen to Code 1 and 11 fungicides and to the Code 7 fungicide boscalid (Endura, Pristine) have continued to be very common, therefore these continue to not be recommended for managing powdery mildew. Resistance to Code U6 and 13 has been found more commonly toward the end of the growing season. Fungicides in these groups are no longer recommended; growers with product left over could consider using at the start of powdery mildew development when resistant isolates have been less common. Testing isolates has revealed existence of isolates resistant to multiple fungicides in different chemical groups.

Recommended fungicide program to manage powdery mildew and fungicide resistance is to alternate among targeted, mobile fungicides in the 4 chemical groups below, and apply these with protectant fungicide. There are several protectants for powdery mildew, including chlorothalonil, sulfur, botanical and mineral oils, copper, and several biopesticides. Sulfur is most effective, but can injure cantaloupe leaves. Begin very early in disease development (one older leaf out of 50 with symptoms). Expect symptoms after plants start to product fruit.

Vivando (FRAC Code 50) has continued to provide excellent control in fungicide evaluations. Activity is limited to powdery mildew. Do not mix with horticultural oils. It can be applied three times per year with no more than two consecutive applications. REI is 12 hr. PHI is 0 days. Proливо is a new Code 50 fungicide; it was tested at LIHREC in 2016 and found not to be as effective as Quintec; Vivando was not included in that evaluation.

DMI fungicides (Code 3) include Proline, Procure, and Rhyme (these are considered most effective) plus Aprovia Top, Folicur, Inspire Super, Mettle, Rally, Tebuzol, and

TopGuard (also has Code 11 ingredient). Resistance is quantitative. Highest label rate is recommended because the pathogen has become less sensitive to this chemistry. Efficacy has varied in fungicide evaluations. Procure applied at its highest label rate provides a higher dose of active ingredient than the other Code 3 fungicides. Five applications can be made at this rate. REI is 12 hr for these fungicides. PHI is 0 - 7 days. Powdery mildew is the only labeled cucurbit disease for some of these; see last section for additional labeled diseases.

Gatten is in a new fungicide group (Code U13). Activity is limited to powdery mildew. It was not as effective as Vivando in a fungicide evaluation at LIHREC in 2018, but was as effective in a similar evaluation in 2019. Currently labeled for use on cantaloupe, cucumber, and squash. REI is 12 hr. PHI is 0 days.

Carboxamide fungicides (Code 7) include Luna fungicides (Luna Experience and Luna Sensation), Miravis Prime (also has Code 12 ingredient which targets other diseases), Fontelis, Endura, Pristine and Merivon. Powdery mildew pathogen strains resistant to boscalid, active ingredient in Endura and Pristine, have been detected since 2009 on Long Island and likely are the reason its efficacy has been poor in some fungicide evaluations. In laboratory assays boscalid-resistant strains exhibited sufficient cross resistance with Fontelis and Merivon that these are expected to be ineffective as well, but not with Luna fungicides. However, Luna Sensation failed in experiment at LIHREC in 2017. Luna Experience is the best choice. REI is 12 hr. PHI is 7. Maximum number of applications is 2-5, depending on rate used. Low rate is not recommended. Luna Experience also contains tebuconazole (Code 3), which needs to be considered when developing an alternation program. Luna Sensation is not recommended because it also contains trifloxystrobin (Code 11); resistance to this chemistry is very common. Limited use of Luna Experience is suggested.

Downy mildew is also primarily managed with fungicides due to lack of other management practices. Cucumbers with a new source of resistance are becoming available. Those that performed well in variety evaluations are DMR 401, NY264, Bristol and Citadel, which is a pickling type suitable for fresh market. Some suppression, albeit variable, can be obtained with varieties bred to be resistant to pathogen strains present before 2004. An important tool for determining when fungicide application is warranted is the forecast web site for this disease at <http://cdm.ipmpipe.org>. The forecast program monitors where the disease occurs and predicts where the pathogen likely will be successfully spread. Forecast system success depends on knowledge of where downy mildew is occurring; therefore, prompt reporting of outbreaks by growers to extension staff or the website is critical.

