CALIFORNIA CHERRY BOARD

ANNUAL RESEARCH REVIEW

FEBRUARY 2ND, 2026

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Annual Reports + Presentation Slides

CALIFORNIA CHERRY RESEARCH REVIEW

DATE: Monday, February 2nd, 2026
LOCATION: San Joaquin County RJC Agricultural Center – 2101 E. Earhart Avenue, Stockton, CA 95206
TIME: 9:00 AM – 12:00 PM

Sponsored by the California Cherry Board and the University of California

9:00 AM Coffee Welcome

9:30 AM Introduction

PRESENTATIONS ON ANNUAL AND FINAL REPORTS + Q&As

9:40 AM **Cherry Stem Retention as a Function of Cultivar, Maturity, and Postharvest Management.**
Barbara Blanco- Ulate – Department of Plant Sciences, UC Davis

10:00 AM **An Integrated Approach to Improve Winter Chill Accumulation and Dormancy Breaking in California Cherry Orchards.**
Giulia Marino - UCCE Orchard Systems Specialist; Department of Plant Sciences, UC Davis

10:20 AM **Evaluation of Methyl Benzoate as Oviposition Deterrent & Repellent against Spotted Wing Drosophila in Cherry Orchards**
Jhalendra Rijal - UCCE IPM Advisor, Stanislaus County

10:40 AM Break

10:55 AM **Assessing Disease Risk for an Integrated Management of Bacterial Blast of Sweet Cherry.**
Florent Trouillas - UCCE Pathologist, Department of Plant Pathology, UC Davis

11:15 AM **Management and Epidemiology of Pre- and Postharvest Diseases of Sweet Cherry.**
Jim Adaskaveg - Professor, Department of Plant Pathology, UC Riverside

11:35 AM Open discussion on research priorities

11:55 AM Adjourn for lunch

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CALIFORNIA CHERRY BOARD:
2026-2027 RESEARCH PRIORITIES

PRODUCTION RESEARCH PRIORITIES

For the 2026-2027 fiscal year (FY), the California sweet cherry industry identified the following production-related challenges of greatest priority for addressment through intentionally designed research:

- Pest Management with emphasis on management of spotted wing drosophila (SWD)
    - New chemistry
    - Timing of application
- Tree Health with emphasis on pre- and postharvest disease biology and management, soilborne and canker diseases, and orchard replant diseases with emphasis on nematode management and alternatives to fumigations.
- Variety and Rootstock Development and Evaluation
    - Evaluation of New Cherry Rootstocks
- Dormancy
    - New chemistry
- Pre- and Post-Harvest Fruit Quality
    - Firmness
    - Heat stress
    - New chemistry to improve and maintain fruit quality
- Irrigation
    - Evapotranspiration
    - Efficient water usage as water supply costs increase in CA
    - Right amount/timing
    - New technology
- Weed Management
    - Pre- and Post-Harvest Herbicide Application with emphasis on new technology
- Invertebrate Control
    - Gophers
    - Ground squirrels

POST HARVEST RESEARCH PRIORITIES

For the 2026-2027 fiscal year (FY), the California sweet cherry industry identified the following post-harvest-related challenges of greatest priority for addressment through intentionally designed research:

- Marketing/Sales
    - Implications of grocery store purchases on applications (i.e. pick-up) instead of in-store
    - Consumer buying practices
    - Storage and handling in-store
    - Promotion of nutritional value
- Consumer Preferences and quality including minimizing Defects, fruit quality attributes such

as Brix, Acid content.

- Minimum Maturity and Grade Standards
- Crop management to match market demands.
- Stem retention
- Nutrition
    - Human health benefits

California Cherry Board

2025-2026 Research Review:
Annual Reports + Presentation Slides

California Cherry Board

Blanco-Ulate, Barbara

"Cherry Stem Retention as a Function of Cultivar, Maturity, and Postharvest Management"

POSTHARVEST
RESEARCH AND EXTENSION CENTER
UNIVERSITY OF CALIFORNIA

Annual Project Report

Pedicel Retention in Sweet Cherries:

Assessing impact of cultivar, maturity, and preharvest treatments

Prepared for: California Cherry Board

Date: January 2026

Principal Investigator:

Dr. Barbara Blanco-Ulate
Department of Plant Sciences, UC Davis

Co-Principal Investigator:

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1 Project Overview

The main goal of this project is to assess the stem retention potential of two commercially important sweet cherry (*Prunus avium* L.) cultivars under different preharvest conditions. While stem retention is a key factor influencing postharvest marketability and shelf-life, this study focuses on preharvest factors that may influence this trait.

We evaluated two cultivars, 'Coral Champagne' and 'Bing', grown in three different commercial orchard blocks. The trial tested two preharvest treatments, *Apogee* (a gibberellin biosynthesis inhibitor) and *Harvista* (1-methylcyclopropene, 1-MCP), applied according to industry-relevant practices.

Stem pull force was measured repeatedly across fruit development stages on the same trees, capturing a range of maturities before commercial harvest. Fruit quality measurements (firmness, soluble solids, titratable acidity, and color) began when fruit reached full red color (approximately 100% red), and were repeated at subsequent key maturity stages, mahogany and commercial harvest. Samples from each block-treatment-cultivar combination were evaluated the following day for stem retention and fruit quality attributes.

This work aims to help growers understand how cultivar choice, orchard conditions, and preharvest treatments interact to influence stem retention potential, providing science-based guidance for improving the visual quality and market value of California sweet cherries.

2 Research Objectives

The specific objectives of this research are:

1. **Compare stem retention potential between cultivars**
   Quantify and compare stem pull force in 'Coral Champagne' and 'Bing' cherries across fruit development to determine varietal differences in stem retention.

2. **Assess the effect of preharvest treatments on stem retention**
   Evaluate the impact of *Apogee* and *Harvista* applications, relative to untreated controls, on stem pull force and fruit quality in both cultivars.

3. **Evaluate block-to-block variation in stem retention**
   Identify whether orchard differences (e.g., microclimate, management history) contribute significantly to variation in stem retention.

3 Trial Setup

3.1 Orchard Locations and Bloom Dates

The trial was conducted during the 2025 growing season in three commercial sweet cherry orchard blocks located near Linden, California. Table 1 presents the GPS coordinates for each orchard block along with the bloom dates for each cultivar within those blocks.

Block	Cultivar	Full Bloom Date (2025)	Coordinates
1	Coral	March 25	38.04629°N, 121.12092°W
	Bing	March 31	
2	Coral	March 23	38.02994°N, 121.12969°W
	Bing	March 25	
3	Coral	March 14	38.03981°N, 121.15731°W
	Bing	March 24	

Table 1: Full bloom dates for 'Coral Champagne' and 'Bing' cherries at each block, with coordinates.

3.2 Tree Selection and Treatments

On April 23, 2025, ten trees per cultivar were selected and tagged at each block as **control** trees, chosen for similar crop load, canopy size, and overall health.

Block 1: Harvista Treatment — Twelve additional 'Coral Champagne' trees were tagged for preharvest *Harvista* (1-MCP) application:

- Four trees sprayed once at ∼50% color (May 3, 2025) — referred to as Early treatment
- Four trees sprayed once at ∼100% pink (May 10, 2025) — referred to as Late treatment
- Four trees sprayed at both timings — referred to as Double treatment

Block 3: Apogee Treatment — The grower regularly applies *Apogee* (gibberellin biosynthesis inhibitor) to all trees but flagged six 'Coral Champagne' trees and four 'Bing' trees to **not** receive *Apogee* for comparison.

3.3 Sampling Dates and Evaluations

Cherries were sampled across their development for each cultivar (Figure 1). On each sampling date, ten cherries were collected from each tagged tree, from at least eight branches, selecting fruit of similar maturity. Fruit quality measurements (firmness, °Brix, titratable acidity, and color) were conducted only starting when fruit reached approximately 100% red color, and repeated at mahogany and commercial harvest maturity stages. All sampled fruits were assigned to the **Dark Cherry Maturity Scale** (Figure 2), allowing stem retention and fruit quality to be analyzed across a color-based maturity spectrum.

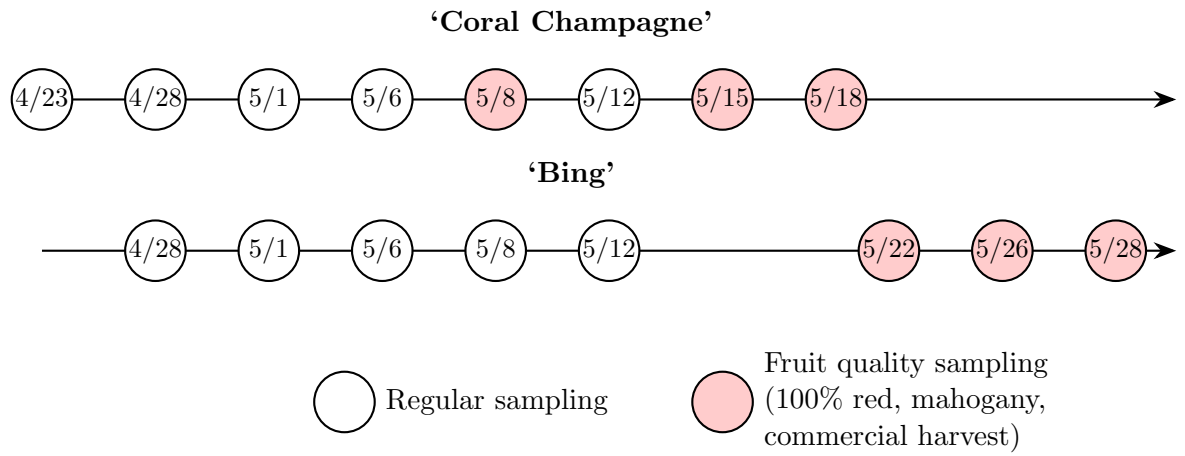

Figure 1: Sampling schedule for 'Coral Champagne' and 'Bing' cherries in 2025. Dates with shaded markers indicate fruit quality sampling at key maturity stages.

4 Evaluation Methods

Samples were transported to the Mann Laboratory at UC Davis and stored overnight at 7.5°C. Evaluations were performed the following day. Tissue samples for Brix and TA analyses were stored at −23°C until testing.

4.1 Stem Removal Work

Stem retention was quantified as the **total work** required to remove the stem, expressed in inch-pounds (in-lb). This value was calculated from the area under the force–distance curve (gf·mm) recorded by the instrument and converted to in-lb.

Measurements were made using a TA-XT Texture Analyzer (Stable Micro Systems, Surrey, UK) fitted with a modified funnel to hold the cherry upside down and a clamp to secure the stem to the base. The instrument arm was moved upward to separate the stem from the fruit, continuously recording force over the full distance of stem removal. From these force–distance curves, the total work required to remove each stem (area under the curve) was calculated, and the maximum force achieved during the pull was also recorded for each of the 10 cherries sampled from every tree on each sampling date.

4.2 Fruit Quality

Fruit quality measurements were conducted on cherries when fruit reached approximately 100% red color, and were repeated at mahogany and commercial harvest maturity stages. All fruits were subsequently assigned to the **Dark Cherry Maturity Scale** (stages 1–10) based on skin color. Firmness was measured on the same day as stem removal and photography. For each sampled tree, all 10 cherries were depitted and combined into a single homogenized sample, which was then frozen at −23°C for later analysis of °Brix and titratable acidity (TA).

Juice used for °Brix/TA analyses was extracted from these frozen homogenates. °Brix was measured on undiluted juice, and TA was determined on diluted juice following °Brix measurement. All measurements were linked to the corresponding maturity stage to allow analysis of fruit quality across the color-based maturity scale.

4.2.1 Firmness

Firmness (in grams) was measured using a FirmTech II (BioWorks Inc., Cleveland, OH). Each cherry was placed in the instrument to measure firmness individually before depitting for tissue freezing.

4.2.2 Soluble Solids

Soluble solids, measure as °Brix, was determined using an Atago RX-5000i digital refractometer. Frozen juice homogenates were thawed and °Brix was measured on the filtered, undiluted juice prior to dilution for titratable acidity testing. The °Brix value represents the soluble solids content, primarily consisting of sugars.

4.2.3 Titratable Acidity

Titratable Acidity (TA %) was measured after juice dilution following °Brix determination. A mixture of 4 mL of juice and 20 mL of distilled water was titrated with standardized NaOH using an automatic titrator until reaching a pH endpoint of 8.2. TA values are expressed as percent citric acid equivalents.

4.2.4 Sugar/Acid Ratio (°Brix:TA)

The ratio of soluble solids to titratable acidity (°Brix:TA) was calculated for each sample to provide a combined measure of sweetness relative to acidity, which is a key indicator of fruit flavor and eating quality. This ratio was analyzed across the Dark Cherry Maturity Scale to evaluate how fruit taste characteristics change with increasing maturity.

4.3 Photography and Color-Based Maturity Analysis

Following stem pull testing, cherries were imaged using a Nikon DSLR camera under standardized lighting conditions against a uniform white background. Camera settings, distance, and orientation were held constant across all sampling dates to minimize variation in illumination and color capture.

Prior to color analysis, all images were white-balanced to correct for variation in lighting conditions across imaging sessions and to ensure color fidelity. White balancing establishes a reference for neutral white in each image, allowing recorded pixel values to accurately represent true fruit skin color as perceived by the human eye. Without this correction, color values would be systematically biased by illumination conditions. Background removal was performed using a custom Python-based image-processing pipeline implemented with OpenCV. Images were converted to the CIELAB color space, and pixels corresponding to the white background were identified using LAB thresholding and removed, leaving only fruit pixels. Background regions were replaced with transparency, and a light Gaussian blur was applied to the transparency mask to smooth fruit boundaries and reduce edge artifacts.

Each image contained cherries from two tagged trees and was automatically cropped into two sub-images corresponding to individual trees. Within each cropped image, individual cherries were identified using contour detection applied to the transparency channel. The ten largest contours were retained and spatially ordered based on centroid position to ensure consistent identification of the ten cherries sampled per tree. This approach enabled automated, reproducible segmentation of individual fruits without manual selection.

For each cherry, all non-background pixels were extracted and converted to the CIELAB color space. Mean values of lightness (L*), redness–greenness (a*), and yellowness–blueness (b*) were calculated for each fruit. Chroma (C*) and hue angle (°) were subsequently derived from a* and b* values. In addition, the proportion of red surface area was quantified by classifying pixels based on hue angle relative to red (target hue of 10° with a ±40° tolerance), with minimum chroma and lightness thresholds applied to exclude low-saturation or shadowed regions. Percent red coverage was calculated as the fraction of red-classified pixels relative to total fruit surface area.

To standardize cherry maturity based on skin color, k-means clustering was applied to the combined dataset of individual-cherry color measurements using scaled L*, a*, and b* values. All cherries were clustered simultaneously in an unsupervised manner, with the number of clusters set to $k = 10$ to capture the full continuum of color development observed across sampling dates. Principal component analysis (PCA) was used to visualize color-space structure and assess separation among clusters. Clusters were subsequently ordered post hoc according to the median sampling date of fruit within each cluster to establish a monotonic progression in maturity.

5 Summary of Results

5.1 Dark Cherry Maturity Scale

Unsupervised k-means clustering of individual-cherry CIELAB color measurements resulted in ten distinct color groupings spanning the full range of skin color observed across the sampling period, from green to dark mahogany fruit (Figure 2). Principal component analysis confirmed clear separation among clusters in color space, indicating that clusters represented discrete and biologically meaningful color states.

When clusters were ordered by the median sampling date of their constituent fruit, they formed a consistent and monotonic progression corresponding to increasing maturity. Early clusters were dominated by green and yellow fruit, intermediate clusters by progressively redder fruit, and late clusters by fully red to dark mahogany fruit. The average color of each cluster was visualized to create the **Dark Cherry Maturity Scale**, with Stage 1 representing the least mature (green) fruit and Stage 10 representing the most mature (dark mahogany) fruit (Figure 2).

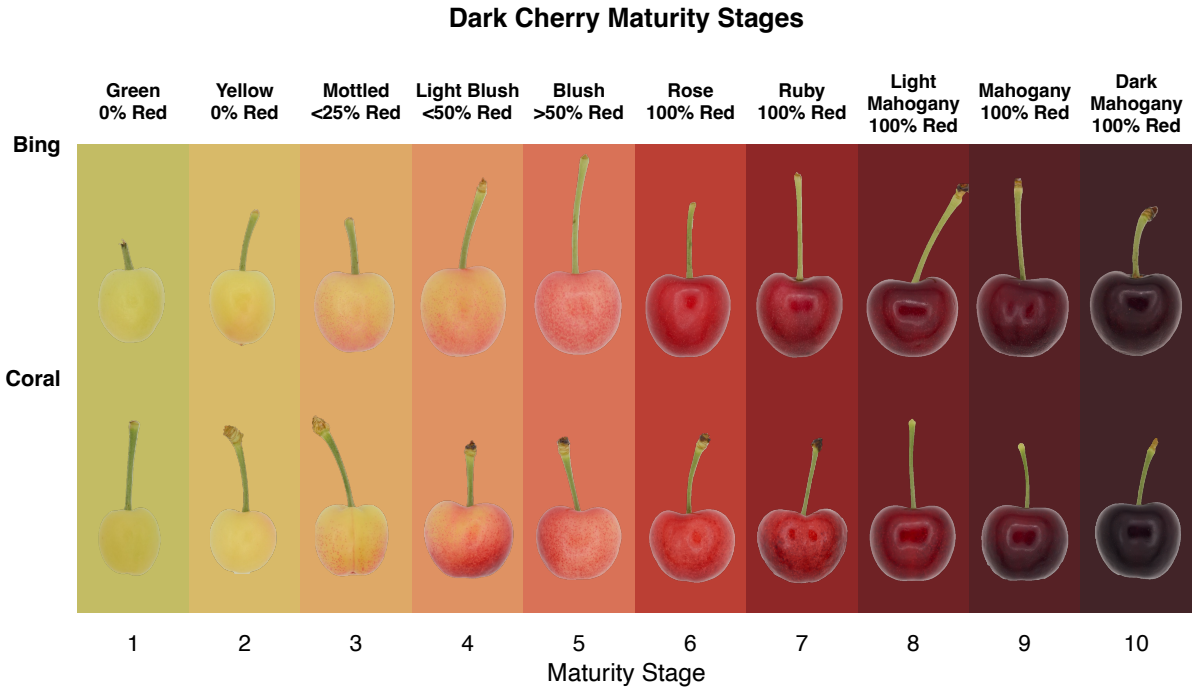

Figure 2: Dark Cherry Maturity Scale derived from unsupervised k-means clustering of CIELAB color values (n = 4884 cherries). Clusters were ordered post hoc based on median sampling date to represent a progression from green (Stage 1) to dark mahogany (Stage 10) fruit.

Each individual cherry was assigned the maturity stage corresponding to its cluster membership, and these color-derived stages were used as categorical maturity variables in subsequent analyses. This scale provides a continuous and visually interpretable framework for evaluating stem retention and fruit quality traits across the full spectrum of cherry maturity. By decoupling maturity from discrete sampling dates, the approach accounts for substantial within-date and within-tree variability and enables quantitative comparisons across cultivars.

