Final Annual Report

Proposal Title: Grape Powdery Mildew Management—A Fungicide Timing and Selection Conundrum

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UGMVE Proposal Number: 2015-1826

Project Summary (May 2015 – May 2016)

Fungicide timing trials were conducted at the Botany and Plant Pathology Farm in Corvallis, Oregon during the 2015 growing season in order to determine the optimum timing of fungicide applications to control grape powdery mildew (GPM). The growing season of 2015 began early due to warm temperatures early in the growing season leading to rapid growth. The fungicide timing and selection trial was able to be conducted despite the rapid succession of flowering developmental stages. Fungicide treatments were applied during three phenological stages hypothesized to be particularly susceptible to GPM infection (BBCH 55, 65, 69). Disease progress was monitored during the growing season by weekly scouting for leaf incidence and severity, and clusters were collected just before véraison to assess for GPM severity. Fungicide mobility to the fruit was additionally examined in the field by covering selected clusters during fungicide applications. Cluster severity data is in preliminary analysis, and the results of the field mobility assay will be used to direct greenhouse mobility assays. Preliminary analysis has shown that utilizing grape phenology to time fungicides significantly reduces disease incidence on the leaf tissue compared to the standard calendar application treatments ($P < 0.01$). Analysis of the berry data has shown that the two later timing treatments (BBCH65 & 69) reduced disease significantly compared to the calendar sulfur and no treatment controls ($P < 0.05$). Fungicide selection for application during grape flowering significantly reduces leaf and berry disease incidence, with fluopyram and trifloxystrobin being significantly different from other treatments ($P < 0.05$). This experiment will be repeated in the 2016 growing season, and the results from the 2015 and 2016 growing will be used to select a fungicide timing and selection regime for the 2017 commercial implementation trial.

During the course of this experiment, fungicide resistance to strobilurin and DMI fungicides was reported within the Willamette Valley. Isolates collected from fields with suspected fungicide resistance were collected and cultured in the lab on detached leaves to assay

with various fungicide chemistries commonly used within the Willamette Valley. While this information was not directly related to the original proposed project, this information may impact optimal fungicide selection and timing regimes when this project is expanded to commercial vineyard tests.

Objectives and Experiments Conducted:

The goal of this research is to improve the efficiency of grape production by optimizing fungicide selection and timing to manage powdery mildew of grape berries. We hypothesize that targeting mobile fungicides to critical inflorescence developmental stages will reduce berry infection and the need for short application intervals during berry development. The specific objectives are to:

1. Determine the most effective fungicide application timing with relation to grape inflorescence development/phenological stage
2. Examine the effect of different fungicide chemistries with varying levels of plant mobility that are commonly used to manage grapevine powdery mildew
3. Test commercial implementation of phenological stage-driven fungicide application timing

Objective 1: Fungicide application timing with relation to phenological stage

Fungicides were applied at the Botany and Plant Pathology Research vineyard on Pinot Noir grapes in the 2015 growing season at three different grapevine developmental stages: BBCH 55, 65, and 69. These growth stages were chosen due to the potential effect of inflorescence architecture on fungal spore deposition that may influence disease development on flowers and berries. Various fungicides used to manage grape powdery mildew (Table 1) were chosen based on chemistry mobility to test the interaction of fungicide selection and timing. These were each applied at the three different timings in a randomized complete block factorial design. To assess the impact of the fungicide timing and selection on disease development, plants were scouted weekly for disease incidence, and then scouted for disease severity once percent incidence was nearly 80% in the non-treated control plots. Berry clusters were collected at the onset of véraison to assess the effect of fungicide application timing and selection on berry disease incidence.

Objective 2: Effect of fungicide mobility on disease development on clusters.

Fungicide chemistries (Table 1) were chosen based on the prevalence of use within the region to test the effect of mobility on disease incidence. To test the specific mobility of fungicides on inflorescences, 10 inflorescences/clusters were covered with a plastic bag at each fungicide application and removed after fungicide application was completed. Covered and uncovered berry clusters were collected at the onset of véraison, and microscopically examined for disease incidence. The results from this experiment will aid in directing fungicide selection for greenhouse trials to test specific fungicide mobility within a single plant with optimal fungicide application coverage. Greenhouse studies will utilize Pinot Meunier and Chardonnay seedlings in future studies directed by field fungicide mobility assays.