Resistance has been documented in the pathogen to fungicides in FRAC Codes 4 (e.g. Ridomil), 11 (Quadris), and 40 (Revus) and is suspected to have developed to other chemistry based on results from fungicide evaluations and fungicide sensitivity seedling bioassays conducted in several states recently. Poor to ineffective control has often been obtained with Forum (40) and Presidio (43), and less frequently with Previcur Flex (28) and Curzate or Tanos (both 27). Zampro (40+45) and Elumin (22) have sometimes exhibited poor control. Most effective fungicides are Orondis Ultra and Orondis Opti (49), Omega (29), Ranman (21), and Zing! (22). The pathogen is now known to exist as two host-specific clades and resistance / poor control has mostly been documented using isolates from cucumber and cucumber in fungicide evaluations and seedling bioassays. Cucumber is primarily infected by Clade A1 which also has been found on melons, except watermelon, which is infected by Clade A2 as are squashes and pumpkin. Fungicides ineffective on cucumber due to resistance may be effective on these other crops.

Phytophthora blight pathogen survives in soil with limited movement between farms, therefore fungicide use on a farm is a more important determinant of resistance occurrence on that farm than with the mildew pathogens. Resistance to FRAC Code 4 fungicides has been documented where they have been used repeatedly. Little additional research on resistance has been done with this pathogen. Resistance to Ranman and Presidio has been detected in the southeastern US. Other fungicides labeled and recommended for Phytophthora blight include Orondis Gold or Orondis Ultra (only one formulation can be used), Omega, Gavel, Zampro, and Tanos. Phosphorous acid fungicides (33) are recommended tank-mixed with these. There are many cultural practices for managing Phytophthora blight and thus resistance. Most focus on minimizing favorable conditions (saturated soil). More information about management and fungicides is at http://vegetablemdonline.ppath.cornell.edu/NewsArticles/PhytoBlight_cucurbits-others.html.

Gummy stem blight / black rot pathogen has proven more adept at developing resistance than expected. Resistance has been documented to fungicides in FRAC Codes 1 (e.g. Topsin M) and 11 (Quadris), and to some fungicides in Code 7 (Endura, Pristine) and Code 3 (Tebuconazole). Fortunately, fungicides with new Code 7 chemistry (e.g. Aprovia and Miravis Prime) have been effective in fungicide evaluations where boscalid-resistant isolates are common. And Code 3 resistance so far has been found in only one of the three species of *Stagonosporopsis* causing this disease; however, with continued use of this chemistry over time resistance could become more common and also develop in the other species.

Two fungicide programs expected to provide good control are Inspire Super alternated with Miravis Prime and Switch alternated with Aprovia Top. Due to overlap in chemistry for some of these and need to alternate amongst chemistry (label use restrictions for resistance management), these are the best simple alternation options with these four. If GSB is occurring in a crop that commonly gets powdery mildew, then the first program is the best since Switch has no activity for powdery mildew. All can be applied at most two times sequentially before need to rotate. They can be applied four to five times, depending on product and rate, except Miravis Prime which can be applied only twice. Switch (FRAC code 9+12) is the only registered targeted fungicide with chemistry to which resistance has not been detected in the pathogen yet.

Sources of resistant pathogen isolates include on-farm selection from repeated use of a fungicide chemistry (the pathogen survives in soil) or selection on nearby farms (spores are dispersed short distances by wind and splashing water), seed contaminated with a resistant pathogen strain, and transplants infected when grown in a greenhouse where the pathogen is resistant. Crop rotation of at least two years is an important cultural practice to include in the management program for this disease and for fungicide resistance.

See <http://vegetablemdonline.ppath.cornell.edu> for more information about diseases of cucurbit crops and their management.

Please Note: The specific directions on pesticide labels must be adhered to -- they supersede these recommendations, if there is a conflict due to label change or error. Any reference to commercial products, trade or brand names is for information only; no endorsement is intended.