5.2 Summary of Results - Block 1

This section summarizes differences in stem retention and fruit quality attributes between the two cultivars, 'Coral Champagne' and 'Bing,' across maturity stages within experimental block 1. While the primary focus was on characterizing 'Coral' by comparing it to 'Bing' at each

stage using two-sample t-tests, we also assessed the effect of fruit maturity on stem retention and quality traits within each cultivar. These within-cultivar comparisons were performed using linear models followed by post hoc pairwise tests (emmeans with Tukey-adjusted CLD letters), as shown in the tables below. Together, these analyses provide a baseline for interpreting cultivar-specific differences and the influence of maturity stage on stem and fruit quality traits.

Cultivar Differences in Stem Retention - Block 1

Stem removal work differed significantly between cultivars across most maturity stages in experimental block 1 (Figure 3, Table 2). At early maturity stages, 'Bing' fruit consistently required greater work to remove the stem compared with 'Coral'. At maturity stage 1, stem removal work for 'Bing' averaged 0.396 in·lb, more than double that of 'Coral' (0.159 in·lb; $p < 0.001$). This cultivar difference remained significant through stages 2–5, with 'Bing' exhibiting higher stem removal work than 'Coral' ($p \leq 0.01$).

As fruit maturity advanced, stem removal work decreased for both cultivars. At stage 6, no significant difference in stem removal work was detected between cultivars ($p = 0.14$). However, from stages 7 through 10, cultivar differences re-emerged, with 'Bing' again requiring significantly greater work to remove stems than 'Coral' ($p < 0.001$ at all stages). At the most advanced maturity stage (stage 10), mean stem removal work was 0.058 in.lb for 'Bing' and 0.040 in·lb for 'Coral'.

Overall, 'Bing' cherries exhibited higher stem removal work than 'Coral' across nearly all maturity stages in block 1, indicating stronger stem–fruit attachment in 'Bing' throughout fruit development.

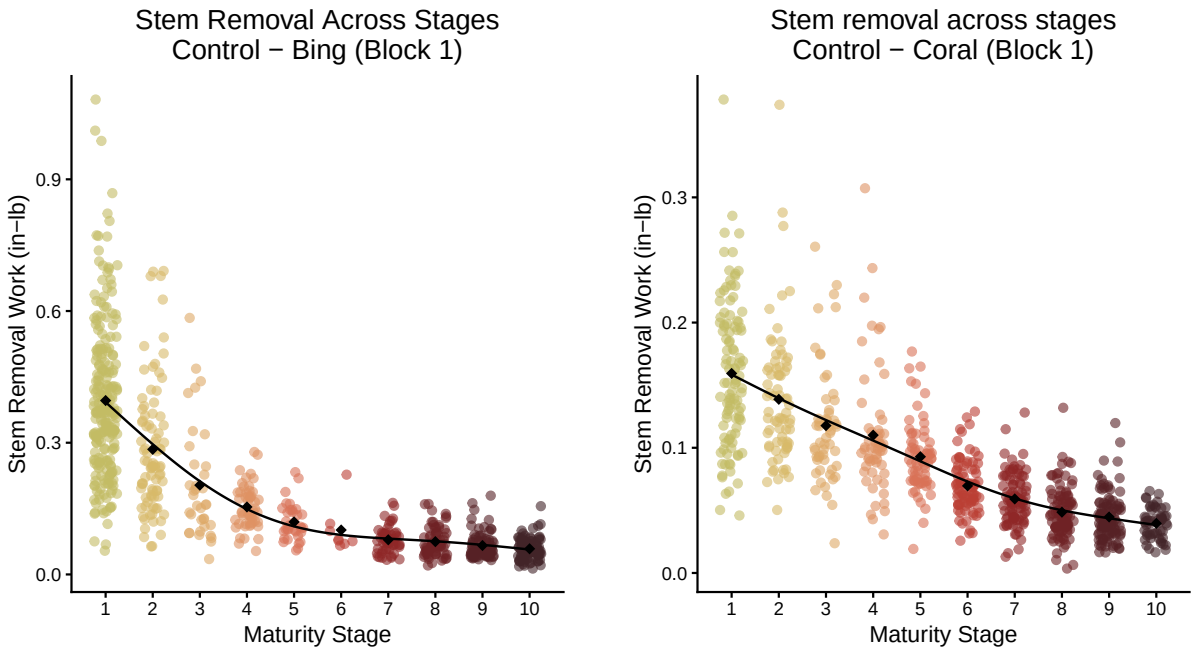

Figure 3: Relationship between fruit maturity stage and stem removal work for 'Bing' and 'Coral' sweet cherries in experimental block 1. Stem removal work (in-lb) is plotted against maturity stage (1–10) with separate y-axes for each cultivar. Points represent individual fruits from block 3 and are colored by average CIELAB values for each maturity stage. Black diamonds indicate mean stem removal work per stage, and solid lines show GAM fits showing decreasing stem removal work with advancing maturity.

Table 2: Results of stem removal work (in-lb) for 'Bing' and 'Coral' sweet cherry cultivars in experimental block 1. Between-cultivar differences at each maturity stage were assessed using two-sample t-tests, with mean values, p-values, and significance levels reported (ns = not significant; * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$). Within each cultivar, differences across maturity stages were evaluated using linear models with post hoc pairwise comparisons (emmeans with Tukey-adjusted CLD letters); stages sharing the same letter are not significantly different from one another.

Trait	**Stage**	**Bing**	**Coral**	p-value	**Significance**
Stem Removal	1	0.396^{d}	0.159^{f}	< 0.001	***
Work (in.lb)	2	0.285^{c}	0.139^{e}	< 0.001	***
	3	0.203^{b}	0.118^{d}	< 0.001	***
	4	0.154^{b}	0.110^{cd}	< 0.001	***
	5	0.119^{ab}	0.093^{c}	< 0.01	**
	6	0.101^{ab}	0.070^{b}	0.1396	ns
	7	0.079^{a}	0.059^{ab}	< 0.001	***
	8	0.075^{a}	0.049^{a}	< 0.001	***
	9	0.066^{a}	0.045^{a}	< 0.001	***
	10	0.058^{a}	0.040^{a}	< 0.001	***

Cultivar Differences in Fruit Quality Attributes - Block 1

Fruit quality traits differed between 'Bing' and 'Coral' cherries across maturity stages in experimental block 1 (Table 3). Firmness showed variable cultivar effects across maturity. At stage 6, firmness did not differ significantly between cultivars; however, at stage 7, 'Coral' fruit were significantly firmer than 'Bing' (382.27 vs. 345.21 g; $p < 0.01$). No cultivar differences were detected at stages 8 or 10, while at stage 9, 'Bing' fruit were firmer than 'Coral' (370.99 vs. 349.02 g; $p < 0.05$).

Soluble solids concentration (°Brix) was consistently higher in 'Bing' than in 'Coral' across all evaluated maturity stages. Differences were significant at every stage from 6 through 10 ($p \leq 0.01$), with °Brix increasing with advancing maturity in both cultivars. At stage 10, 'Bing' fruit averaged 24.09 °Brix compared with 21.44 °Brix in 'Coral'.

Titratable acidity (TA %) also differed between cultivars at most maturity stages. 'Bing' fruit exhibited higher TA than 'Coral' at stages 6, 7, 9, and 10 ($p \leq 0.01$), while no significant difference was observed at stage 8. Notably, at the most advanced maturity stage, TA in 'Bing' (1.367%) was substantially higher than in 'Coral' (0.792%; $p < 0.001$).

The sugar-to-acid ratio (°Brix:TA) showed fewer consistent cultivar differences. No significant differences were detected at stages 6 or 7. At stage 8, 'Bing' exhibited a higher sugar-to-acid ratio than 'Coral' ($p < 0.01$), whereas at stage 10, 'Coral' had a markedly higher ratio than 'Bing' (27.15 vs. 17.93; $p < 0.001$). No cultivar difference was detected at stage 9.

Overall, 'Bing' fruit in block 1 were characterized by higher soluble solids and titratable acidity across most maturity stages compared with 'Coral', while cultivar effects on firmness and sugar-to-acid balance varied with maturity.

Table 3: Results of fruit quality traits for 'Bing' and 'Coral' sweet cherry cultivars in experimental block 1. Between-cultivar differences at each maturity stage were assessed using two-sample t-tests, with mean values, p-values, and significance levels reported (ns = not significant; * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$). Within each cultivar, differences across maturity stages were evaluated using linear models with post hoc pairwise comparisons (emmeans with Tukey-adjusted CLD letters); stages sharing the same letter are not significantly different from one another.

Trait	**Stage**	**Bing**	**Coral**	p-value	**Significance**
Firmness	6	390.93^{a}	403.52^{b}	0.7902	ns
(grams)	7	345.21^{a}	382.27^{b}	< 0.01	**
	8	353.27^{a}	355.01^{a}	0.8767	ns
	9	370.99^{a}	349.02^{a}	< 0.05	*
	10	362.26^{a}	342.82^{a}	0.0648	ns
Soluble Solids	6	20.74^{ab}	16.67^{a}	< 0.01	**
(°Brix)	7	20.82^{a}	16.90^{a}	< 0.001	***
	8	21.71^{b}	19.94^{b}	< 0.001	***
	9	22.88^{c}	20.72^{c}	< 0.001	***
	10	24.09^{d}	21.44^{d}	< 0.001	***
Titratable Acidity	6	0.992^{a}	0.788^{a}	< 0.001	***
(TA %)	7	0.996^{a}	0.797^{a}	< 0.001	***
	8	0.941^{a}	0.920^{b}	0.2287	ns
	9	0.996^{a}	0.915^{b}	< 0.01	**
	10	1.367^{b}	0.792^{a}	< 0.001	***
Sugar/Acid Ratio	6	20.95^{abc}	21.25^{a}	0.7166	ns
(°Brix:TA)	7	20.94^{b}	21.30^{a}	0.1767	ns
	8	23.20^{c}	21.98^{ab}	< 0.01	**
	9	23.56^{c}	23.03^{b}	0.284	ns
	10	17.93^{a}	27.15^{c}	< 0.001	***

5.3 Summary of Results - Block 2

This section summarizes differences in stem retention and fruit quality attributes between the two cultivars, 'Coral Champagne' and 'Bing,' across maturity stages within experimental block 2. While the primary focus was on characterizing 'Coral' by comparing it to 'Bing' at each stage using two-sample t-tests, we also assessed the effect of fruit maturity on stem retention and quality traits within each cultivar. These within-cultivar comparisons were performed using linear models followed by post hoc pairwise tests (emmeans with Tukey-adjusted CLD letters), as shown in the tables below. Together, these analyses provide a baseline for interpreting cultivar-specific differences and the influence of maturity stage on stem and fruit quality traits.

Cultivar Differences in Stem Retention - Block 2

Stem removal work differed between 'Bing' and 'Coral' sweet cherry cultivars across several maturity stages in experimental block 2 (Table 4). At the earliest maturity stage (stage 1), 'Bing' fruit required substantially greater work to remove the stem than 'Coral' (0.411 vs. 0.214 in.lb; $p < 0.001$). A significant cultivar difference was also observed at stage 2, with higher stem removal work in 'Bing' compared with 'Coral' (0.260 vs. 0.212 in.lb; $p < 0.01$).

No significant differences in stem removal work were detected between cultivars at intermediate maturity stages 3 and 4. At stage 5, 'Bing' again exhibited higher stem removal work than 'Coral' (0.158 vs. 0.109 in.lb; $p < 0.05$), while no cultivar difference was observed at stage 6.

At more advanced maturity stages, cultivar effects became more pronounced. From stages 7 through 10, 'Bing' consistently required greater work to remove stems than 'Coral', with differences significant at all stages ($p \leq 0.01$). The largest differences were observed at stages 9 and 10, where stem removal work in 'Bing' exceeded that of 'Coral' by more than 40

Overall, stem removal work declined with increasing fruit maturity in both cultivars. However, 'Bing' cherries exhibited stronger stem–fruit attachment than 'Coral' across most maturity stages in block 2, particularly at early and late stages of fruit development.

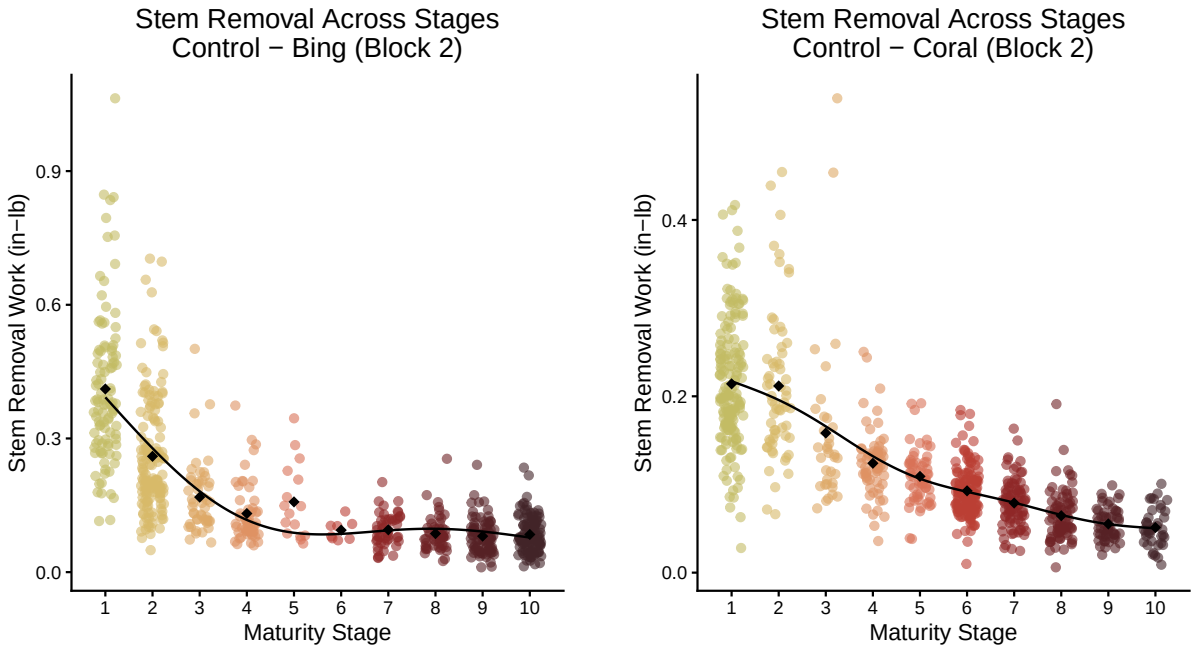

Figure 4: Relationship between fruit maturity stage and stem removal work for 'Bing' and 'Coral' sweet cherries in experimental block 2. Stem removal work (in-lb) is plotted against maturity stage (1–10) with separate y-axes for each cultivar. Points represent individual fruits from block 3 and are colored by average CIELAB values for each maturity stage. Black diamonds indicate mean stem removal work per stage, and solid lines show GAM fits showing decreasing stem removal work with advancing maturity.

Table 4: Results of stem removal work (in-lb) for 'Bing' and 'Coral' sweet cherry cultivars in experimental block 2. Between-cultivar differences at each maturity stage were assessed using two-sample t-tests, with mean values, p-values, and significance levels reported (ns = not significant; * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$). Within each cultivar, differences across maturity stages were evaluated using linear models with post hoc pairwise comparisons (emmeans with Tukey-adjusted CLD letters); stages sharing the same letter are not significantly different from one another.

Trait	**Stage**	**Bing**	**Coral**	p-value	**Significance**
Stem Removal	1	0.411^{d}	0.214^{f}	< 0.001	***
Work (in.lb)	2	0.260^{c}	0.212^{f}	< 0.01	**
	3	0.168^{b}	0.158^{e}	0.6176	ns
	4	0.132^{ab}	0.124^{d}	0.4666	ns
	5	0.158^{ab}	0.109^{cd}	< 0.05	*
	6	0.094^{ab}	0.093^{bc}	0.8598	ns
	7	0.095^{a}	0.079^{ab}	< 0.01	**
	8	0.087^{a}	0.065^{a}	< 0.01	**
	9	0.081^{a}	0.055^{a}	< 0.001	***
	10	0.085^{a}	0.051^{a}	< 0.001	***

Cultivar Differences in Fruit Quality Attributes - Block 2

Fruit quality traits differed markedly between 'Bing' and 'Coral' sweet cherry cultivars across maturity stages in experimental block 2 (Table 5). Fruit firmness showed increasing cultivar separation with advancing maturity. No significant differences in firmness were detected at stages 6 or 7. However, beginning at stage 8, 'Bing' fruit were significantly firmer than 'Coral', with differences persisting through stages 9 and 10 ($p < 0.001$ at all stages). At stage 9, firmness of 'Bing' averaged 407.85 g compared with 323.58 g in 'Coral'.

Soluble solids concentration (°Brix) was consistently higher in 'Bing' than in 'Coral' across all evaluated maturity stages. Cultivar differences were significant at every stage from 6 through 10 ($p < 0.001$). In both cultivars, °Brix increased with advancing maturity; however, 'Bing' fruit maintained substantially higher soluble solids throughout development, reaching 25.15 °Brix at stage 10 compared with 20.14 °Brix in 'Coral'.

Titratable acidity (TA %) also differed significantly between cultivars at all maturity stages. 'Bing' fruit exhibited higher TA than 'Coral' from stages 6 through 10 ($p < 0.001$). The magnitude of this difference increased at later maturity, with TA in 'Bing' reaching 1.274% at stage 10 compared with 0.736% in 'Coral'.

In contrast, the sugar-to-acid ratio (°Brix:TA) showed limited cultivar differentiation across most maturity stages. No significant differences were detected between cultivars at stages 6 through 9. At the most advanced maturity stage (stage 10), however, 'Coral' exhibited a significantly higher sugar-to-acid ratio than 'Bing' (27.65 vs. 20.08; $p < 0.001$).

Overall, 'Bing' cherries in block 2 were characterized by higher firmness, soluble solids concentration, and titratable acidity across most maturity stages compared with 'Coral', while cultivar differences in sugar-to-acid balance were evident only at the latest stage of fruit maturity.

Table 5: Results of fruit quality traits for 'Bing' and 'Coral' sweet cherry cultivars in experimental block 2. Between-cultivar differences at each maturity stage were assessed using two-sample t-tests, with mean values, p-values, and significance levels reported (ns = not significant; * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$). Within each cultivar, differences across maturity stages were evaluated using linear models with post hoc pairwise comparisons (emmeans with Tukey-adjusted CLD letters); stages sharing the same letter are not significantly different from one another.

