2015 Research Report to the
Michigan Grape & Wine Industry Council

Proposal Title:
Optimizing fungicide use and timing based on weather conditions.

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Original goals and objectives for the project:
1) Study the effect of weather conditions during fungicide application on fungicide persistence and efficacy
2) Determine the effect of temperature after application on fungicide residue distribution
3) Determine the pre- and post-infection activity of selected fungicides against *Phomopsis*
4) Evaluate the effect of selected fungicides on fruit set in juice grapes

Literature Review
Many new insecticide and fungicide chemistries have become available over the past decade for grapes (Wise et al., 2011). Fungicides differ in their behavior on and in the plant. Some are strictly protectants (contact materials) that remain on the plant surface, while others are systemic and are absorbed by plant tissues. The chemical constituents (both the active ingredient and additives) of the various products determine their mode of action and physical behavior (FRAC website). Many of the new products represent reduced-risk pesticides, and some products are labeled for organic production (Wise et al., 2011). One issue that is poorly understood by growers as well as the academic community is the effect of temperature on the efficacy of fungicides. It has been reported that sterol inhibitor fungicides do not work at temperatures under 40˚F (Buchholz, 2006). However, high temperatures may increase movement and dilution and/or breakdown of fungicides in plants or high temperatures combined with drought conditions may reduce the absorption ability of the plant cuticle and thereby fungicide activity (Bouma, 2006). In 2010 and 2011, we observed below-expected efficacy of some fungicides which may have been related to hot dry conditions during which the fungicides were applied. However, very little information is available, especially as it relates to grapes.

In addition, not much is known about the degree of residual and/or curative activity of fungicides against against Phomopsis cane and leaf spot in grapes (Wise et al., 2011). The degree of curative activity is especially important when using fungicides as post infection treatments in response to predictive model outputs. While a disease prediction model has been developed for Phomopsis in grapes, it has limited use since we have no fungicides with strong post-infection activity. Phosphites (e.g., Phostrol and ProPhyt) may be useful in this regard since they have strong systemic and post-infection activity against downy mildew. We have found good efficacy of phosphites against Phomopsis under field conditions, but the mode of action is unknown (Schilder et al, 2008).

An additional observation in a 'Concord' field trial showed that overall yield per vine was reduced in some plots that received fungicides versus plots that received no fungicides (L. A. Miles, 2011), which was unexpected. This suggests that some fungicides, when applied during bloom, may reduce fruit set. It is important to know if this is the case, and if so, what fungicides are risky to use during bloom. This proposal aims to understand the effects of timing and weather conditions on fungicide uptake and efficacy as well as any potential deleterious effects on fruit set. This is anticipated to optimize use patterns and minimize wastage and undesirable side effects on the vine and the environment.

Results and Conclusions

The project showed that temperature at the time of fungicide application can have an effect on fungicide uptake and retention. A field study using Ziram in 'Niagara' grapes showed that more ziram was retained when applied at 75°F than 62°F or 86°F. Temperature did not seem to affect rainfastness as over 80% of ziram was removed up by 3.5 inches of rainfall and 50% by 0.6 inches of rainfall. Remaining residues were more tenacious during subsequent rainfall events. Temperature studies with Abound showed that low temperatures (40°F) resulted in almost no detectable residues (i.e., the fungicide seemed to have broken down) and that 60°F was better than 90°F for retention. It is advisable, therefore, not to apply strobilurins during cold periods. In general, we can conclude that moderate temperatures are optimal for fungicide uptake and adherence. In a potted-plant experiment with Abound, Manzate and Phostrol all fungicides had protective activity against Phomopsis cane and leaf spot and Abound appeared to be the strongest protectant. Curative activity was lower and diminished with each consecutive day after inoculation. The overall conclusion is that these fungicides are best applied as preventative applications within a week before anticipated infection. Fungicide application to juice grape flower clusters in full bloom resulted in increased fruit set but subsequently lower cluster weight and number of berries per cluster compared to untreated or water-treated controls. This suggests that fungicide sprays at full bloom may lower yields and may need to be avoided. Further research is needed to confirm these results.