Objective 3: Test commercial implementation

Commercial implementation will be assessed at 3 to 4 participating vineyards within the Oregon wine grape growing region in 2017. This objective will test the implementation of optimal fungicide selection and application timing regimes determined most effective from the previous two objectives.

Table 1. Selected fungicide mechanisms and application rates utilized in the proposed research

Fungicide Name		Fungicide Mechanism			Application Rate	
Technical	Trade	FRAC Classification	Mode of Action	Mobility	Label Rate/ Acre	Fungicide/ Gallon
Quinoxyfen (Henry 2003)	Quintec	13	Inhibit early cell signaling and appressorium development	Motility in xylem or volatilization on surface	5 fl oz	0.2 fl oz
Tebuconazole (Kwok and Loeffler 1993)	Toledo	3	Sterol demethylation inhibition	xylem mobile	4 fl oz	0.16 fl oz
Fluopyram (Ishii, Miyamoto et al. 2011)	Luna Privilege	7	succinate-dehydrogenase inhibition	locally systemic	3.2 fl oz	0.13 fl oz
Trifloxystrobin (Bartlett, Clough et al. 2002)	Flint	11	Q_0I inhibitor that inhibits the bc1 complex of mitochondria	locally systemic	2 fl oz	0.08 fl oz
Sulfur (Bloem, Haneklaus et al. 2007)	Microthiol	M2	unknown multi-site activity	non-systemic, mobile via volatilization on plant surface	4 lbs	0.05 lbs

PROCEDURES TO ACCOMPLISH OBJECTIVES:

Results

Objective 1: Fungicide application timing with relation to phenological stage

Using leaf incidence AUDPCs, all timing regimes were significantly different from the non-treated control plots including the BBCH-timed sulfur application (Figure 1), and timing treatments were significantly different from the calendar standard treatment (Figure 2). There was an effect of fungicide selection (Figure 3) with fluopyram showing the least leaf disease incidence in treatment plots. No interaction between fungicide and timing was observed in the leaf incidence data, which may be due to the rapid progression of grapevine development in the 2015 growing season where all growth stages occurred within 2 weeks of each other.

Over all there was a significant effect of application timing on berry (Figure 5). However, with some fungicides there was little impact compared to the to the controls (Figure 4). The two later timings (BBCH65 & 69) provided significantly better control than the calendar sulfur and no-treatment control plots (Figure 5). Fungicide selection had a similar effect on berries to that of leaves with Flint and Luna providing the best disease control (Figure 6). These data indicate that targeting some chemistries to later part of flowering may improve disease management on berries.

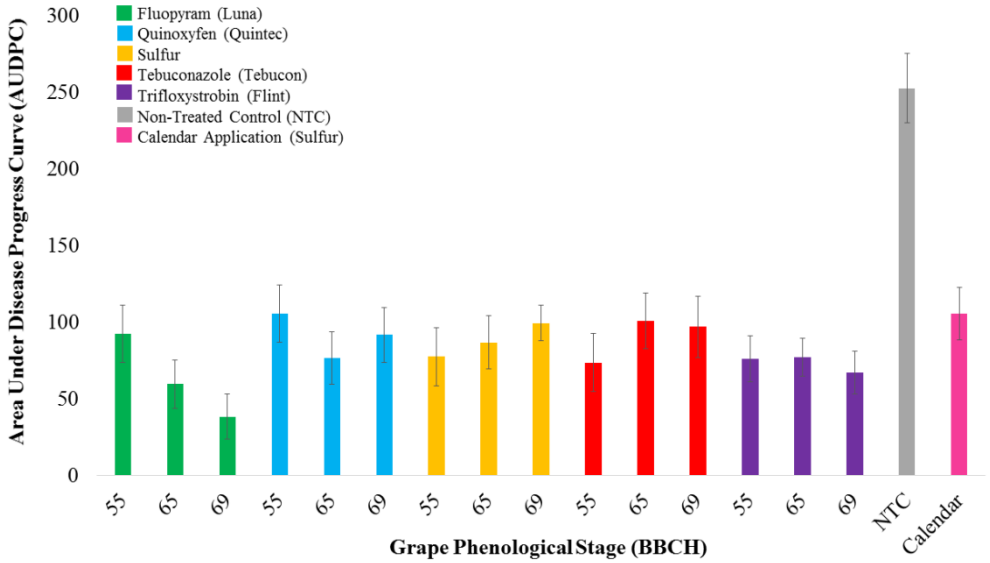

Figure 1. Area under disease progress curve means across fungicide and phenological stage treatments. Fungicides were applied at three different phenological stages (BBCH 55, 65, 69). Fungicides with varying mobility and modes of action were chosen for this study, including fluopyram (green bars), quinoxyfen (blue bars), sulfur (yellow bars), tebuconazole (red bars), and trifloxystrobin (purple bars). All treatments were compared to a non-treated control, whereby no fungicides were applied for the duration of the growing season, and a calendar-based application schedule of sulfur, representing the general standard practice. All treatments significantly reduced disease compared to the non-treated control.