Trait	**Stage**	**Bing**	**Coral**	p-value	**Significance**
Firmness	6	368.85^{ab}	344.23^{ab}	0.4418	ns
(grams)	7	368.66^{ab}	342.50^{ab}	0.1117	ns
	8	366.76^{ab}	324.03^{a}	< 0.001	***
	9	407.85^{b}	323.58^{a}	< 0.001	***
	10	364.64^{a}	316.62^{a}	< 0.001	***
Soluble Solids	6	21.19^{a}	15.92^{a}	< 0.001	***
(°Brix)	7	21.08^{a}	17.02^{b}	< 0.001	***
	8	21.87^{a}	17.95^{c}	< 0.001	***
	9	23.35^{b}	19.01^{d}	< 0.001	***
	10	25.15^{c}	20.14^{e}	< 0.001	***
Titratable Acidity	6	1.012^{a}	0.761^{a}	< 0.001	***
(TA %)	7	1.001^{a}	0.827^{b}	< 0.001	***
	8	1.005^{a}	0.824^{b}	< 0.001	***
	9	1.024^{a}	0.805^{b}	< 0.001	***
	10	1.274^{b}	0.736^{a}	< 0.001	***
Sugar/Acid Ratio	6	20.97^{abc}	20.98^{ab}	0.9797	ns
(°Brix:TA)	7	21.13^{b}	20.64^{a}	0.0829	ns
	8	21.83^{b}	21.89^{b}	0.8456	ns
	9	23.08^{c}	23.88^{c}	0.0905	ns
	10	20.08^{a}	27.65^{d}	< 0.001	***

5.4 Summary of Results - Block 3

This section summarizes differences in stem retention and fruit quality attributes between the two cultivars, 'Coral Champagne' and 'Bing,' across maturity stages within experimental block 3. While the primary focus was on characterizing 'Coral' by comparing it to 'Bing' at each stage using two-sample t-tests, we also assessed the effect of fruit maturity on stem retention and quality traits within each cultivar. These within-cultivar comparisons were performed using linear models followed by post hoc pairwise tests (emmeans with Tukey-adjusted CLD letters), as shown in the tables below. Together, these analyses provide a baseline for interpreting cultivar-specific differences and the influence of maturity stage on stem and fruit quality traits.

Cultivar Differences in Stem Retention - Block 3

Stem removal work differed significantly between 'Bing' and 'Coral' sweet cherry cultivars at every evaluated maturity stage in experimental block 3 (Table 6). At the earliest maturity stage (stage 1), 'Bing' fruit required greater work to remove the stem than 'Coral' (0.2751 vs. 0.1646 in.lb; $p < 0.001$). This pattern persisted across all subsequent maturity stages.

Across stages 2 through 10, stem removal work was consistently higher in 'Bing' compared with 'Coral', with significant differences detected at each stage ($p \leq 0.01$). Although stem removal work declined with advancing maturity in both cultivars, the magnitude of the cultivar difference remained evident throughout fruit development. At the most advanced maturity

stage (stage 10), 'Bing' fruit required nearly twice the work to remove the stem compared with 'Coral' (0.0777 vs. 0.0441 in.lb; $p < 0.001$).

Overall, block 3 exhibited the most consistent cultivar separation in stem retention, with 'Bing' cherries demonstrating stronger stem–fruit attachment than 'Coral' across all maturity stages.

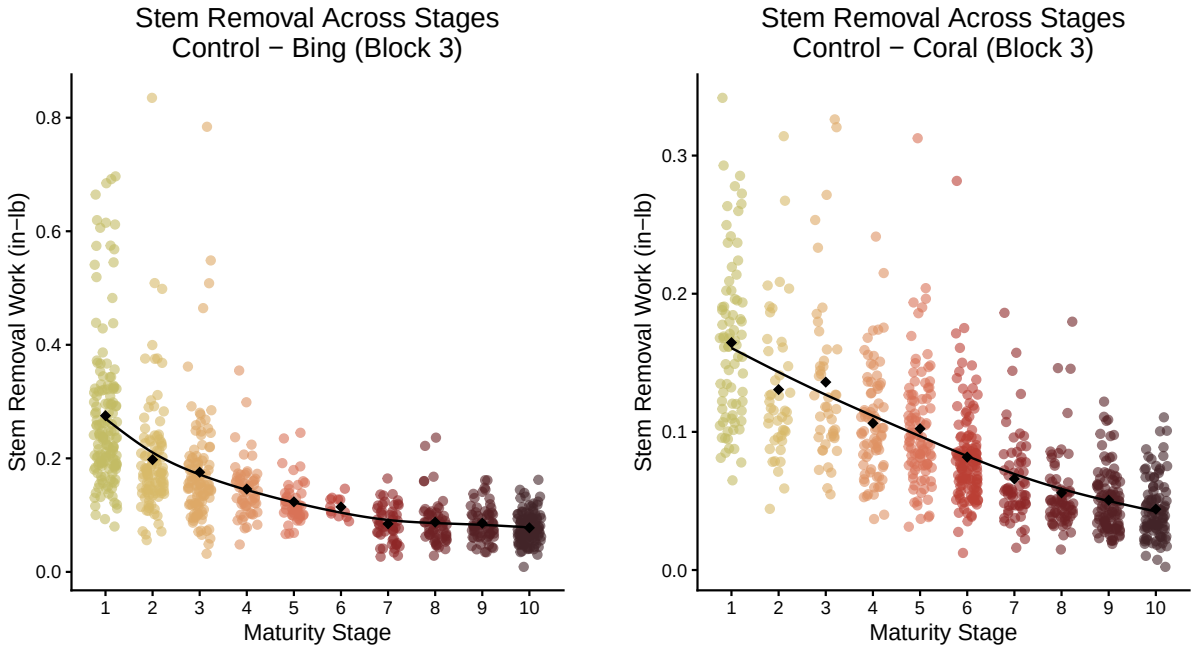

Figure 5: Relationship between fruit maturity stage and stem removal work for 'Bing' and 'Coral' sweet cherries in experimental block 3. Stem removal work (in-lb) is plotted against maturity stage (1–10) with separate y-axes for each cultivar. Points represent individual fruits from block 3 and are colored by average CIELAB values for each maturity stage. Black diamonds indicate mean stem removal work per stage, and solid lines show GAM fits showing decreasing stem removal work with advancing maturity.

Table 6: Results of stem removal work (in-lb) for 'Bing' and 'Coral' sweet cherry cultivars in experimental block 3. Between-cultivar differences at each maturity stage were assessed using two-sample t-tests, with mean values, p-values, and significance levels reported (ns = not significant; * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$). Within each cultivar, differences across maturity stages were evaluated using linear models with post hoc pairwise comparisons (emmeans with Tukey-adjusted CLD letters); stages sharing the same letter are not significantly different from one another.

Trait	**Stage**	**Bing**	**Coral**	*p*-value	**Significance**
Stem Removal	1	0.2751^{e}	0.1646^{f}	< 0.001	***
Work (in.lb)	2	0.1978^{d}	0.1306^{e}	< 0.001	***
	3	0.1755^{cd}	0.1360^{e}	< 0.01	**
	4	0.1460^{bc}	0.1063^{d}	< 0.001	***
	5	0.1234^{ab}	0.1023^{d}	< 0.01	**
	6	0.1144^{abc}	0.0817^{c}	< 0.001	***
	7	0.0846^{a}	0.0660^{bc}	< 0.01	**
	8	0.0876^{a}	0.0559^{ab}	< 0.001	***
	9	0.0858^{a}	0.0506^{ab}	< 0.001	***
	10	0.0777^{a}	0.0441^{a}	< 0.001	***

Cultivar Differences in Fruit Quality Attributes - Block 3

Fruit quality traits differed significantly between 'Bing' and 'Coral' sweet cherry cultivars across most maturity stages in experimental block 3 (Table 7). Fruit firmness exhibited maturity-dependent cultivar differences. At stage 6, firmness did not differ significantly between cultivars ($p = 0.050$). At stage 7, 'Coral' fruit were significantly firmer than 'Bing' (354.36 vs. 323.50 g; $p < 0.05$), while no cultivar difference was detected at stage 8. At later maturity stages, firmness of 'Bing' exceeded that of 'Coral', with significant differences observed at stages 9 and 10 ($p < 0.001$ at both stages).

Soluble solids concentration (°Brix) was consistently higher in 'Bing' than in 'Coral' across all evaluated maturity stages. Cultivar differences were significant from stages 6 through 10 ($p \leq 0.05$), and °Brix increased with advancing maturity in both cultivars. At stage 10, 'Bing' fruit averaged 23.62 °Brix compared with 18.54 °Brix in 'Coral'.

Titratable acidity (TA %) differed significantly between cultivars at all maturity stages. 'Bing' fruit exhibited higher TA than 'Coral' from stages 6 through 10 ($p \leq 0.01$). The magnitude of this difference increased at later maturity stages, with TA reaching 1.342% in 'Bing' compared with 0.670% in 'Coral' at stage 10.

The sugar-to-acid ratio (°Brix:TA) also showed strong cultivar effects across maturity stages, but in contrast to °Brix and TA individually, values were consistently higher in 'Coral' than in 'Bing'. Differences were significant at all stages from 6 through 10 ($p \leq 0.01$). At the most advanced maturity stage, 'Coral' exhibited a substantially higher sugar-to-acid ratio (28.68) than 'Bing' (18.04).

Overall, in block 3, 'Bing' cherries were characterized by higher soluble solids concentration and titratable acidity, whereas 'Coral' fruit exhibited higher sugar-to-acid ratios across all maturity stages, reflecting contrasting flavor balance between cultivars as fruit matured.

Table 7: Results of fruit quality traits for 'Bing' and 'Coral' sweet cherry cultivars in experimental block 3. Between-cultivar differences at each maturity stage were assessed using two-sample t-tests, with mean values, p-values, and significance levels reported (ns = not significant; * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$). Within each cultivar, differences across maturity stages were evaluated using linear models with post hoc pairwise comparisons (emmeans with Tukey-adjusted CLD letters); stages sharing the same letter are not significantly different from one another.

Trait	**Stage**	**Bing**	**Coral**	p-value	**Significance**
Firmness	6	271.99^{ab}	382.46^{d}	0.0501	ns
(grams)	7	323.50^{a}	354.36^{cd}	< 0.05	*
	8	341.52^{ab}	325.13^{bc}	0.0802	ns
	9	372.31^{b}	313.15^{ab}	< 0.001	***
	10	367.92^{b}	294.02^{a}	< 0.001	***
Soluble Solids	6	18.10^{ab}	14.78^{a}	< 0.05	*
(°Brix)	7	18.38^{a}	15.36^{a}	< 0.001	***
	8	19.27^{b}	17.12^{b}	< 0.001	***
	9	21.70^{c}	17.18^{b}	< 0.001	***
	10	23.62^{d}	18.54^{c}	< 0.001	***
Titratable Acidity	6	1.002^{a}	0.676^{ab}	< 0.01	**
(TA %)	7	0.993^{a}	0.632^{a}	< 0.001	***
	8	0.987^{a}	0.790^{c}	< 0.001	***
	9	0.993^{a}	0.726^{bc}	< 0.001	***
	10	1.342^{b}	0.670^{ab}	< 0.001	***
Sugar/Acid Ratio	6	18.07^{ab}	22.06^{a}	< 0.01	**
(°Brix:TA)	7	18.59^{ab}	24.62^{b}	< 0.001	***
	8	19.62^{b}	22.15^{a}	< 0.001	***
	9	21.94^{c}	24.15^{b}	< 0.001	***
	10	18.04^{a}	28.68^{c}	< 0.001	***

5.5 Summary of Results - All Blocks

This section summarizes differences in stem retention and fruit quality traits between the two cultivars, 'Coral Champagne' and 'Bing,' across all three experimental blocks. The primary focus was on characterizing 'Coral' by comparing it to 'Bing' at each maturity stage using two-sample t-tests. In addition, we evaluated the effect of fruit maturity on stem retention and quality traits within each cultivar using linear models followed by post hoc pairwise comparisons (emmeans with Tukey-adjusted CLD letters), as presented in the tables below. Together, these analyses provide a comprehensive baseline for understanding cultivar-specific differences and how stem and fruit quality traits change with developmental stage.

Cultivar Differences in Stem Retention - All Blocks

Analysis of stem removal work across all three experimental blocks revealed consistent differences between 'Bing' and 'Coral' sweet cherry cultivars at all maturity stages (Table 8). Across early maturity stages, 'Bing' fruit required substantially more work to remove the stem than 'Coral'. At stage 1, stem removal work for 'Bing' averaged 0.362 in.lb compared with 0.186 in.lb for 'Coral' ($p < 0.001$), and significant differences persisted through stages 2–5 ($p < 0.001$ for all).

At intermediate maturity (stage 6), 'Bing' still exhibited higher stem removal work than 'Coral' (0.105 vs. 0.083 in.lb; $p < 0.01$). From stage 7 onward, cultivar differences became more pronounced again, with 'Bing' consistently requiring greater work to remove the stem at stages

7–10 ($p < 0.001$ for all). At the most advanced maturity stage (stage 10), stem removal work in 'Bing' was 0.074 in.lb compared with 0.044 in.lb in 'Coral', representing nearly a twofold difference.

Overall, combining data from all blocks highlights that 'Bing' cherries exhibit stronger stem–fruit attachment than 'Coral' throughout fruit development, with the largest relative differences observed at the earliest and latest maturity stages. This cross-block analysis confirms the consistent cultivar-specific pattern in stem retention identified within individual experimental blocks.

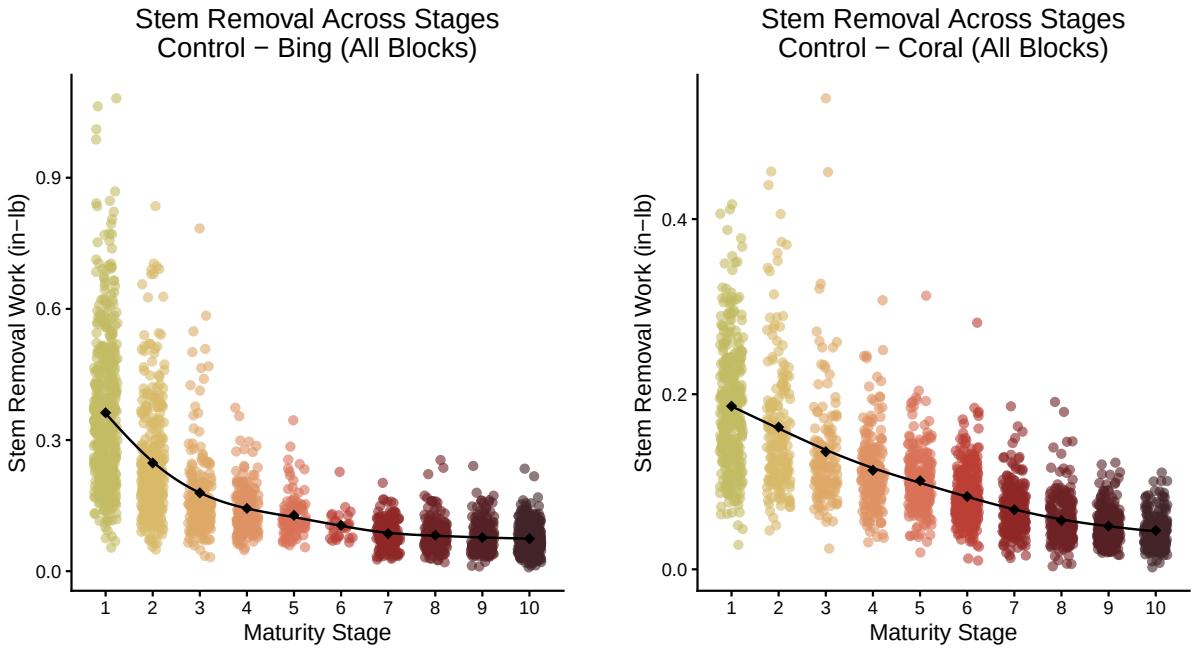

Figure 6: Relationship between fruit maturity stage and stem removal work for 'Bing' and 'Coral' sweet cherries. Stem removal work (in-lb) is plotted against maturity stage (1–10) with separate y-axes for each cultivar. Points represent individual fruits from all three blocks and are colored by the average CIELAB values for each maturity stage. Black diamonds indicate mean stem removal work per stage, and solid lines show GAM fits illustrating decreasing stem removal work as maturity advances.

Table 8: Results of stem removal work (in-lb) for 'Bing' and 'Coral' sweet cherry cultivars across all three experimental blocks. Between-cultivar differences at each maturity stage were assessed using two-sample t-tests, with mean values, p-values, and significance levels reported (ns = not significant; * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$). Within each cultivar, differences across maturity stages were evaluated using linear models with post hoc pairwise comparisons (emmeans with Tukey-adjusted CLD letters); stages sharing the same letter are not significantly different from one another.

Trait	**Stage**	**Bing**	**Coral**	p-value	**Significance**
Stem Removal	1	0.362^{f}	0.186^{g}	< 0.001	***
Work (in.lb)	2	0.248^{e}	0.162^{f}	< 0.001	***
	3	0.179^{d}	0.134^{e}	< 0.001	***
	4	0.144^{cd}	0.113^{d}	< 0.001	***
	5	0.128^{bc}	0.101^{d}	< 0.001	***
	6	0.105^{abc}	0.083^{c}	< 0.01	**
	7	0.086^{ab}	0.068^{b}	< 0.001	***
	8	0.082^{a}	0.056^{ab}	< 0.001	***
	9	0.077^{a}	0.049^{a}	< 0.001	***
	10	0.074^{a}	0.044^{a}	< 0.001	***

Cultivar Differences in Fruit Quality Attributes - All Blocks

Firmness of sweet cherries varied with both cultivar and maturity across all blocks (Table 9). At stages 6 and 7, firmness did not differ significantly between 'Bing' and 'Coral' ($p > 0.05$), but beginning at stage 8, 'Bing' fruit were significantly firmer than 'Coral' (353.30 vs. 335.90 g; $p < 0.01$), with this difference increasing at later maturity stages. At stages 9 and 10, 'Bing' maintained higher firmness (384.80 and 365.05 g) compared with 'Coral' (330.08 and 313.14 g; $p < 0.001$).

Soluble solids concentration (°Brix) was consistently higher in 'Bing' than in 'Coral' across all maturity stages ($p < 0.001$ for stages 6–10), increasing with fruit maturity in both cultivars. By stage 10, 'Bing' reached 24.31 °Brix compared with 19.73 °Brix in 'Coral', reflecting persistent differences in sugar accumulation during fruit development.

Titratable acidity (TA %) was also higher in 'Bing' than in 'Coral' at all stages ($p < 0.001$). TA declined slightly from early to mid-maturity stages but increased in 'Bing' at stage 10 (1.32%) while remaining low in 'Coral' (0.72%), demonstrating that 'Bing' maintains higher acid levels throughout development.

The sugar-to-acid ratio (°Brix:TA) showed a more complex pattern. At stages 6 and 7, 'Coral' exhibited slightly higher ratios than 'Bing' (stage 6: 21.42 vs. 20.38, $p < 0.05$; stage 7: 21.88 vs. 20.24, $p < 0.001$). At stage 8, ratios were similar between cultivars ($p = 0.192$). At stages 9 and 10, 'Coral' again exhibited higher sugar-to-acid ratios than 'Bing' (stage 9: 23.64 vs. 22.93, $p < 0.01$; stage 10: 28.01 vs. 18.75, $p < 0.001$), indicating higher relative sweetness in 'Coral' at late maturity, despite lower absolute °Brix and TA.