Time Line

This was a 2-year project. We will ***c***omplete the residue analysis of repeated fungicide experiments in the fall of 2015.

Work accomplished during period including methods

1) *Study the effect of weather conditions during fungicide application on fungicide persistence and efficacy.*

We sprayed the protectant fungicide Ziram (ziram) on leaves of field-grown 'Niagara' grapevines at three different temperatures (62°F, 75°F, 86°F) to compare fungicide retention under different weather conditions. Leaf samples were taken within 24 hours of the initial application and after each of three subsequent rain events. Ziram leaf samples were analyzed for total Zinc content in a plant nutrition lab. There was more recoverable ziram ($P = 0.07$) on the leaves when the application occurred at 75°F than at higher or lower temperatures. In all cases, rainfall dislodged ziram within several days of the application, with over 75% of the residue lost after 3.5 inches of rain (first spray), 50% residue lost after 0.6 inches of rain (second spray), and 17% lost after 0.5 inches of rain. Whatever was left after the first rainfall was more tenacious as subsequent rainfall generally dislodged less fungicide. Other trials have shown that rainfall intensity is also an important variable with light rain dislodging less material than the same amount of rain in an intense burst.

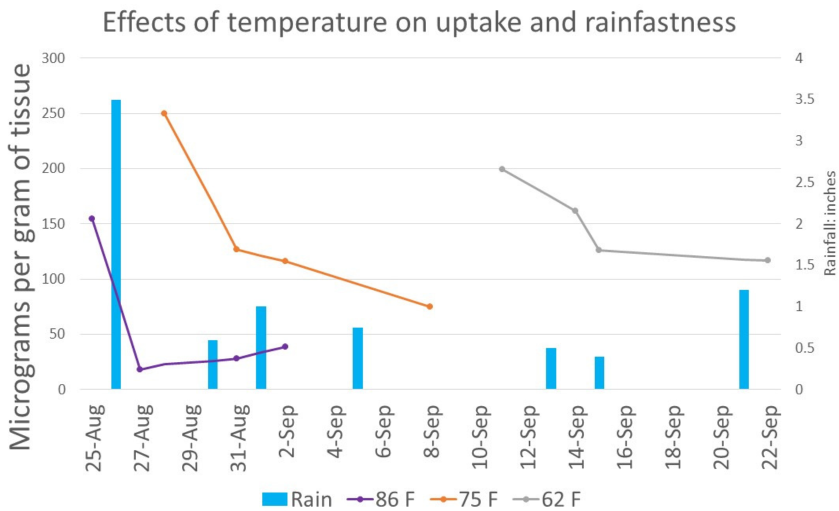

Fig. 1. Effect of temperature at the time of application and rainfall on retention of ziram fungicide on 'Niagara' grape leaves in the field.

2) Determine the effect of temperature after application on fungicide residue distribution
Potted 'Vignoles' plants were sprayed with Abound (azoxystrobin), Phostrol (phosphorous acid) or Ziram (ziram) with three replicates per treatment. The plants placed in growth chambers at 40, 65, or 90˚F for 3 days. At that time, leaf samples were taken and surface residue was extracted with acetonitrile for 60 seconds. To extract subsurface residue, leaves were macerated in the solvent. All aliquots were roto-evaporated to enable them to be run in an HPLC (high pressure liquid chromatography) to determine the amount of fungicide per gram of leaf tissue. Only Abound results were obtained as we are still waiting for the residue analysis of the other fungicides. The results showed that most of the residue was retained on the surface (easily dislodgeable) and that temperature had a big effect on uptake/retention. At 40 F almost no fungicide was retrievable. It is not clear what happened to the active ingredient but we have found similar results in blueberries. The most fungicide was retained at 60°F and about half as much at 90°F. This suggests that Abound (and other strobilurin fungicides) may not be very effective when applied at low temperatures. This experiment is being repeated.