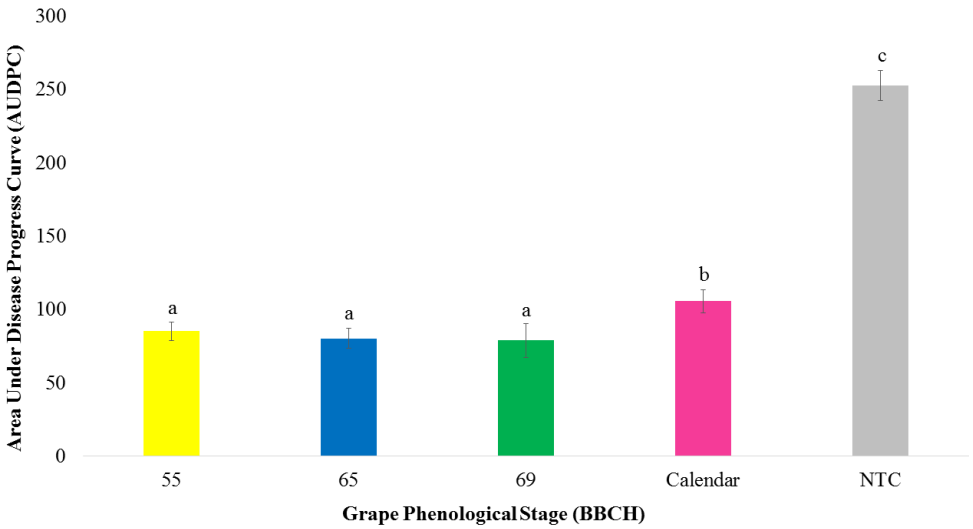

Figure 2. Area under disease progress curve means across phenological stage treatments. Fungicides were applied at three different phenological stages (BBCH 55, 65, 69). Treatments were compared using a Student's t-test, and significantly different treatments are grouped according to the letters shown above the graph. Different timing treatments were not significantly different from one another, but were significantly different from the calendar-application treatment. All treatments were significantly different from the non-treated control plots.