Overall, across all experimental blocks, 'Bing' cherries were characterized by higher soluble solids and titratable acidity at nearly all maturity stages, while firmness differences became apparent only at later stages. Sugar-to-acid ratio showed a more nuanced pattern, with 'Coral' generally higher at early and late maturity stages, reflecting greater relative sweetness compared with acidity. These results highlight consistent cultivar differences in sugar and acid accumulation, whereas firmness and sugar-to-acid balance were more strongly influenced by fruit maturity.

Table 9: Results of fruit quality traits for 'Bing' and 'Coral' sweet cherry cultivars across all three experimental blocks. Between-cultivar differences at each maturity stage were assessed using two-sample t-tests, with mean values, p-values, and significance levels reported (ns = not significant; * = $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$). Within each cultivar, differences across maturity stages were evaluated using linear models with post hoc pairwise comparisons (emmeans with Tukey-adjusted CLD letters); stages sharing the same letter are not significantly different from one another.

Trait	**Stage**	**Bing**	**Coral**	p-value	**Significance**
Firmness	6	356.84^{ab}	371.81^{c}	0.5261	ns
(grams)	7	345.47^{a}	360.85^{c}	0.0600	ns
	8	353.30^{a}	335.90^{b}	< 0.01	**
	9	384.80^{b}	330.08^{b}	< 0.001	***
	10	365.05^{a}	313.14^{a}	< 0.001	***
Soluble Solids	6	20.42^{ab}	15.71^{a}	< 0.001	***
(°Brix)	7	20.11^{a}	16.56^{a}	< 0.001	***
	8	20.95^{b}	18.50^{c}	< 0.001	***
	9	22.71^{c}	19.06^{d}	< 0.001	***
	10	24.31^{d}	19.73^{e}	< 0.001	***
Titratable Acidity	6	1.00^{a}	0.74^{ab}	< 0.001	***
(TA %)	7	1.00^{a}	0.77^{b}	< 0.001	***
	8	0.97^{a}	0.85^{c}	< 0.001	***
	9	1.01^{a}	0.82^{c}	< 0.001	***
	10	1.32^{b}	0.72^{a}	< 0.001	***
Sugar/Acid Ratio	6	20.38^{abc}	21.42^{a}	< 0.05	*
(°Brix:TA)	7	20.24^{b}	21.88^{a}	< 0.001	***
	8	21.64^{c}	21.99^{a}	0.192	ns
	9	22.93^{d}	23.64^{b}	< 0.01	**
	10	18.75^{a}	28.01^{c}	< 0.001	***

5.6 Summary of Results — Treatment Effects

5.6.1 Block 1 — Harvista Treatments ('Coral Champagne')

Comparison of stem removal work and fruit quality among three Harvista spray timings and an untreated control in Block 1. Analyses were conducted at mahogany and commercial harvest stages (mahogany + 2 days). See Table 10 and Figure 7 for a summary of treatment effects.

Table 10: Effect of Harvista sprays on fruit traits of 'Coral Champagne' cherries sampled at mahogany stage and commercial harvest (mahogany + 2 days) in Block 1. Harvista sprays were applied at 50% red color (early), 100% red color (late), both 50% and 100% red color (double), or a no spray control. Mean values are shown. Within each stage, letters indicate significant differences across the four treatments determined by Tukey's HSD ($p < 0.05$, n = 40 cherries).

Trait	Stage	Control	Early	Double	Late	p-value
Soluble Solids (°Brix)	Mahogany	19.765^{a}	19.380^{a}	19.195^{a}	19.120^{a}	0.077
	Commercial	21.255^{bc}	20.568^{c}	22.293^{a}	21.565^{b}	< 0.001
Titratable Acidity (%)	Mahogany	0.958^{b}	1.011^{a}	0.677^{c}	0.994^{a}	< 0.001
	Commercial	0.761^{c}	1.005^{a}	1.030^{a}	0.899^{b}	< 0.001
Sugar/Acid Ratio - Brix:TA	Mahogany	20.635^{b}	19.181^{c}	28.346^{a}	19.224^{c}	< 0.001
	Commercial	27.934^{a}	20.457^{d}	21.693^{c}	24.019^{b}	< 0.001
Firmness (g)	Mahogany	347.859^{a}	348.317^{a}	358.622^{a}	337.699^{a}	0.421
	Commercial	347.505^{a}	320.082^{a}	333.674^{a}	330.276^{a}	0.094
Stem Removal Work (in-lb)	Mahogany	0.0405^{b}	0.0519^{ab}	0.0577^{a}	0.0529^{a}	0.004
	Commercial	0.0425^{a}	0.0416^{ab}	0.0329^{b}	0.0376^{ab}	0.032
Color Lightness	Mahogany	59.209^{c}	71.300^{ab}	74.979^{a}	67.531^{b}	< 0.001
	Commercial	49.722^{ab}	51.570^{a}	46.898^{b}	47.437^{ab}	0.016
Color Chromaticity	Mahogany	32.579^{c}	42.760^{ab}	45.297^{a}	39.528^{b}	< 0.001
	Commercial	21.587^{ab}	24.565^{a}	19.059^{b}	19.579^{b}	0.004
Color Hue°	Mahogany	24.728^{b}	27.653^{a}	28.157^{a}	26.740^{ab}	< 0.001
	Commercial	26.803^{a}	29.911^{a}	41.937^{a}	35.263^{a}	0.076

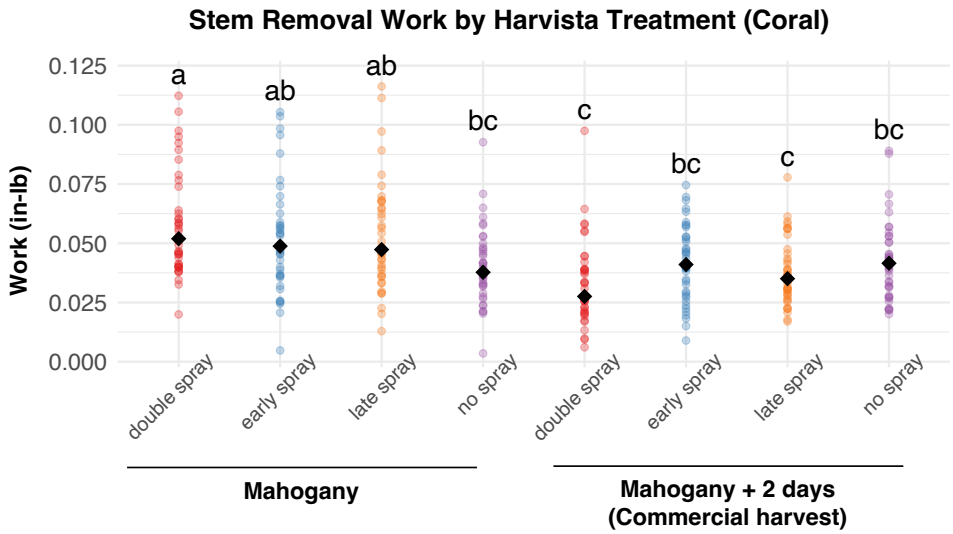

Figure 7: Effect of Harvista sprays on stem removal work (in-lb) when 'Coral Champagne' cherries were sampled at mahogany stage and commercial harvest (mahogany + 2 days) in Block 1. Harvista sprays were applied at 50 % red color (early), 100 % red color (late), or at both 50 % and 100 % red color (double), and a no spray control was included. Each colored point represents an individual cherry. Black points indicate median values. Letters indicate significant differences across the two stages and the four treatments determined by Tukey's HSD ($p < 0.05$, n = 40 cherries).

5.6.2 Block 3 — Apogee Treatments ('Coral Champagne' and 'Bing')

Comparison of stem removal work and fruit quality among Apogee treatments and untreated controls in Block 3. For each treatment, ***n* = 40 cherries** were evaluated for 'Bing' and ***n* = 60 cherries** for 'Coral Champagne'. Analyses conducted at **commercial harvest time.** See Table 11 and Figure 8 for a summary of treatment effects.

Table 11: Results of t-tests for each trait within each cultivar, comparing (+) Apogee to (-) Apogee. Data are for 'Bing' (n = 40) and 'Coral Champagne' (n = 60) cherries sampled at commercial harvest in Block 3. Significance: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, n.s. = not significant.

Trait	Bing		Coral Champagne		*p*-value
	(-) Apogee	(+) Apogee	(-) Apogee	(+) Apogee	
Soluble Solids (°Brix)	24.86***	23.83***	16.78***	18.27***	< 0.001 / < 0.001
Titratable acidity (%)	1.03***	1.49***	0.61*	0.65*	< 0.001 / 0.045
Sugar/Acid Ratio - Brix:TA	24.19***	15.98***	27.64 n.s.	28.90 n.s.	< 0.001 / 0.061
Firmness (g)	357.73 n.s.	372.99 n.s.	313.84 n.s.	295.19 n.s.	0.350 / 0.119
Stem Removal Work (in-lb)	0.083 n.s.	0.079 n.s.	0.063 n.s.	0.053 n.s.	0.381 / 0.056
Lightness	46.35 n.s.	45.47 n.s.	53.97***	44.75***	0.544 / < 0.001
Chromaticity	16.91 n.s.	14.82 n.s.	25.72***	16.68***	0.075 / < 0.001
Hue°	35.88 n.s.	47.86 n.s.	27.95***	43.08***	0.168 / 0.001

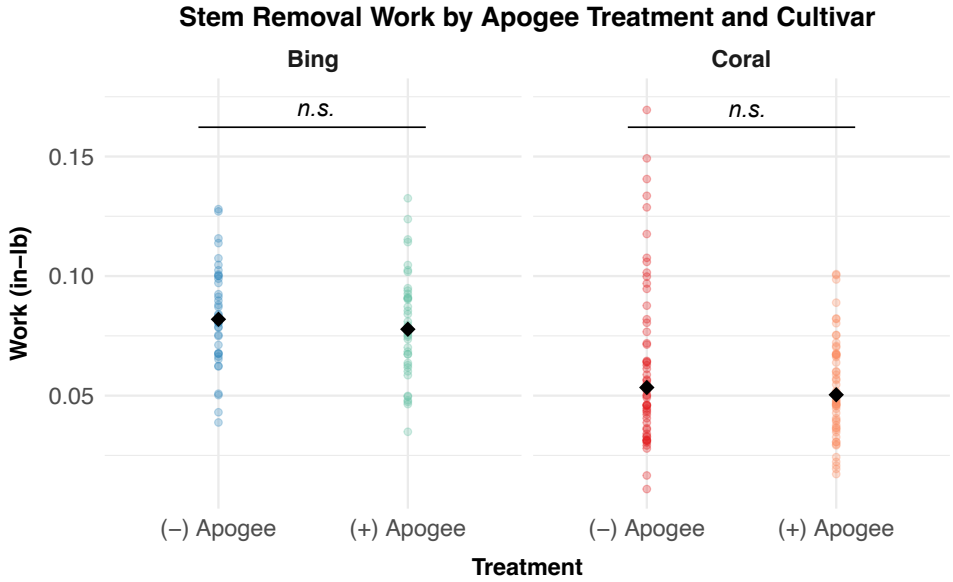

Figure 8: Effect of applying Apogee on stem removal work (in-lb) when 'Bing' and 'Coral Champagne' cherries were sampled at commercial harvest in Block 3. Each colored point represents an individual cherry. Black points indicate median values. There were no significant (n.s.) differences calculated by t-test ($p < 0.05$) between treatments for each cultivar (n = 40 'Bing' cherriers and n = 60 'Coral Champagne' cherries).

6 Conclusions and Next Steps

Across all three experimental blocks within a single growing season, clear and consistent cultivar-level differences in stem retention and fruit quality were observed between 'Coral Champagne' and 'Bing' sweet cherries. Analysis across blocks revealed that 'Bing' consistently required more work to remove the stem than 'Coral' at nearly all maturity stages, confirming that weaker stem retention is an inherent and repeatable trait of 'Coral'. The largest relative differences were evident at the earliest and latest stages of fruit maturity, providing a robust baseline characterization of stem retention behavior for both cultivars across the full developmental range.

Fruit quality traits also differed consistently by cultivar. 'Bing' cherries exhibited higher soluble solids concentration and titratable acidity across nearly all maturity stages, while 'Coral' fruit generally displayed higher sugar-to-acid ratios at early and late stages. Firmness differences were more strongly maturity-dependent: 'Bing' tended to be firmer at later maturity stages, whereas 'Coral' was sometimes firmer at intermediate stages. These patterns highlight a fundamental trade-off between stem retention strength and flavor balance that varies with both cultivar and harvest timing.

Preharvest growth regulator treatments produced relatively modest and stage-dependent effects on stem retention. In Block 1, Harvista sprays affected stem removal work in a harvest stage–specific manner. At the mahogany stage, the double application increased stem removal work compared to the untreated control, indicating temporarily stronger stem retention. However, by commercial harvest, the double application reduced stem removal work below the control, while other spray timings had intermediate effects. These results demonstrate that Harvista's influence on stem retention is sensitive to both application timing and fruit maturity.

While effects on stem retention were limited, Harvista treatments had more pronounced and consistent impacts on fruit quality. Soluble solids, titratable acidity, and sugar-to-acid ratio responded to spray timing in a maturity-dependent manner, suggesting that treatment strategies may more readily modify flavor attributes than stem retention. These observations indicate that further optimization of timing, rate, or formulation will be necessary to achieve meaningful improvements in stem retention without compromising eating quality.

Interpretation of treatment effects is limited by the experimental scope. All data were collected during a single growing season, within a single production region in the San Joaquin Valley of California, with blocks located in close proximity. Treatments were applied to only one block each and involved fewer trees than the untreated controls. Consequently, conclusions regarding treatment efficacy should be considered preliminary.

Future research should expand the study across multiple growing seasons to capture interannual variability and include orchards in additional production regions, particularly cooler or coastal environments. Evaluation of a broader range of preharvest and postharvest treatments, combined with increased replication at the block and tree level, will improve the ability to detect meaningful effects on stem retention. Continued data collection will also refine the Dark Cherry Maturity Scale and support the development of cultivar-specific harvest recommendations that balance stem retention with optimal fruit quality.

Pedicel Retention in Sweet Cherries:
Assessing the impact of cultivar, maturity, and orchard treatments

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UCDAVIS
DEPARTMENT OF PLANT SCIENCES
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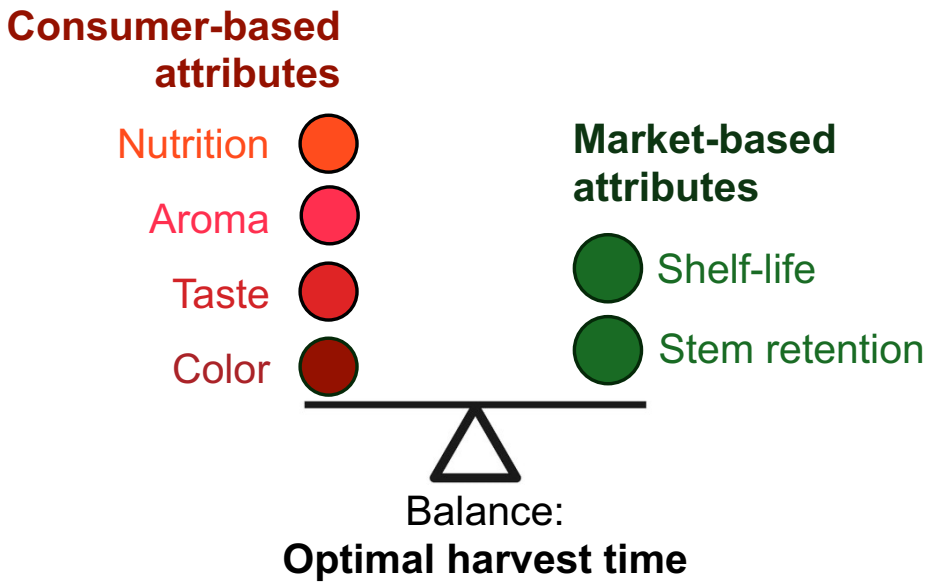
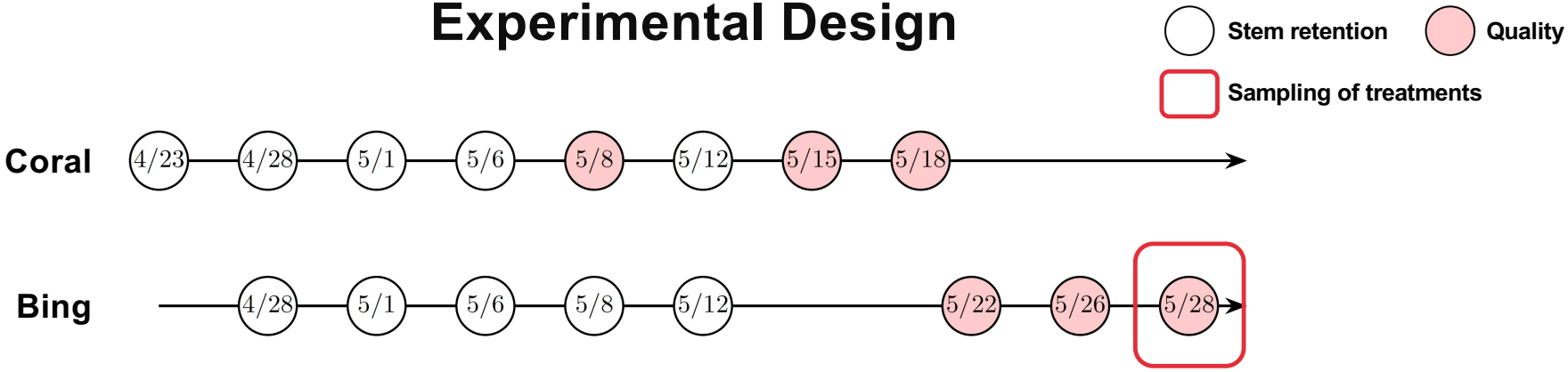
Why Stem Retention Matters?

- **Green, attached stems** = freshness, higher value, longer shelf life.
- **Stem detachment after harvest** → water loss, browning, softening, and reduced marketability.
- **Harvest timing trade-off**:
  - Early harvest: stronger stems, but less color and flavor.
  - Later harvest: better eating quality, but weaker stems.
- **'Coral Champagne' is especially prone to stem loosening**.



Experimental Design



Maturity Assessments

Stem retention across 10 stages, quality evaluation for the last 4 stages.

Orchards: 3

Cultivars: 2

Trees per Orchard: 10

Cherries per Tree: 10

Preharvest Tests (Preliminar)

Stem retention and quality evaluation at commercial harvest.