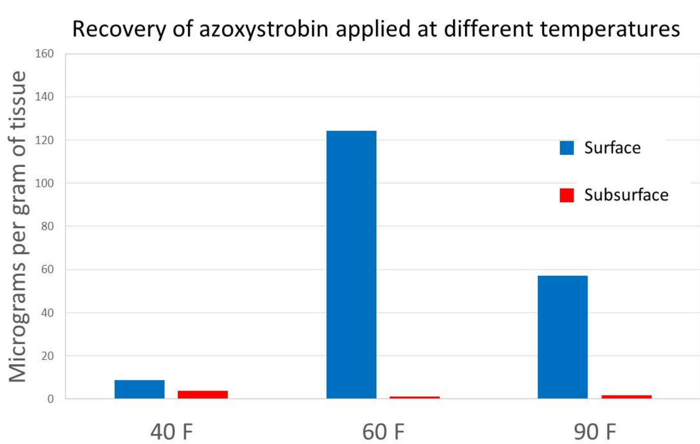

Fig. 2. Recovery of Abound (azoxystrobin) when applied to grape leaves at different temperatures.

3) Determine the pre- and post-infection activity of selected fungicides against Phomopsis
We evaluated the activity of ProPhyt (highly systemic; 3 pt/acre equivalent), Abound (locally systemic; 12 fl oz/acre equivalent) and Manzate (protectant; 3 lb/acre equivalent) against

Phomopsis viticola. The fungicides were sprayed on detached shoots of the cultivar Vignoles placed in test tubes with water. Applications were made 10, 7, 5, 3, and 1 days before inoculation to determine protective activity and 1, 3, 5, and 7 and 10 days post-inoculation to determine curative activity against the disease. Shoots were inoculated with *Phomopsis viticola* inoculum (10^6 spores/ml) and kept moist for 72 hours. There were three replicates per treatment. Disease severity was evaluated after 2 weeks. Some of the tips of the shoots had started dying back due to infection or possible phytotoxicity in the case of Phostrol. All fungicides had protective activity, although applications longer than 7 days before inoculation were somewhat less effective. Abound overall was the best protectant. All fungicides showed curative activity against leaf spot which diminished with time after inoculation. Despite Phostrol being the most systemic fungicide, it did not have the most curative activity. The curative efficacy of manzate was somewhat unexpected and needs further investigation. The overall conclusion is that these fungicides are best applied as preventative applications within a week before anticipated infection periods. If post-infection applications need to be made, then apply Abound or manzate within 24 hours of the suspected infection period.