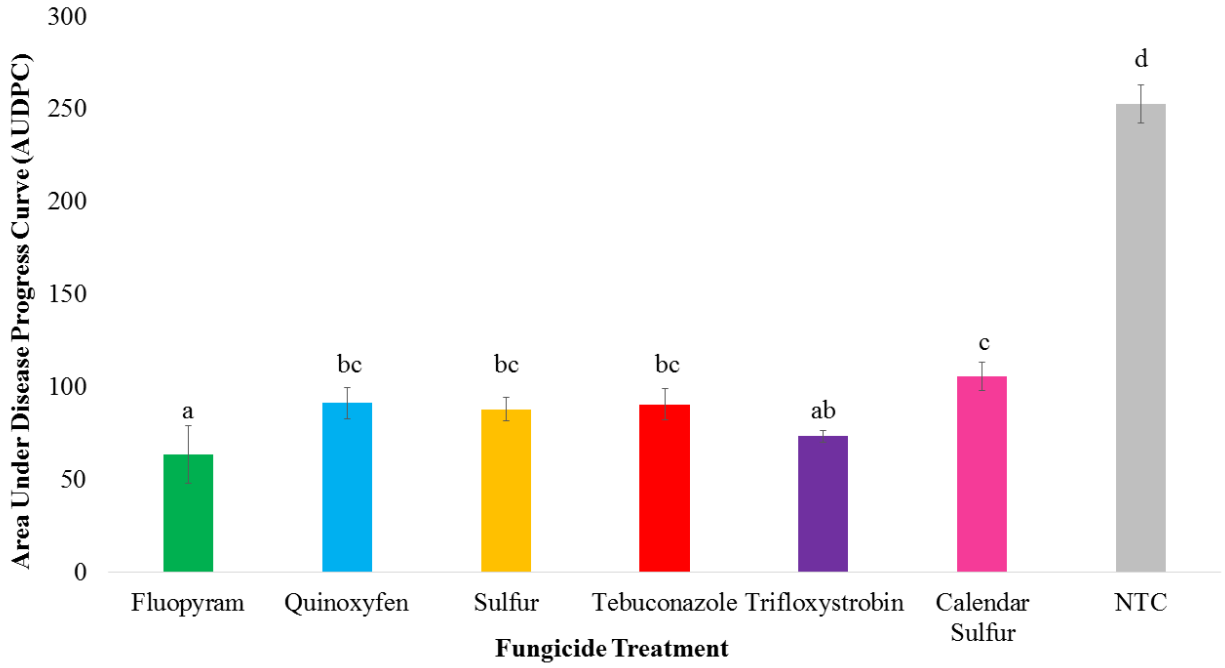

Figure 3. Area under disease progress curve means across fungicide treatments. Treatments were compared using a Student's t-test, and significantly different treatments are grouped according to the letters shown above the graph. All fungicide treatments were significantly different from the non-treated control plots. Fluopyram and

trifloxystrobin showed significantly reduced leaf disease incidence compared to the calendar-application of sulfur. Quinoxyfen, BBCH-timed sulfur, and tebuconazole showed similar control of leaf disease incidence, but were not significantly different from the calendar-application of sulfur.