Orchards for each Treatment: 1

Cultivars: 1

Trees per Treatment and Control: 4

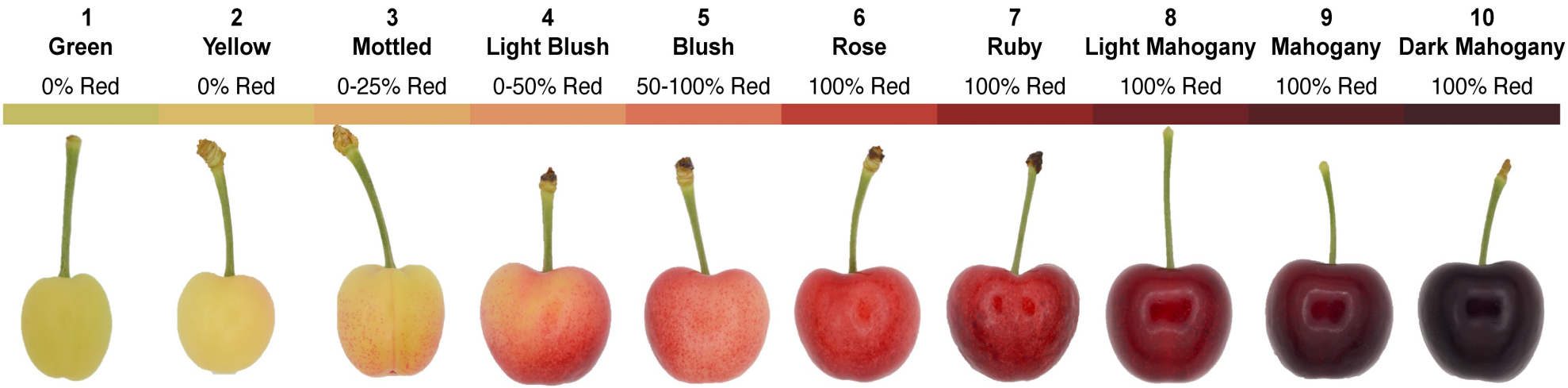
Cherries per Tree: 10

Treatments:

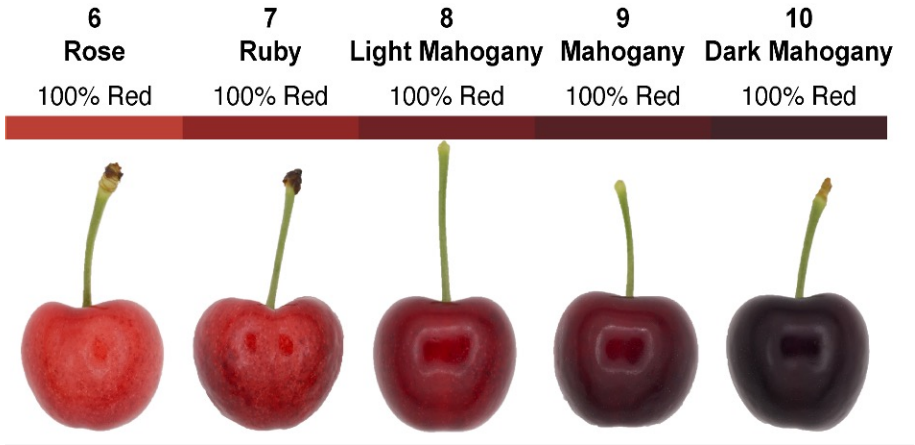
- Harvista (Ethylene inhibitor)
- Apogee (Gibberellin inhibitor)

Finding #1: Fruit maturity–quality relationships

- Evaluated ‘Bings’ vs ‘Corals’ in multiple orchards throughout the growing season.
- Built a **10-stage maturity scale** using image-based color analysis.
- Measured **key fruit traits**: stem pull force, firmness, °Brix, TA, Brix: TA.
- Determined the changes in these fruit traits across the 10 maturity stages for both cultivars



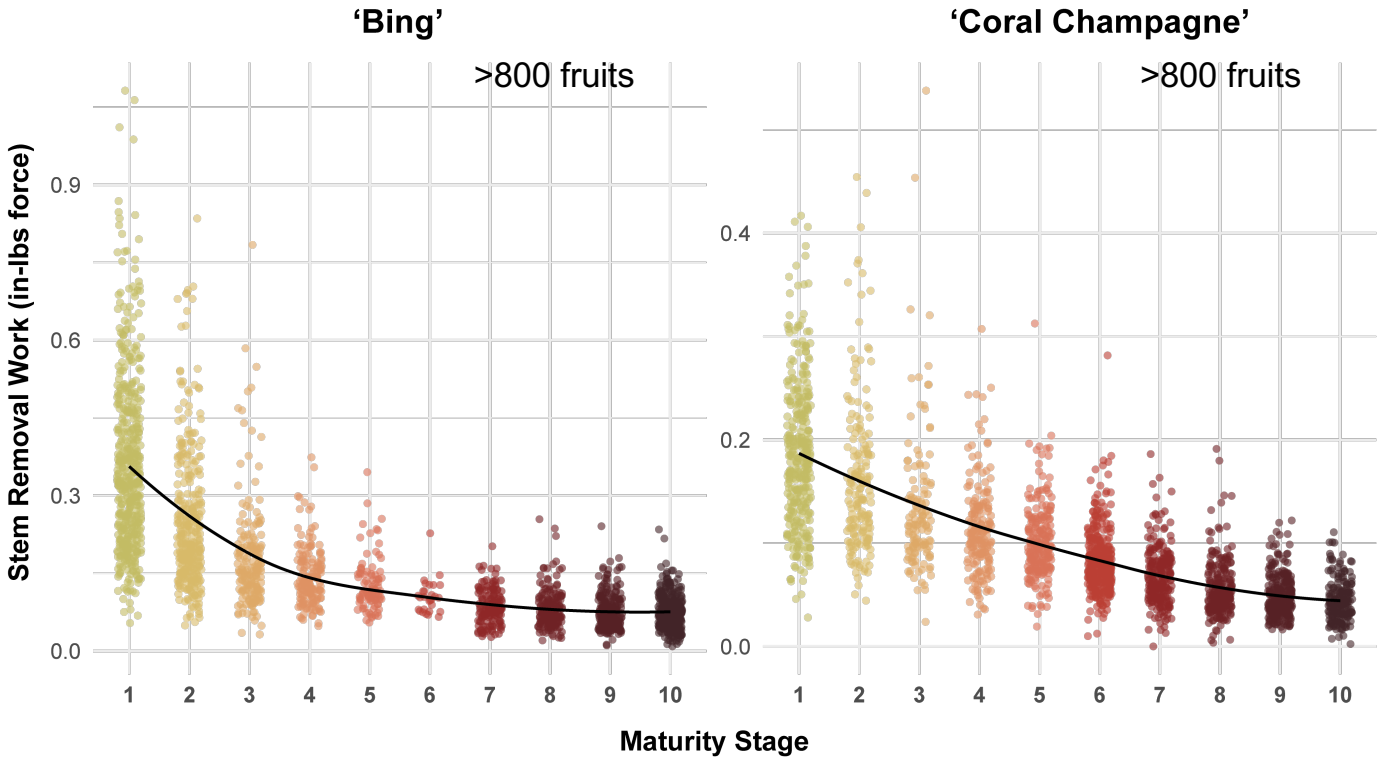
Finding #1: Fruit maturity–quality relationships



Trait	Stage	Bing	Coral
Firmness (grams)	6	271.99	382.46
	7	323.50	354.36
	8	341.52	325.13
	9	372.31	313.15
	10	367.92	294.02
Soluble Solids (°Brix)	6	18.10	14.78
	7	18.38	15.36
	8	19.27	17.12
	9	21.70	17.18
	10	23.62	18.54
Titratable Acidity (TA %)	6	1.002	0.676
	7	0.993	0.632
	8	0.987	0.790
	9	0.993	0.726
	10	1.342	0.670
Sugar/Acid Ratio (Brix:TA)	6	18.07	22.06
	7	18.59	24.62
	8	19.62	22.15
	9	21.94	24.15
	10	18.04	28.68

Finding #2: Stem Strength Curve

- We found a clear, steady decline in steam retention as fruit colors in both cultivars.
- In ‘Corals, ’ the drop is earlier and faster than in ‘Bings.’

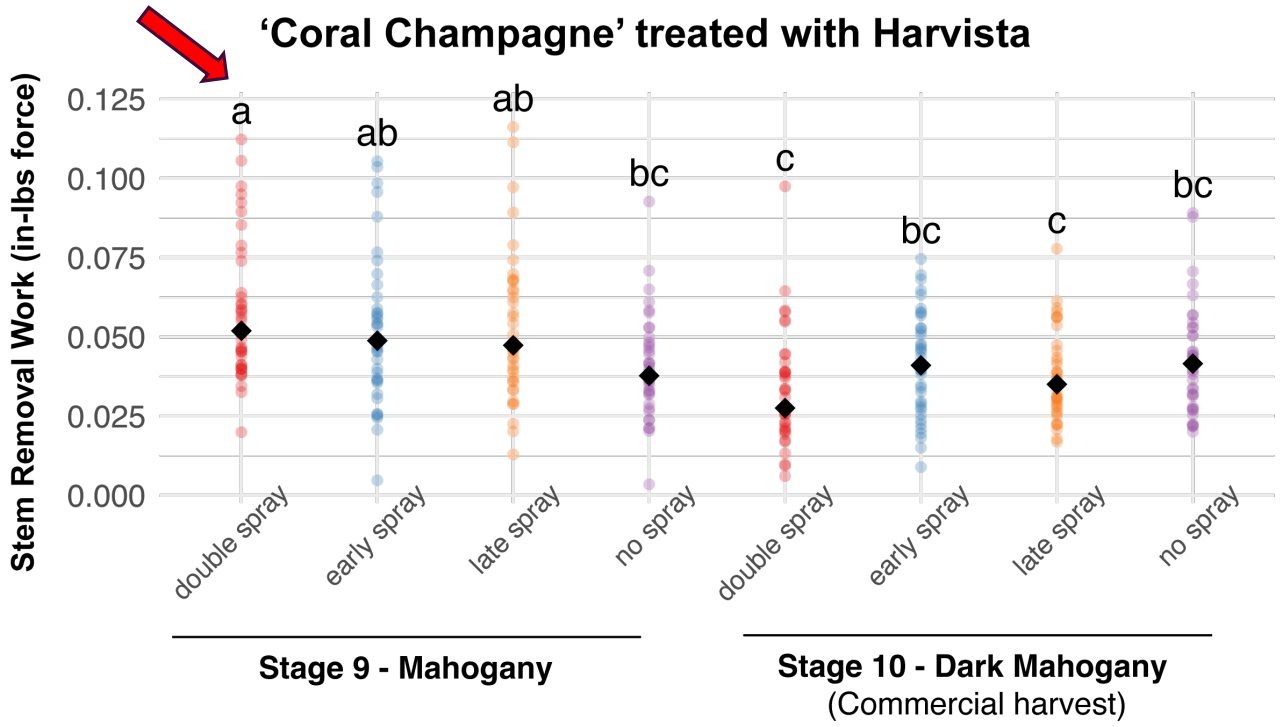


The “y-axis” scale is different between cultivars

Each point = 1 fruit

Finding #3: Preharvest Treatments

- **Harvista**: double spray increased stem retention by ~30–40%.
- **Apogee:** inconsistent for stems; the only result was that the treated ‘Corals’ had higher °Brix.



What We Learned in Year 1

Stem Retention Depends on Maturity (and Cultivar) — Treatments Are Timing-Sensitive

- Stem retention declines steadily as fruit matures, especially in Coral Champagne.
- Preharvest treatments only helped within a narrow maturity window.
- Timing relative to maturity mattered more than the product itself.

2026 Project Continuation: What's Next?

- Single-cultivar **focus on 'Coral'** → deeper sampling and clearer interpretation.
- **More orchards** (up to 5) → capture real-world weather variability.
- **Weather integration** → temperature, RH, VPD, degree-days.
- Refining **harvest timing** using the maturity and stem-loss curves developed this year.
- Testing **Harvista (double) and calcium sprays**, alone and in combination, under commercial conditions.

From Physiology → Practical Recommendations

POSTHARVEST

RESEARCH AND EXTENSION CENTER

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Marino, Giulia

"An Integrated Approach to improve Winter Chill Accumulation and Dormancy Breaking in California Cherry Orchards"

An integrated approach to improve winter chill accumulation and dormancy breaking in California Cherry orchards

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SUMMARY:

This report refers to the 2024-2025 winter season data collection, however we are also reporting some updates of outcomes and accomplishments from previous years' project. The last winter we tested the effects of 'Dormex' application time on flower and fruit quantity, quality, and timing. We applied 'Dormex' at 40, 45, 50, 55 and 60 Chill Portions (CP) calculated based on air temperature. We found that bloom time was directly correlated with Dormex application time, with the application at 40 CP anticipating full bloom by 38 days, the application at 45 CP by 28 days, and the application at 50-55 and 60 CP anticipated bloom by 20 days with respect to 'Control' (untreated trees). The early applications (40 and 45 CP) resulted in a more protracted bloom, probably because of the low temperatures during bloom. Late application (60 CP) resulted in a higher proportion of vegetative buds developing during bloom. Fruit ripening was more advanced in all the sprayed trees with respect to the 'Control'. Among the treatments, the fruits from the 55 CP spray ripened earlier than the ones sprayed at 40 CP, probably influenced by the difference in temperature during early fruit growth. Dormex application clearly impacted carbohydrates with sugar decreasing after spray and starch increasing, suggesting the strong correlation between these indicators and dormancy breaking. Another objective of last year data collection was to characterize the chill requirements of new cherry cultivars. We found that 'Royal Lee' had the lowest chill requirements, followed very closely by 'Royal Lynn', and then by 'Black Pearl'. 'Royal Haze' and 'Ranier' had similar and intermediate chill requirements, and 'Coral' and 'Brooks' had the highest chill requirements. The low-chill cultivars satisfied their chill requirements as early as mid-January, while the cultivars with the highest chill requirements at mid- to late-February.

1. INTRODUCTION

Lack of sufficient winter chill in many of the cherry-producing areas results in prolonged tree dormancy with delayed foliation, poor and unsynchronized bud break, and suboptimal productivity (Cook and Jacobs, 2000; Atkinson et al., 2013). Growers can overcome this problem with various management decisions. The most used is to apply chemical dormancy-breaking agents to promote early and uniform bud break, sustainable yields and profitability. However, these chemicals must be applied at the right time to be effective and avoid phytotoxicity. Based on previous studies made in CA, it is recommended to spray Dormex at 45-55 chill portions (CP) alone or in combination with CAN 17, which is applied slightly later, at 48-58 CP, to maximize its efficacy. These recommendations, developed about 20 years ago, should be revised according to the current context of climate change, new varieties, and chemical regulations. In particular:

1- Climate change has impacted the reliability of chill accumulation predictions, with large discrepancies in chill requirements reported among locations and years. This lack of precision and reliability has affected growers' capability to time applications accurately.
2- New varieties with different chill requirements relative to the ones tested in the original UC trials (Bing) have been recently adopted by growers.
3- The United States Department of Agriculture classifies cyanamide within the highest category of toxicity (Settimi et al., 2005). Restrictions on its use have already been imposed in several countries and the US may face the same challenge in the near future.

2. OBJECTIVES

The main objective of this long-term project is to develop tools and management guidelines for CA cherry growers to maintain profitability under low chill conditions. Based on the previous considerations, we developed the following priorities for the cherry industry:

1- Improve the precision of chill accumulation calculations (ongoing, started in 2020)
2- Develop updated guidelines for timing the dormancy-breaking agent applications (started in winter 2024-2025)
3- Characterize the chill requirements of new cherry varieties in CA (started in winter 2024-2025)
4- Find equally effective but safer replacements for Dormex® (starting this winter 2025-2026)

3. METHODS AND RESULTS

3.1. Objective 1: Improve the precision of chill accumulation calculations (2020 to date)

We want to improve the precision of winter chill calculations by integrating more information on what is happening at both the orchard and tree levels. From a meteorological perspective, we aim to use tree temperature instead of air temperature for calculating chill accumulation. From a physiological perspective, we aim to develop a biomarker of winter dormancy that can be used to optimize dormancy-breaking agent spray time.

Developing the '*TreeChill'* accumulation calculator:

We developed a model and an application that predicts tree temperature and uses it to calculate the chill accumulation. The application compares the 'TreeChill' with the 'AirChill' (i.e. the chill calculated using tree temperature and air temperature). Links to the publication of the model and the Chill Calculator follow (**Figure 1**). We are continuously working on their improvement and on including the new 'TreeChill' parameter in our routine management practices (see more in the next objectives).

Scientific Publication

Chill Calculator

Figure 1. QR codes to access the scientific publication and chill calculator with the 'TreeChill model'. Corresponding links are: https://doi.org/10.1016/j.agrformet.2025.110647 (publication), and https://ucanr-igis.shinyapps.io/cherrychill/ (calculator).

Developing a non-structural carbohydrate (NSC) model to track cherry dormancy dynamics:

We developed the first prototype of a model that predicts how levels of non-structural carbohydrates (NSC) change from endodormancy to ecodormancy using air temperature data from nearby weather stations and bark temperature measured on different sides of branches (**Figure 2**). The goal is to develop a mechanistic model that can simulate and forecast NSC dynamics across years and orchards, using only a few NSC measurements collected during the season.

In winter, the NSC (soluble sugars and starch) stored in dormant cherry tree tissues play a key role in both freeze protection and the regulation of dormancy. Starch and soluble sugars are continuously converted back and forth. These conversions are controlled by temperature-dependent enzymes, and the way temperatures fluctuate through the season helps explain observed changes in NSC levels and the timing of dormancy transitions and spring growth.

Our model structure follows previous research from Charrier et al. (2018), representing NSC as two pools: starch and soluble sugars. Starch breaks down into sugars through enzymes that are most active within specific temperature ranges, while sugars are used for respiration and can be converted back into starch through other temperature-dependent processes. Because NSC samples were collected every 1-2 weeks, the model operates at a daily time step, which matches the biological and data resolution and avoids over-fitting to processes that cannot be observed at hourly scales.

Overall, this modeling approach provides a biologically realistic framework to better understand winter carbon dynamics in cherry trees and to support future tools for predicting dormancy transitions, frost risk, and early-season growth.