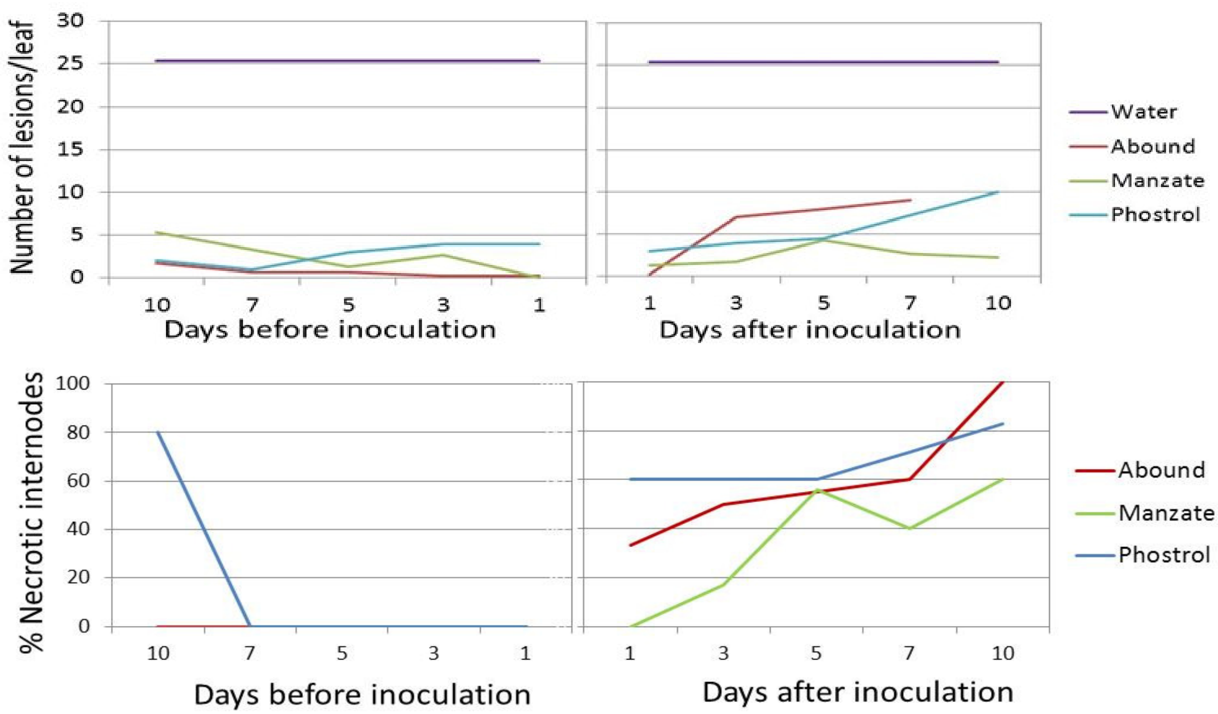

Fig. 3. Effect of fungicide timing on the level of protective activity (when applied before inoculation) and curative activity (when applied after inoculation) against Phomopsis. The top graphs shows disease as the number of lesions per leaf and bottom graph as % necrotic internodes.

4) Evaluate the effect of selected fungicides on fruit set in juice grapes

We evaluated potential negative effects of fungicide applications on fruit set and yield in 'Concord' grapes in Benton Harbor. We applied the following fungicides at recommended rates directly to selected flower clusters in full bloom with a hand spray bottle: Captan (captan), MilStop (potassium bicarbonate), Sovran (kresoxim methyl), Elite (tebuconazole), Manzate (mancozeb), Cuprofix (copper sulfate), Oxidate (hydrogen peroxide), and Ziram (ziram). Distilled water served as a control. Ten clusters were sprayed per vine with four replicates per treatment in a randomized complete block design. At fruit set and harvest time, five clusters per treatment were harvested per vine and the number of berries per cluster and berry weight determined. At fruit set, the number of berries and cluster weight tended to be higher in most fungicide treatments than the water control, whereas at harvest the opposite was observed. In fact, cluster weight at harvest was reduced over 40% in the Ziram, Oxidate and Cuprofix treatments. The experiment was repeated in 'Niagara' grapes in East Lansing 2014 with a few more fungicides. In this case, whole vines were sprayed with a backpack-style sprayer. Five clusters per vine were evaluated at fruit set and 10 clusters at harvest. A similar scenario to 2013 was observed, however, the water treatment also resulted in a reduction. The mechanism is not clear but the fungicides application may interfere with pollination, resulting in delayed fruit set and then increased shattering later. More research is needed to confirm results but it may be advisable to avoid fungicide (or other pesticide) applications during full bloom if a full crop is desired.