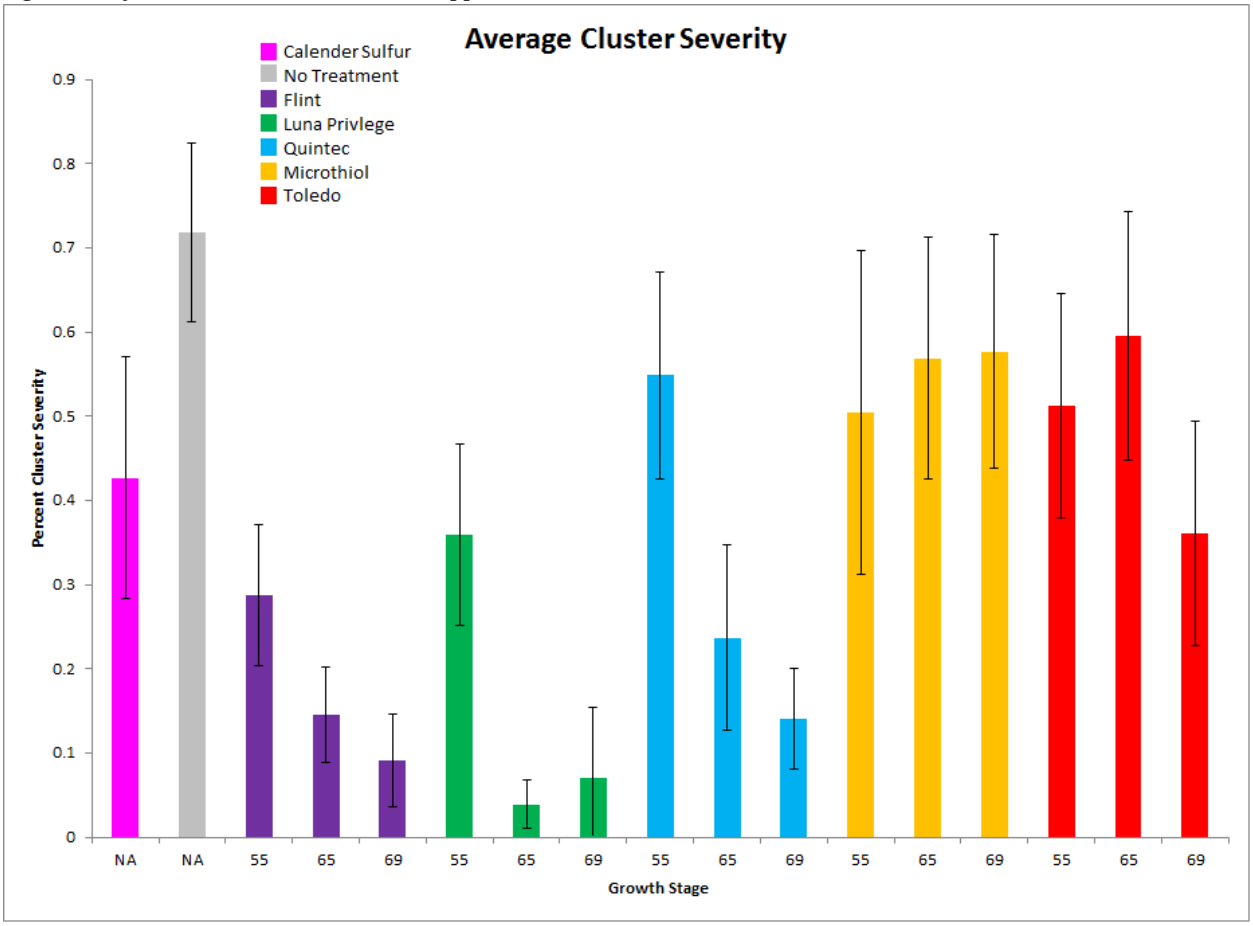

Figure 4. Means of berry severity across fungicide treatments. Fungicides were applied at three different flowering stages (BBCH 55, 65, 69). All treatments were compared to a non-treated control, whereby no fungicides were applied for the duration of the growing season, and a calendar-based application schedule of sulfur, representing the general standard practice.

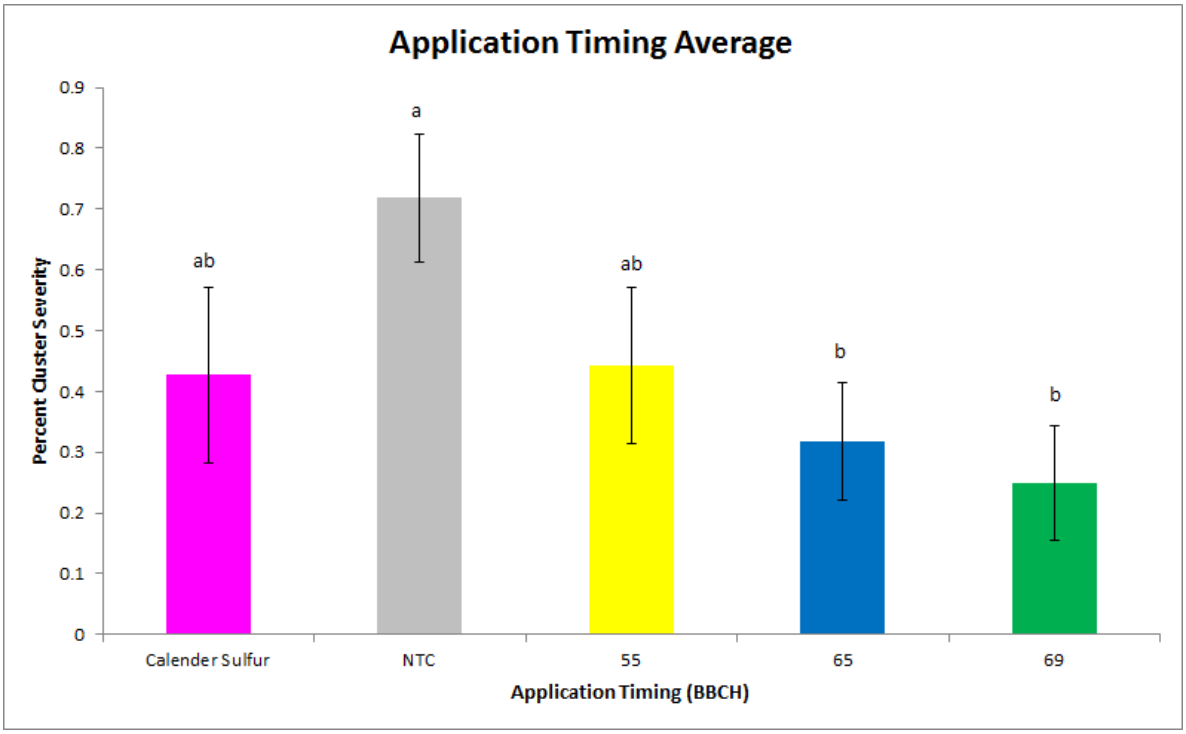

Figure 5. Averages of berry severity separated by timing of the treatment. Treatments were compared using a Student's t-test, and significantly different treatments are grouped according to the letters shown above the graph. On average the later applications provided improved disease control on grape berries.