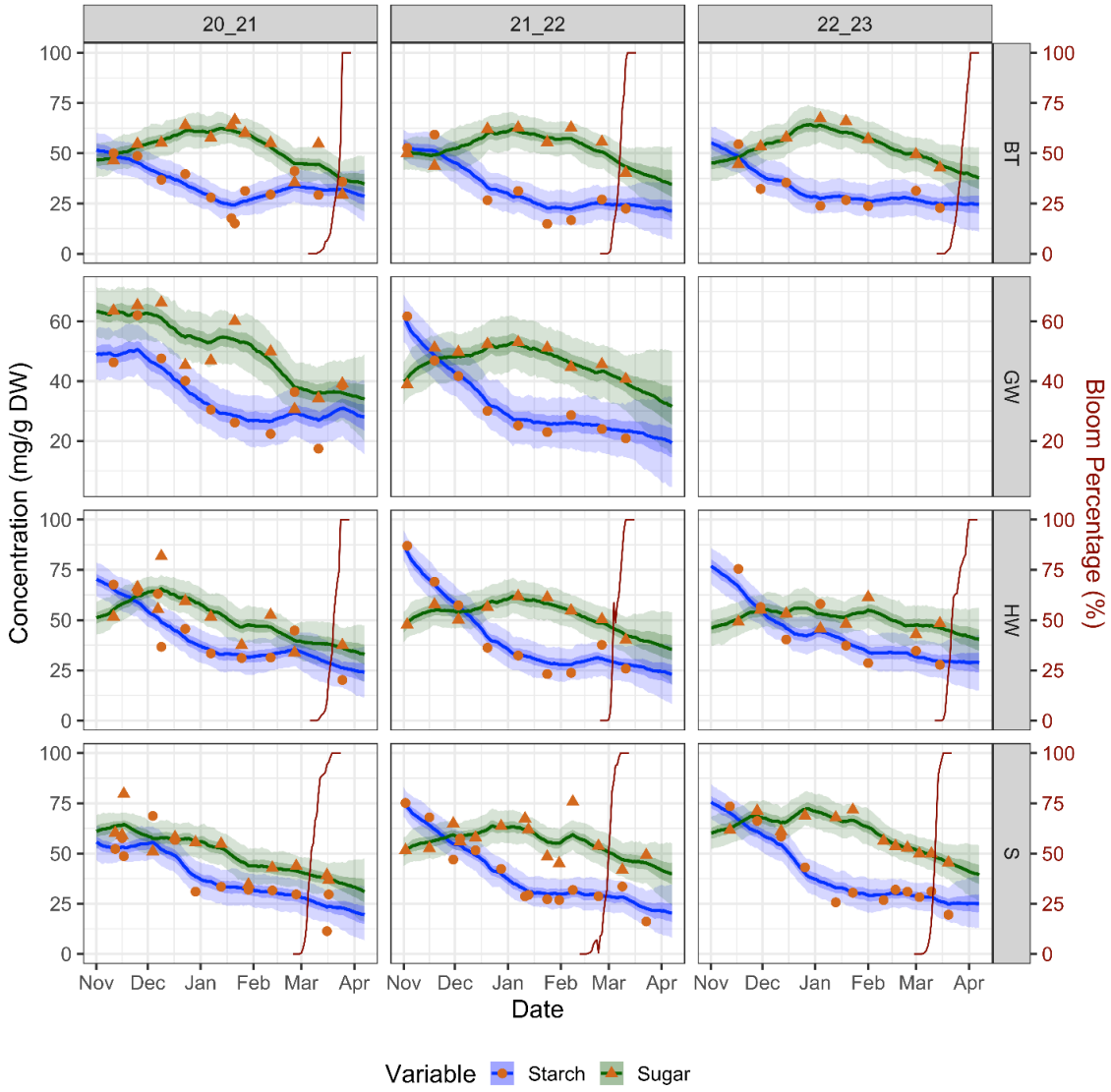

Figure 2. Predictions for sugar and starch concentrations using tree temperature data. Symbols are observed values, lines are median posterior predictions, and shaded areas represent 50 and 95% credible intervals. Bloom percentage data (dark red lines) are overlaid on the NSC predictions.

3.2. Objective 2: Develop updated guidelines for timing dormancy-breaking agent applications

One main goal of our project is to use the tools we developed to refine the timing of dormancy-breaking agent applications. We are testing Dormex at different application times to assess its effects on flower and fruit quantity, quality, and timing. For each spray, we are measuring '*TreeChill*' and twig NSC content to determine relationships between NSC levels and application

efficacy.

Experimental design: A randomized block experimental design was implemented in a cherry plot located at the UC Davis research facilities, with 3 blocks of 12 trees each. Dormex (2%) plus surfactant (Agridex) at 0.5% v/v on 200 gallons per acre of water was sprayed every ~5 CP starting at 40 CP and finishing at 60 CP. The spray dates and relative treatments are shown in **Table 1**.

Table 1. Dates and chill portions accumulated until spray time for each treatment of the study.

Treatment	Spray date	Air Chill portions	Tree Chill portions
D1	January 6	40	35
D2	January 14	45	40
D3	January 21	50	44
D4	January 28	55	48
D5	February 5	60	52
CTR	-	-	-

Phenology data collection: Phenological observations were carried out since the beginning of bud swelling to characterize bloom across the different treatments. The first observation date was February 5. We had two sets of bloom measurements, the first focused on characterizing bloom progression across the tree, and the second focused on characterizing bloom progression within the branch. For the bloom progression across the tree, eight branches on one tree per treatment per block were labelled (two per orientation N, S, E, W) and on those, the BBCH stage of the last three spurs on the last year's growth was determined, based on the phenological scale for sweet cherry (Bound et al., 2022) at weekly intervals (**Supplemental Figure 1**). In total, 24 spurs per tree were observed at each date, resulting in 72 observations per treatment per date (**Figure 3**). For the bloom progression within the branch, one branch, exposed to SW, was labelled in one tree per treatment per block. On this branch, at weekly intervals, the number of buds in each BBCH stage and their respective position along the branch (i.e., sequential number of spurs to which the bud belonged, from apex to bottom of the branch) were annotated (**Figure 4**). The leaf-to-flower ratio was calculated as the number of buds in a vegetative stage divided by the number of buds in a reproductive stage (either flowers or fruits) (**Figure 5**).

Prior to and at harvest, 50 fruits per tagged tree were harvested three times at weekly intervals and graded for maturity (color class). To do so, we used non-destructive image analysis of intact fruits. The 50 fruits per tree were placed in white trays and three sets of photographs were captured, depicting both lateral sides and the top (pedicel end). Then, those photographs (lateral sides) were analyzed using the software ImageJ. First, the color threshold (RGB) tool was used to separate each fruit boundary from the background tray, and an outline was created around the fruit boundary. Then, the area within each fruit outline was calculated. The Lab stack tool was used to obtain values in the L*a*b color space, where L is the lightness value, and a and b are color hue values, for each fruit (**Supplemental Figure 3**).

Results: We identified four spray efficacy indicators to evaluate the best-performing spray times:

1) bloom timing (how early it bloomed?)
2) bloom duration or length (was the bloom spread or compact?)
3) Leaf to flower ratio (are vegetative buds opening at the same time as reproductive buds?)
4) Fruit ripening (how early and homogenously do fruits ripen?)

Preliminary results show that buds developed earlier in all treated trees compared with control trees (**Figures 3 and 4**). Among treated trees, the earliest application (D1, 45 CP) advanced bloom the most (peak of bloom on February 27, 38 days before Control) followed by D2 (28 days before Control). Very small differences in bloom time were observed among D3, D4 and D5 (peak of bloom on March 17, 20 days before Control).

The earlier the bloom occurred, the more it spread, possibly in response to lower temperatures during the early bloom period. This was particularly true for D1 and D2 (**Figures 3 and 4**). Some parameters of interest extrapolated from phenological data are summarized in **Tables 2 and 3**. The latest treatments, D4 and particularly D5, had the highest leaf-to-flower ratio, suggesting that the spray was made too late. More years of data collection are needed to draw any conclusions.

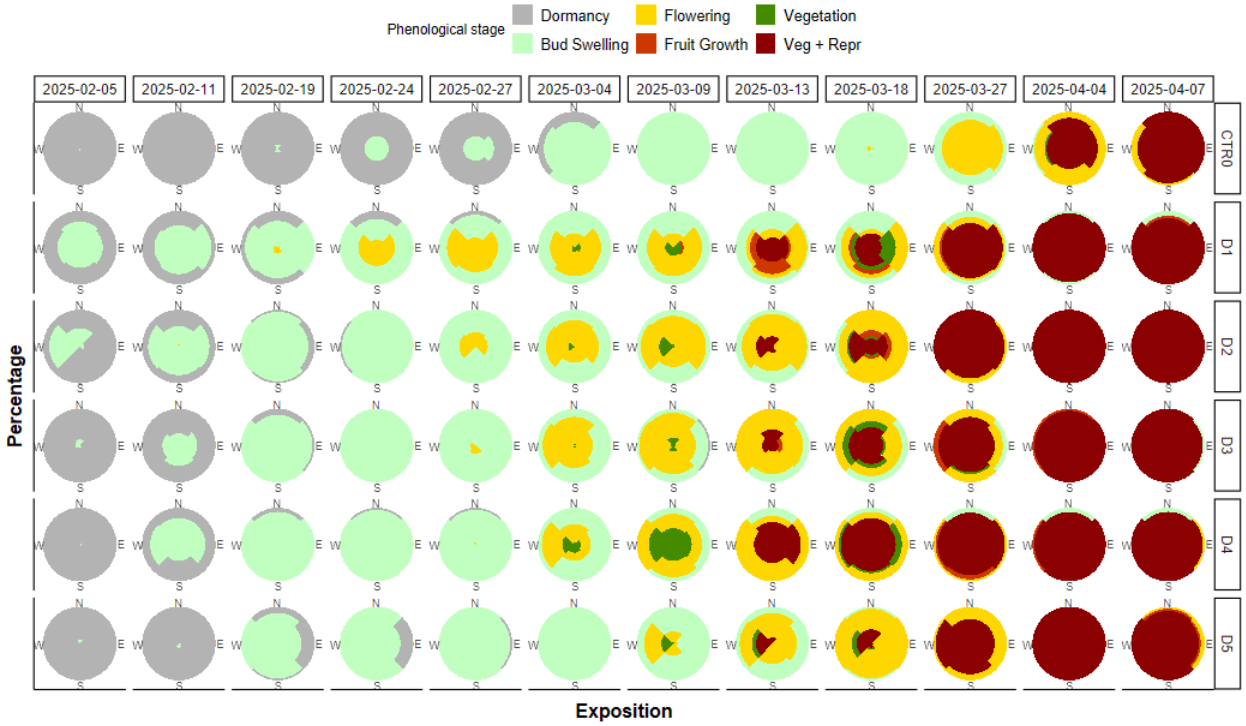

Figure 3. Bloom progression across the canopy. Each color represents a major bloom stage, and the width of the colored radius indicates the percentage of expression of that stage relative to other stages (e.g. a full circle in green means 100% of the canopy was in the bud swelling stage) for each canopy orientation N, S, E and W

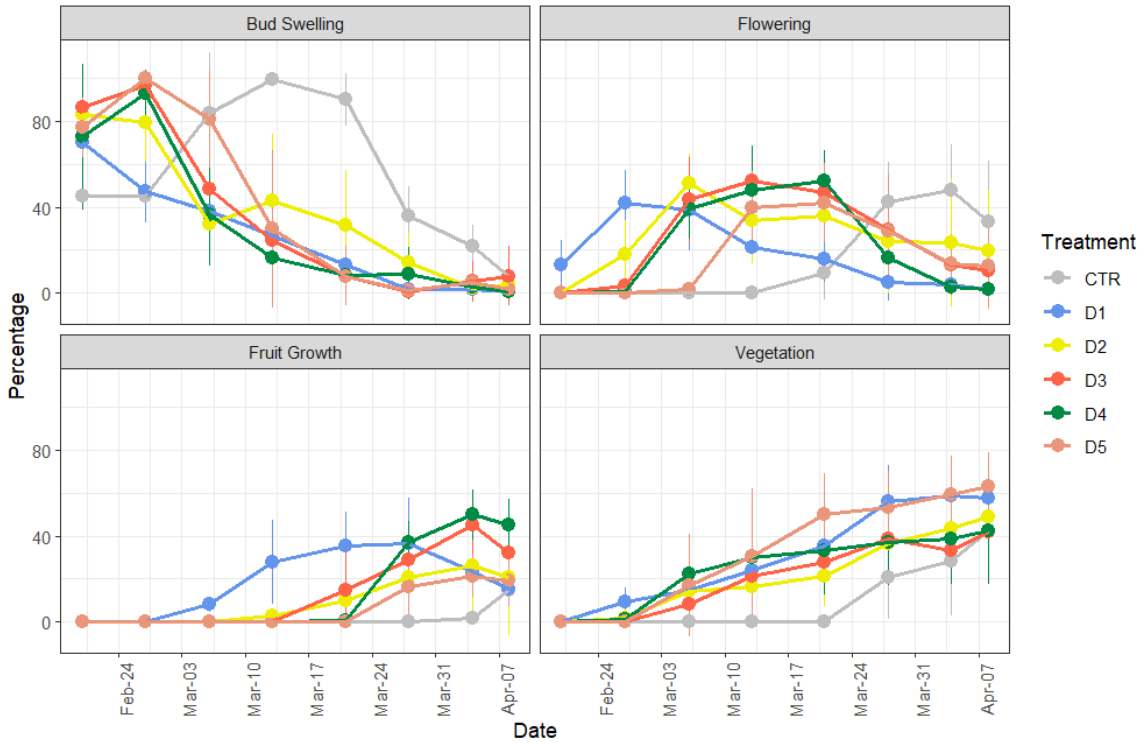

Figure 4. Percentage of buds at different phenological stages for the various treatments measured across the branch length. The 'bud swelling' includes BBCH Stages 51-57, the 'flowering' includes Stages 57-69, the 'fruit growth' includes Stages 70-79 and the 'vegetation' represents the vegetative bud development. See supplemental information at the end of the document for image references of the phenological stages.

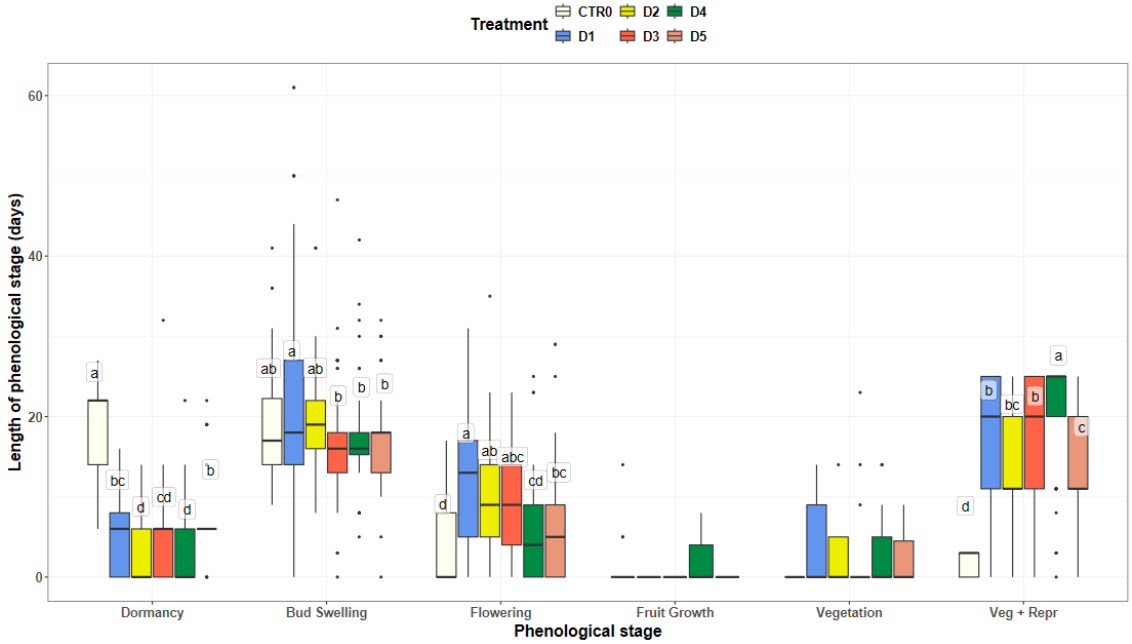

Figure 5 - Duration (in days) of each phenological phase for the different treatments. Different letters within the same phenological stage indicate significant differences between treatments. Treatments which share at least one letter cannot be considered significantly different.

Table 2. Timing of the 'bud swelling' and 'full bloom' phases. The peak refers to the date when the highest percentage of buds was observed in those phenological stages, while the spread refers to the period when more than 50% of the buds with respect to the peak were at that stage (see Supplemental Figure 2).

Treatment	Bud swelling peak	Bud swelling spread	Full bloom peak	Full bloom days before control
Control	Mar 13	Mar 5–Mar 20	Apr 4	0
D1-CPair 40	Feb 11	Feb 11-Feb 17	Feb 27	-38 days
D2-CPair 45	Feb 17	Feb 17–Feb 28	Mar 9	-28 days
D3-CPair 50	Feb 28	Feb 17–Feb 28	Mar 17	-20 days
D4-CPair 55	Feb 28	Feb 17–Feb 28	Mar 17	-20 days
D5-CPair 60	Feb 28	Feb 17–Mar 7	Mar 17	-20 days

Table 3. Timing of full bloom peak (dark blue), bloom spread at 50% of the peak (medium blue) and bloom spread at 25% of the peak (light blue), for the different treatment (see figure 2 of supplemental material for explanation of how the peak, 50% spread and 25% spread were selected).

	February			**March**				**April**	
	week 2	week 3	week 4	week 1	week 2	week 3	week 4	week 1	week 2
D1			Feb 27						
D2					Mar 9				
D3						Mar 17			
D4						Mar 17			
D5						Mar 17			
CTR								Apr 4	

Differences in the leaf-to-flower ratio were not statistically significant, but we observed a trend with *p-values* slightly above 0.05 (almost significant). D5 had a very high leaf-to-flower ratio during bloom, followed by D4. This could reflect a negative effect of the late spray. D3 had a very low value for this parameter. Fruit color analysis showed that fruits from all sprayed trees ripened earlier than the Control. Among the sprayed trees, D4 advanced ripening the most, and D1 the least. This could be the consequence of higher temperatures during early fruit development stages, which is known to advance ripening as demonstrated in peach (Lopez and Dejong, 2007).

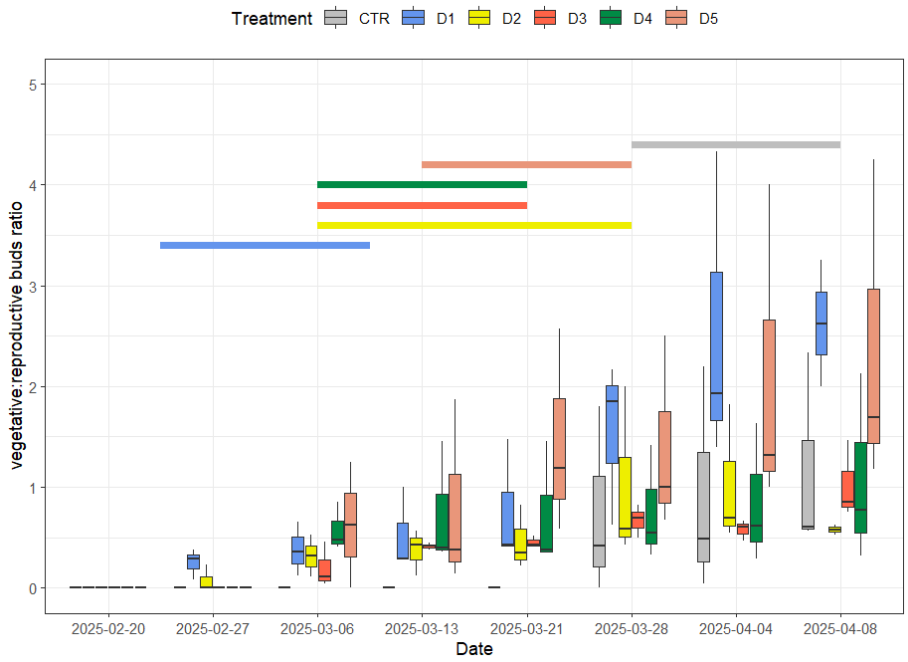

Figure 6. Ratio between the number of vegetative and reproductive buds. The higher the values, the higher the proportion of leaves versus flowers and fruits. Horizontal bars represent the timing of 'bud swelling' plus 'full bloom' as specified in Table 3.