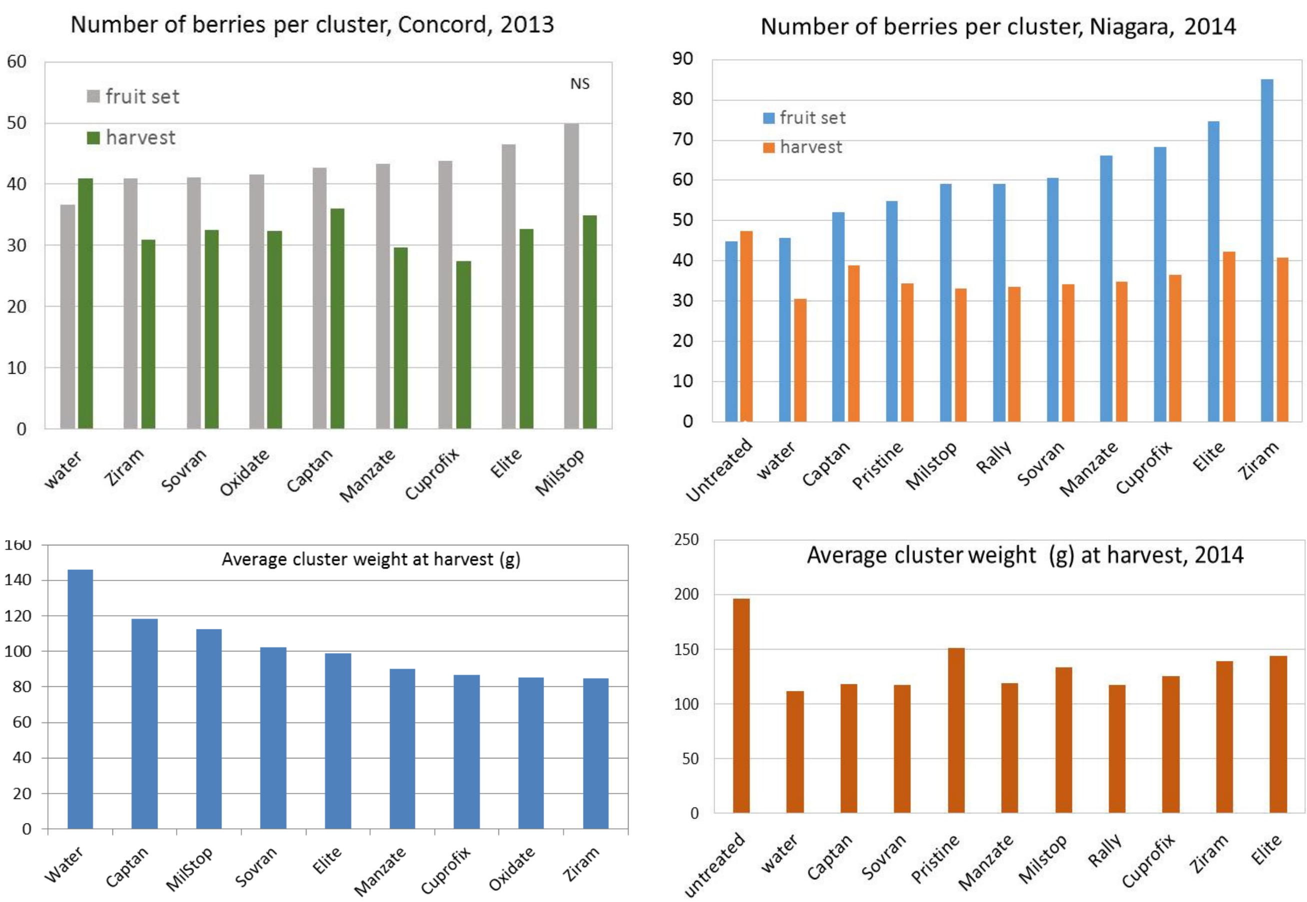

Fig. 4. Effect of fungicides sprayed at full bloom on the number of berries per cluster at fruit set and harvest and average cluster weight at harvest. Water and untreated berries served as control.

Communication Activities, Accomplishments, and Impacts

We have shared preliminary results from this project at the Southwest Michigan Horticulture Days (Feb. 2014), Viticulture Day (July 2014), a grape IPM meeting at Lemon Creek farms (Aug. 2014), and an MSUE Article in May 2015. However, due to problems in the MSU pesticide analysis laboratory, residue sample processing was delayed and a number of samples were lost in the process, such that we are repeating some of the experiments in 2015 and will update this report when we have additional results. In terms of the expected impact, optimizing fungicide timing and use by grape growers is anticipated to lead to improved disease control and higher yields, which are critical for the continued economic viability and environmental sustainability of the grape industry in Michigan.

Research publications resulting from this project

A journal article is in preparation for the journal "Plant Disease" and will be submitted in 2016.

Funding partnerships

This project helped to leverage a GREEEN grant entitled: "Understanding environmental effects on fungicide uptake and efficacy in blueberries and grapes to optimize the cost/benefit ratio" which provides matching funds for this grant ($73,600 total over 2 years). It builds on a 2012 MDA specialty crop block grant entitled "Enhancing the sustainability of small fruit crops in Michigan by optimizing fungicide applications" ($39,861), covering blueberries and grapes. The MGWIC proposal is specific to grapes and complementary to the other projects.

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