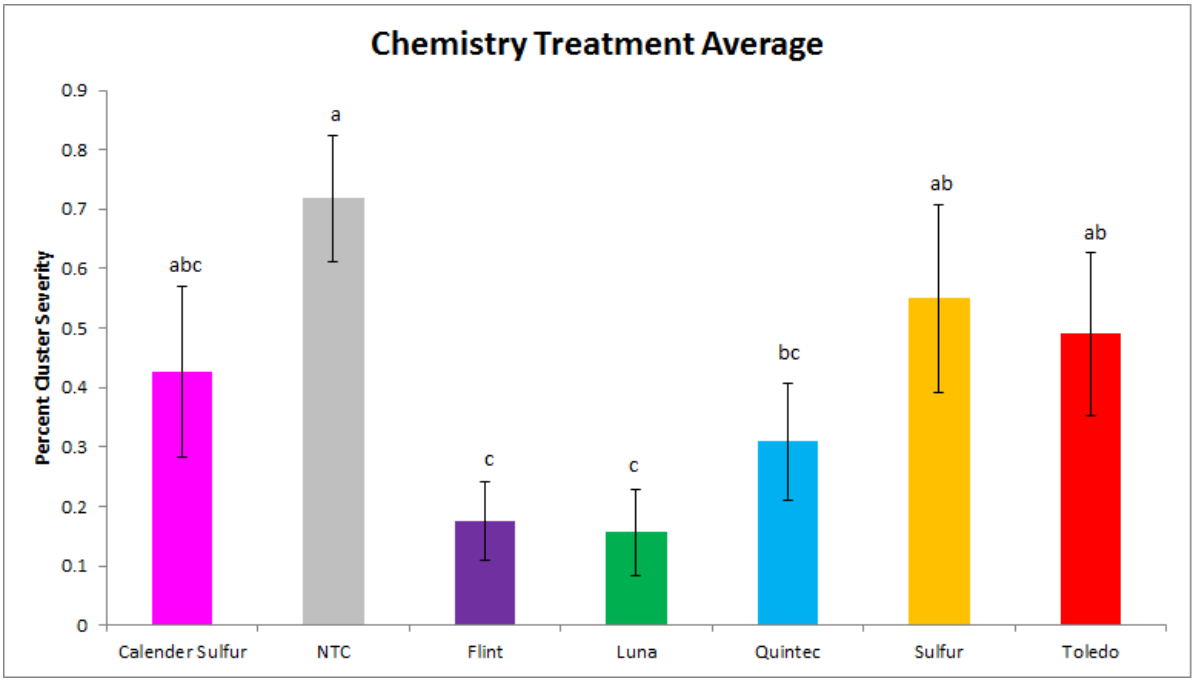

Figure 6. Averages of berry severity separated by fungicide chemistry. Treatments were compared using a Student's t-test, and significantly different treatments are grouped according to the letters shown above the graph. Similar to

the leaf data Luna had the best control on grape berries although Flint was similar. Sulfur and Toledo had disease control similar to that of the calendar sulfur treatment.

Objective 2: Fungicide chemistry selection with varying mobility

In initial greenhouse trials, Chardonnay plants were potted from cuttings collected in the field from dormant canes collected in 2014. These vines showed highly variable development in pots despite similar environmental conditions. Future assays will incorporate Pinot Meunier cuttings to assess fungicide mobility with relation to the inflorescences of vines, and Chardonnay seedlings will be used to assay general fungicide plant mobility and effect of surfactants on disease incidence.

Objective 3: Test commercial implementation

Objective 3 will be conducted in the 2017 field season utilizing the data collected in 2015 and 2016 field and greenhouse trials.

Fungicide Resistance Addendum:

Over the course of the 2015 season reports of GPM control failures around the Willamette Valley led to the investigation of possible presence of fungicide resistance in GPM, specifically to strobilurin and sterol demethylation inhibition (DMI) fungicides (FRAC groups 11 and 3, respectively). In collaboration with Tim Miles, UC Monterey Bay, a genetic assay for Strobilurin resistance was developed and tested. Isolates were collected from numerous spatially distinct vineyards in Oregon and California and used for quantitative Polymerase Chain Reaction (PCR) and bioassay experiments to determine if resistance was present. Strobilurin resistance was determined to be widespread with the cause being the G143A mutation in the target site of the fungicide (Figure 4). DMI resistance is continuing to be assessed using a leaf disc bioassay. While this was not included in the original grant proposal, fungicide resistance may greatly impact the practical application of fungicide selection and timing. Information regarding fungicide resistance will be used to assist making recommendations for fungicide selection in fields with observed fungicide resistance in association with the results of this project.