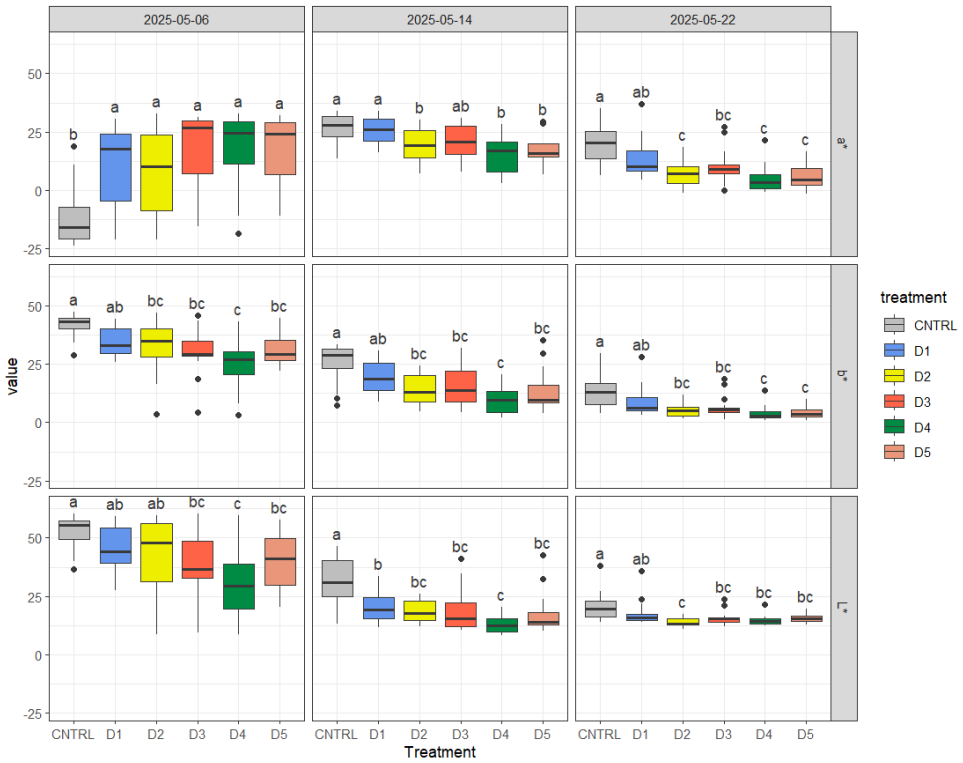

Figure 7. Color values (a*, b*, L*) in the CIELAB scale for lateral and top sides of cherries from the different treatments on different days. Different letters indicate a significant difference among treatment within the same date. L* represents the lightness or darkness, ranging from 0 (black) to

100 (white). a:* positive values indicating red and negative values indicating green. b:* positive values indicate yellow and negative values indicate blue (see Supplemental Figure 3 for further explanation).

Non-structural carbohydrates and dormancy-breaking agent application

Twig samples were collected from trees corresponding to all the treatments at periodic intervals for analysis of their non-structural carbohydrate (NSC) content. For simplicity, we are reporting only the data we found most relevant. In the following two graphs, we show the effect of Dormex application at different times on starch and sugar concentration in the wood (**Figures 8 and 9**). We found that Dormex application consistently caused an increase in starch and a drop in sugars, observed generally one week (maximum 2) after the spray in all treatments, and sugars dropped just slightly below 40 mg/g. We also observed a simultaneous drop in sugar (below 30 mg/g) and starch (below 20 mg/g) in the week before bloom that could be a bloom trigger. While these observational patterns are encouraging and very consistent, they could be affected by year-specific environmental patterns. This is why it is essential to have more years of data followed by a sound statistical analysis to drive final conclusions.

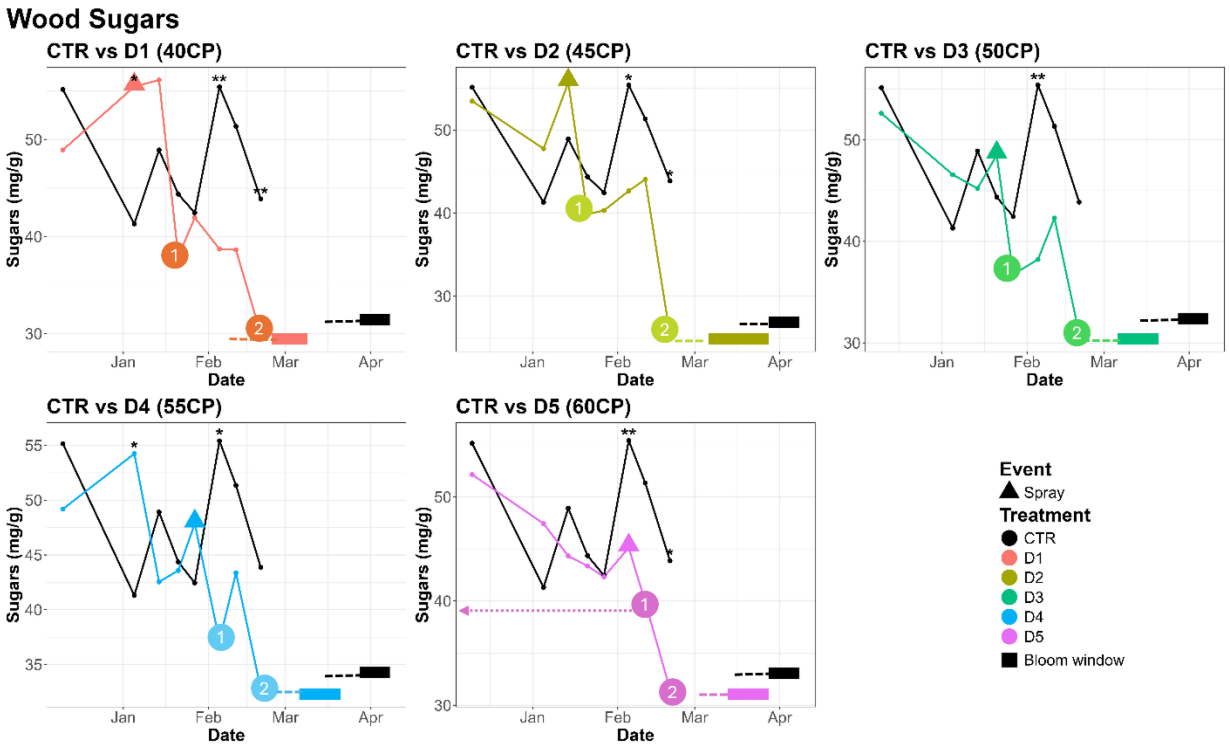

Figure 8. Effect of Dormex spray timing on sugar concentration in the wood of cherry trees. The dark line represents the non-sprayed control, while colored lines represent Dormex-treated trees. Each panel corresponds to a different Dormex application timing. Triangles indicate the dates of Dormex application. Asterisks denote sampling dates on which treated trees were significantly different from the control. Bars on the lower right indicate the full bloom period. The dashed line represents the bud-swelling stage. Numbered circles highlight developmental stages 1, 2, and 3, as described in the text.

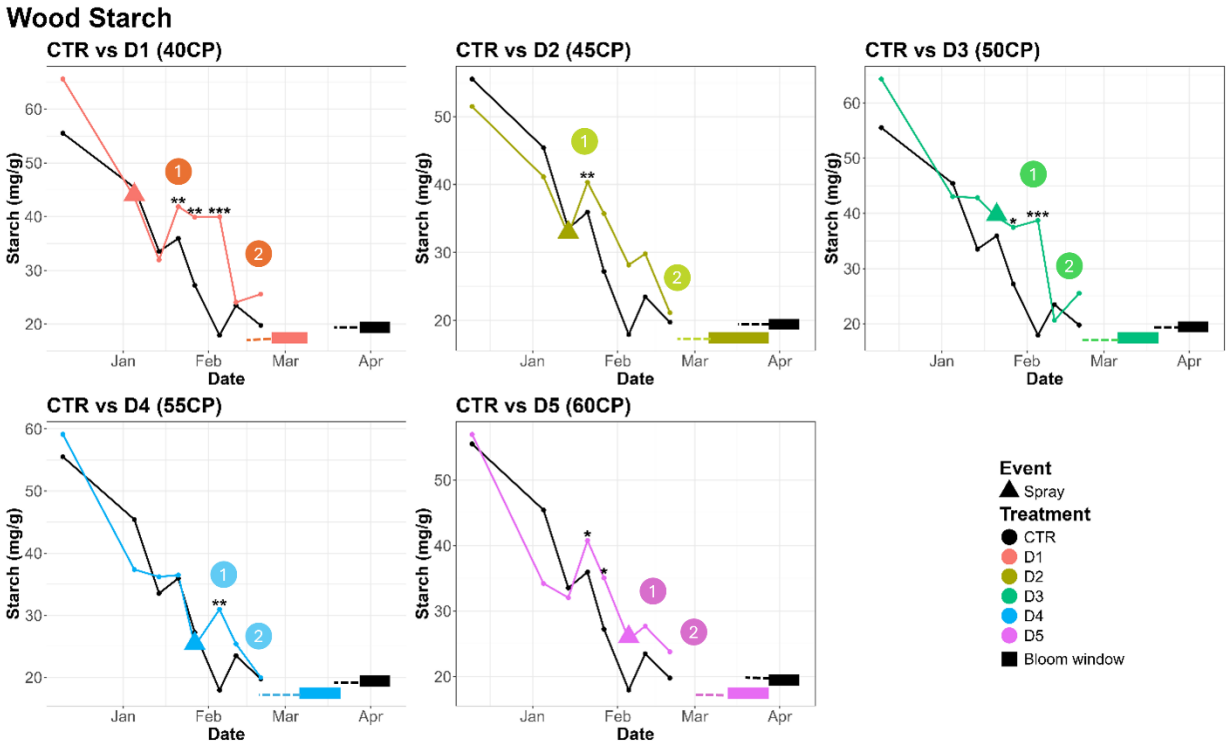

Figure 9. Effect of Dormex spray timing on starch concentration in the wood of cherry trees. The dark line represents the non-sprayed control, while colored lines represent Dormex-treated trees. Each panel corresponds to a different Dormex application timing. Triangles indicate the dates of Dormex application. Asterisks denote sampling dates on which treated trees were significantly different from the control. Bars on the lower right indicate the full bloom period. The dashed line represents the bud-swelling stage. Numbered circles highlight developmental stages 1, 2, and 3, as described in the text.

3.3. Objective 3: Characterize chill requirements of new cherry varieties in CA

Methods: We identified commercial orchards with the cultivars 'Brooks', 'Coral', 'Royal Hazel', 'Royal Lynn', 'Royal Lee', 'Rainier', and 'Black Pearl' in the south SJ Valley. The chill requirements of the selected cultivars were evaluated starting in mid-January. We collected 5 branches of about 15 inches from the orchards weekly and placed them in a controlled environment growth chamber simulating spring. After 3, 6 and 10 days, we monitored bloom in three spurs per branch. Bud phenological stage was annotated and different levels of chill satisfaction were assigned based on how fast more than 50% of the buds had reached or passed the BBCH stage of 53 ('bud swelling'; less conservative approach based on Vimont et al., 2021) or the BBCH stage of 55 ('bloom'; more conservative approach based on Alburquerque et al., 2008). Three chill fulfillment levels were assigned and named as 'maximum', 'good' and 'partial' (Supplemental Figure 4):

1. 'Maximum' chill fulfillment, when full bloom is observed after 3 days in the growth chamber (dark color in **Table 4**)
2. 'Good' chill fulfillment, when bud swell is observed after 3 days in the growth chamber or full bloom after 9 days (medium color in **Table 4**).

3. ‘Partial’ chill fulfillment, when bud swell was observed after 10 days in the growth chamber (light color in **Table 4**).

Results: ‘Royal Lee’ showed the lowest chill requirements, followed tightly by ‘Royal Lynn’ with chill satisfaction starting in mid-January and completing at the beginning of February. ‘Black Pearl’ followed them, and satisfied chill one week after them. ‘Ranier’ and ‘Royal Hazel’ were in the third tier. These cultivars were able to satisfy chill between the first week of February and February 20th. ‘Coral’ and then ‘Brooks’ reached chill satisfaction between February 7 and February 28, and they never achieved bloom in only three days (**Figure 6, Tables 3 and 4**).

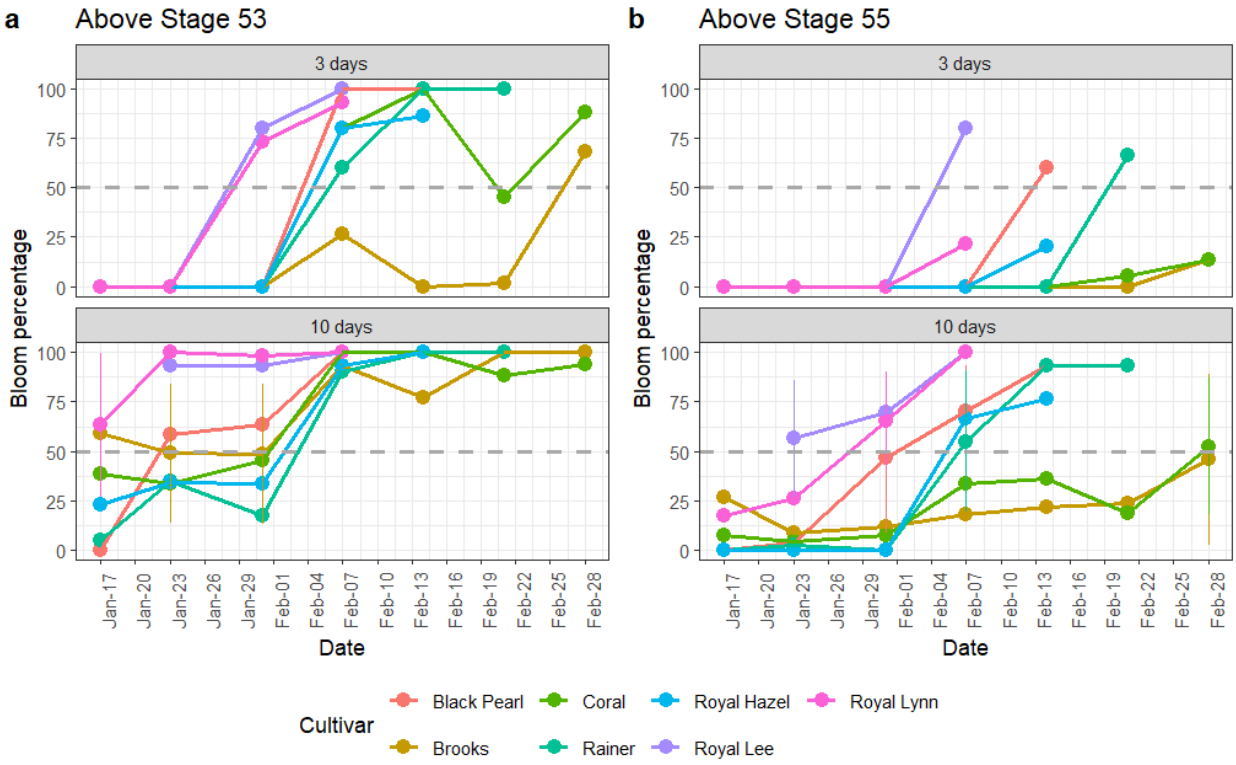

Figure 10. Percentage of buds at ‘bud swelling’ (left, BBCH stage 53 or above), or at ‘full bloom’ (right, BBCH stage 55 or above), after 3 and 10 days in the growth chamber for the different cherry cultivars. The horizontal dashed line represents the threshold for 50% of buds monitored.

Table 4. Timing of the chill fulfillment based on 50% of the buds reaching Stage 55 or 53, and corresponding Air and Tree Chill accumulation (see Supplemental Figure 4 for explanation).

Cultivar	Dormancy break (stage 55)	Air Chill	Tree Chill	Dormancy break (stage 53)	Air Chill	Tree Chill
Royal Lee	Jan 23-Feb7	46-51	36-42	Jan 17-jan 31	40-50	33-40
Royal Lynn	Jan 31- Feb 10	50-54	40-43	Jan 17-jan 31	40-50	33-40
Black Pearl	Jan 31- Feb 13	50-56	40-45	Jan 23- Feb 7	46-51	36-42
Rainier	Feb 7-Feb 20	51-60	42-45	Feb 7	51	42
Royal Hazel	Feb 7-Feb 20	51-60	42-45	Feb 7	51	42
Coral	Feb 28- NA	over 60	46	Feb 7	51	42
Brook	Feb 28- NA	over 60	46	Feb 7 – Feb 28	51-60	42-46

Table 5. Timing of chill fulfillment for each cultivar, and corresponding chill accumulation until that time. The dark, medium and light color refers to what we defined as 'maximum', 'good' and 'partial' chill fulfillment, respectively (see Supplemental Figure 4 for explanation of the chill fulfillment levels).

	January		February			
	week 3	week 4	week 1	week 2	week 3	week 4
Royal Lee						
Royal Lynn						
Black Pearl						
Rainier						
Royal Hazel						
Coral						
Brooks						
Air Chill (CP)	40	46	50	51	60	60
Tree Chill (CP)	33	36	40	42	46	46

4. EXPECTED OUTCOMES

We are developing updated spray timing protocols for cherry based not only on empiric chill portion calculations but also integrating the effects of radiation on tree temperature ('TreeChill') and real-time monitoring of dormancy stages through changes in non-structural carbohydrate (NSC) concentrations. Growers will be able to better time the spray of dormancy-breaking agents' application across years with different weather conditions. Optimal spray time based on 'TreeChill' and NSC will ensure early and compact bloom and fruit ripening, and sustained yields under erratic weather, which can increase growers' income.

5. CONCLUSION

Additional years of data and further analyses are required before drawing definitive conclusions, as weather during bloom and fruit development can strongly influence treatment responses. However, preliminary results from the 2025-2026 season indicate several important trends.