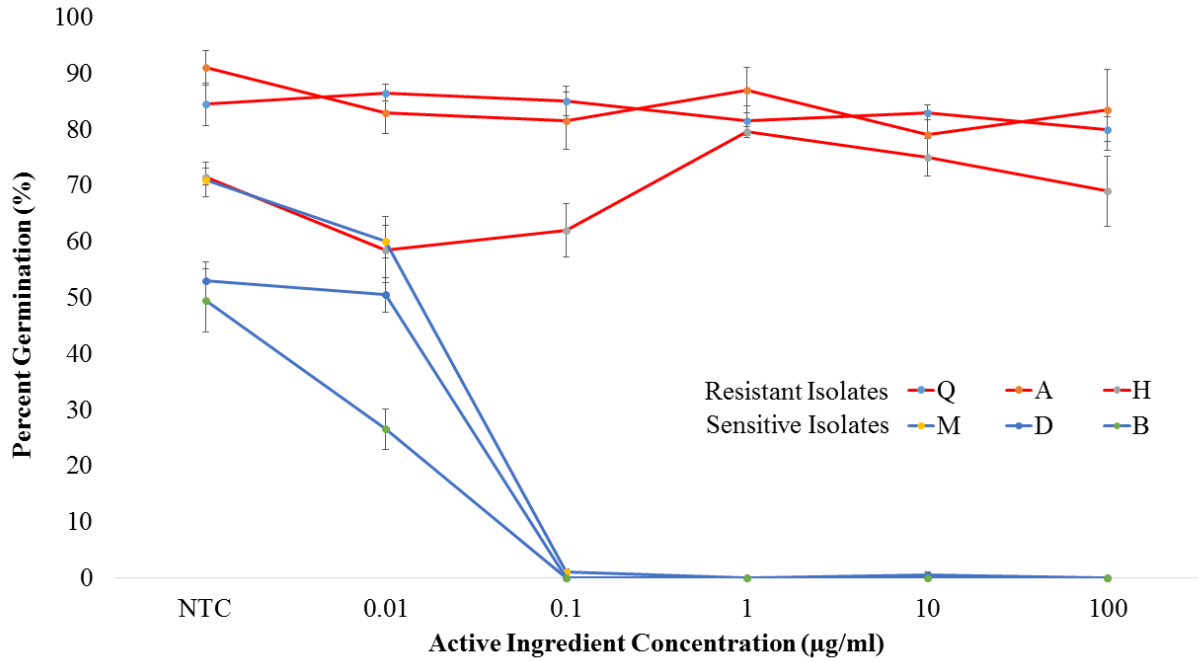

Figure 4. Percent germination of 3 resistant and 3 sensitive *Erysiphe necator* isolates on trifloxystrobin (Flint) amended agar plates. All plates contained salicylhydroxamic acid (100 mg/liter) in addition to trifloxystrobin to block the alternative oxidation pathway that would confound the effects of trifloxystrobin. All resistant isolates germinated on all concentrations of trifloxystrobin amended media, and sensitive isolates were affected at 0.1 µg/ml active ingredient.

Outside Presentations of Research:

No formal presentations of this work to date.

Research Success Statements:

The graduate student, Brent Warneke, was hired and began work June 15, 2015. In 2015, treatment differences in leaf incidence were observed in the fungicide selection and phenological stage timing field trial. This indicates that there may potentially be an optimum fungicide selection and optimum application timing that may reduce the impact of grape powdery mildew damages. Assessments of berries collected from the 2015 growing season will continue to elucidate the impact of fungicide timing on fruit disease incidence, which may differ from disease incidence observed on the leaf tissues. Additionally, berry assessments of treated and untreated clusters will continue to elucidate the fungicide mobility within the field, which may influence fungicide choice during susceptible developmental stages of grapevine. Continuance of the project will help to determine the optimal fungicide selection and application timing to reduce berry damages caused by grape powdery mildew via direct field trials and determining in-field fungicide mobility within infructescences.

Funds Status:

To date, 7 months of funding for the graduate student and about 50% of the supply and travel budget have been spent.