1. Dormex application significantly altered NSC dynamics in a consistent manner across spray timings, suggesting a strong link between Dormex effects on bloom and underlying winter NSC metabolism.
2. We developed the first draft of a NSC winter dynamic prediction model. Although model performance needs to be tested on different years and locations and further improved, this represents an important first step toward making NSC a practical, grower-accessible decision variable.
3. Early Dormex applications resulted in prolonged bloom, while late applications increased the leaf-to-flower ratio during bloom. In this first year, application at 50 chill portions produced the best overall response and advanced bloom by 18 days relative to non-

treated trees. Additional years and refined physiological indicators are needed to drive conclusions.

4. Chill requirements differed substantially among cultivars, with Royal Lee and Royal Lynn showing the lowest chill requirements, followed by Black Pearl, then Rainier and Royal Hazel, and finally Coral and Brooks exhibiting the highest chill requirements.

Literature cited

Alburquerque, N., García-Montiel, F., Carrillo, A., Burgos, L., 2008. Chilling and heat requirements of sweet cherry cultivars and the relationship between altitude and the probability of satisfying the chill requirements. Environ. Exp. Bot. 64, 162–170. https://doi.org/10.1016/j.envexpbot.2008.01.003

Bound, S.A., Foo, E., Gélinas-Marion, A., Nichols, D.S., Nissen, R., 2022a. The Impact of Dormancy Breakers on Hormone Profiles, Fruit Growth and Quality in Sweet Cherry. Agriculture 12, 270. https://doi.org/10.3390/agriculture12020270

Charrier G, Lacointe A, Améglio T. 2018. Dynamic modeling of carbon metabolism during the dormant period accurately predicts the changes in frost hardiness in walnut trees Juglans regia L. Frontiers in Plant Science 9, 1746. https://doi.org/10.3389/fpls.2018.01746

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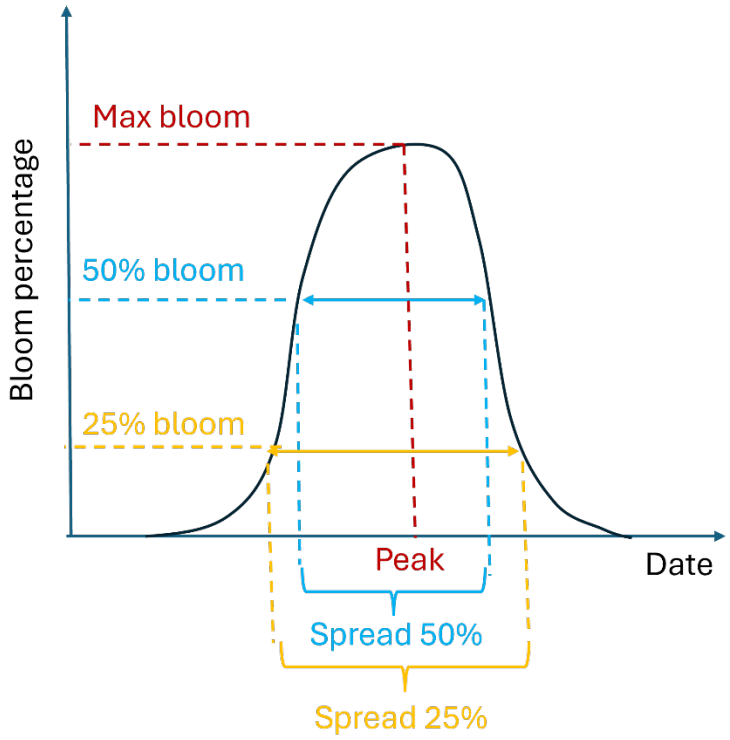
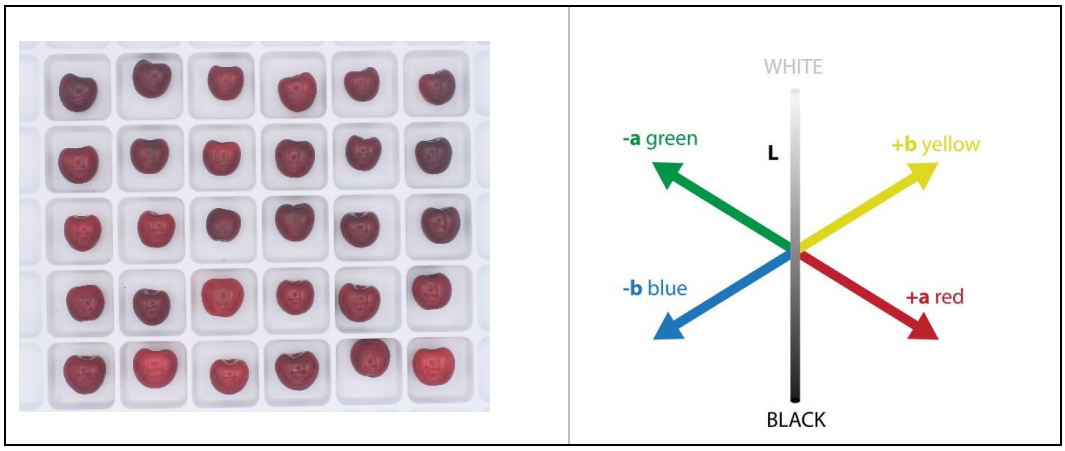
SUPPLEMENTAL INFORMATION

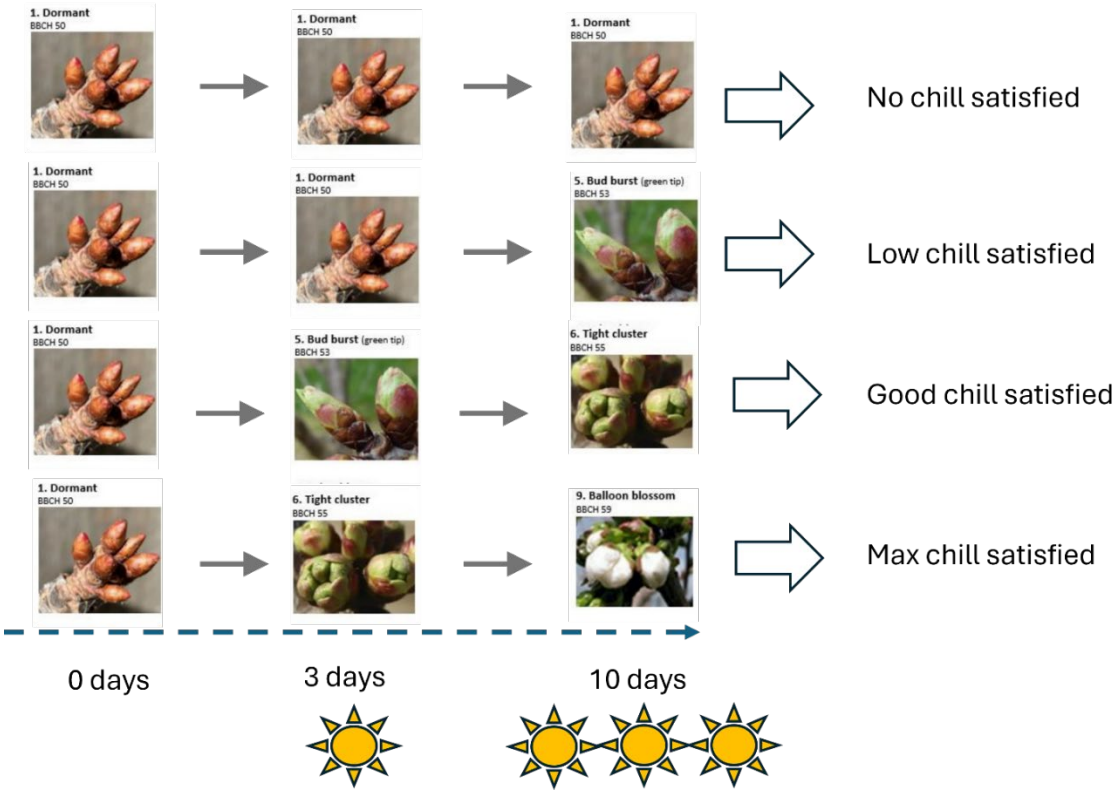
Supplemental Figure 1. Stage of bloom in the BCHH scale from Bound et al., 2022



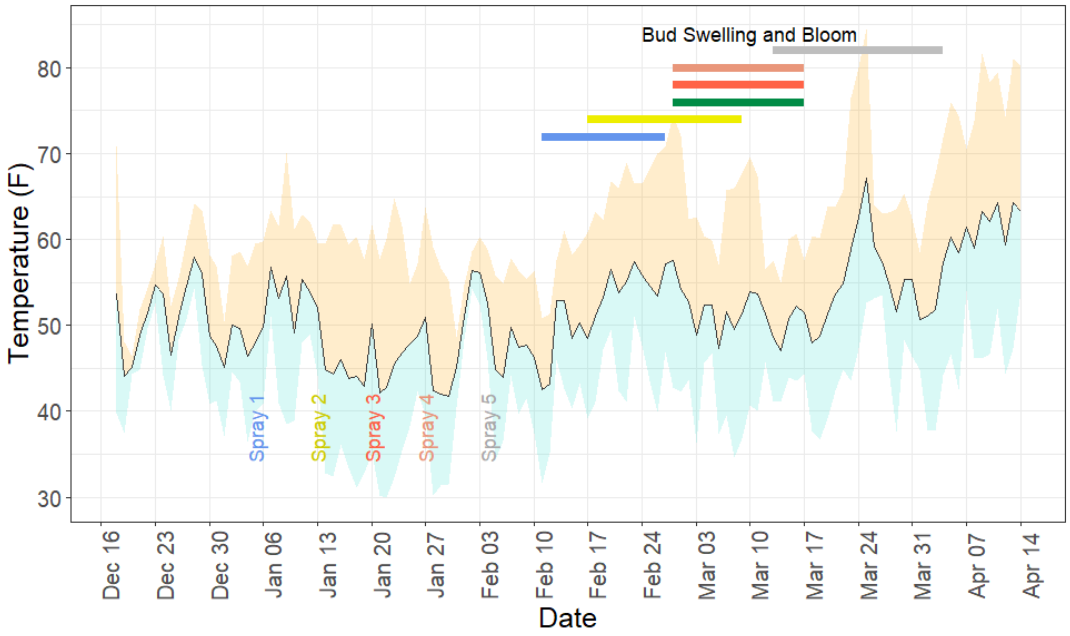
Supplemental Figure 2. Visual description of the bloom peak, bloom spread 50% of peak and bloom spread 25% of peak



Supplemental Figure 3. Example of cherry picture used to detect the color (left) and typical diagram of color values (a*, b*, L*) in the CIELAB scale (right).



Supplemental Figure 4. Schematic explanation of different levels of chill fulfillment based on the response of dormant buds to heat exposure in the growth chamber.



Supplemental Figure 5. Mean air temperature (black line surrounded by light blue and light orange areas, representing daily maximum and minimum temperature) during the experimental period. Spray time is reported as text of different colors (control = grey, D1 = blue, D2= yellow, D3 = red, D4 = green, D5 = orange). Horizontal bars represent the timing of bud swelling plus full bloom as specified in Table 3.

Innovative solutions to improve winter chill accumulation and dormancy breaking in California Cherry orchards

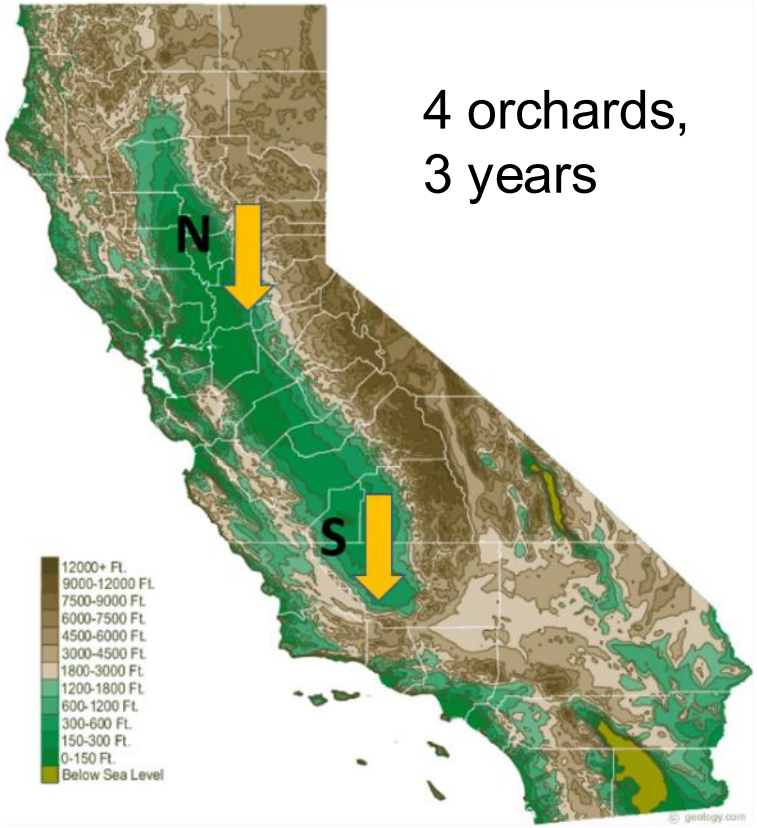
Giulia Marino, Paula Guzman-Delgado, Mohammad Yaghmour

Emilio Laca, Andy Lyon, Breanna Pool, Amrit Pokhrel, Aileen Salas, Tommy Ngo, Kaya Kurtz, Pedro Gonçalves, Barbara Blanco-Ulate, Erick Espinoza Núñez

Objectives:

1. Improve the efficacy of dormancy-breaking agent applications by optimizing application timing
    - Climate change
    - New varieties
    - Regulations
2. Using tree-based information of dormancy progression and chill accumulation

Phase 1: develop a new framework for chill accumulation in California cherry



4 orchards,
3 years

Measurements:

- Tree bark temperature
- Phenology (bloom and senescence)
- weather parameter
- Twigs non-structural carbohydrates (NS): starch and sugars in wood and bark

Historical chill portion (CP) accumulation: 70 (S) – 80 (N)

Contents lists available at ScienceDirect

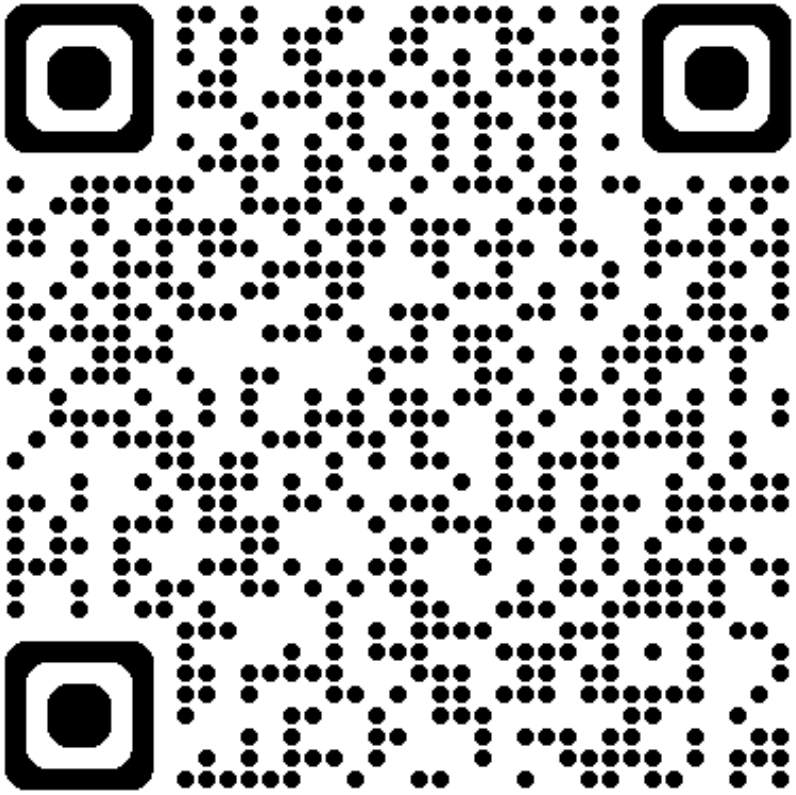
Agricultural and Forest Meteorology

journal homepage: www.elsevier.com/locate/agrformet

The TreeChill model: A new framework for predicting the impact of erratic winter weather on trees

Paula Guzmán-Delgado [a,*], Emily Santos [a], Mohammad Yaghmour [b], Emilio A. Laca [a], Kari Arnold [d], Amrit Pokhrel [a], Kosana Suvočarev [c], Mohamed Nouri [b], Katherine Jarvis-Shean [b], Louise Ferguson [a], Aileen Salas [a], Daniel Ruiz [a], Giulia Marino [a,*]

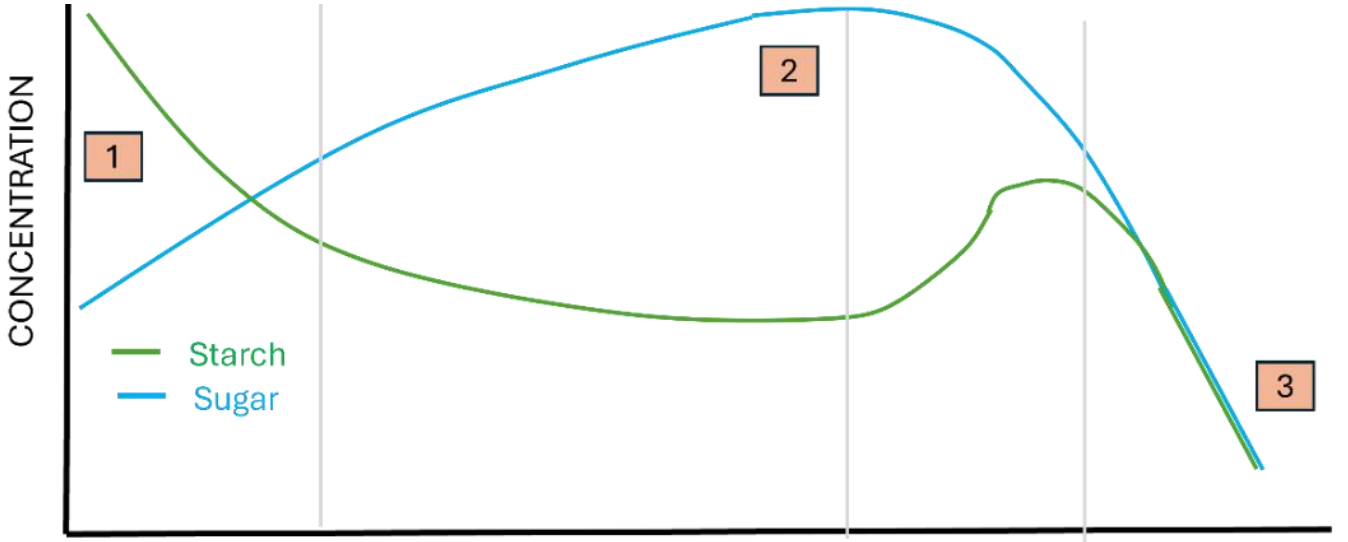
Online TreeChill calculator for Cherry:



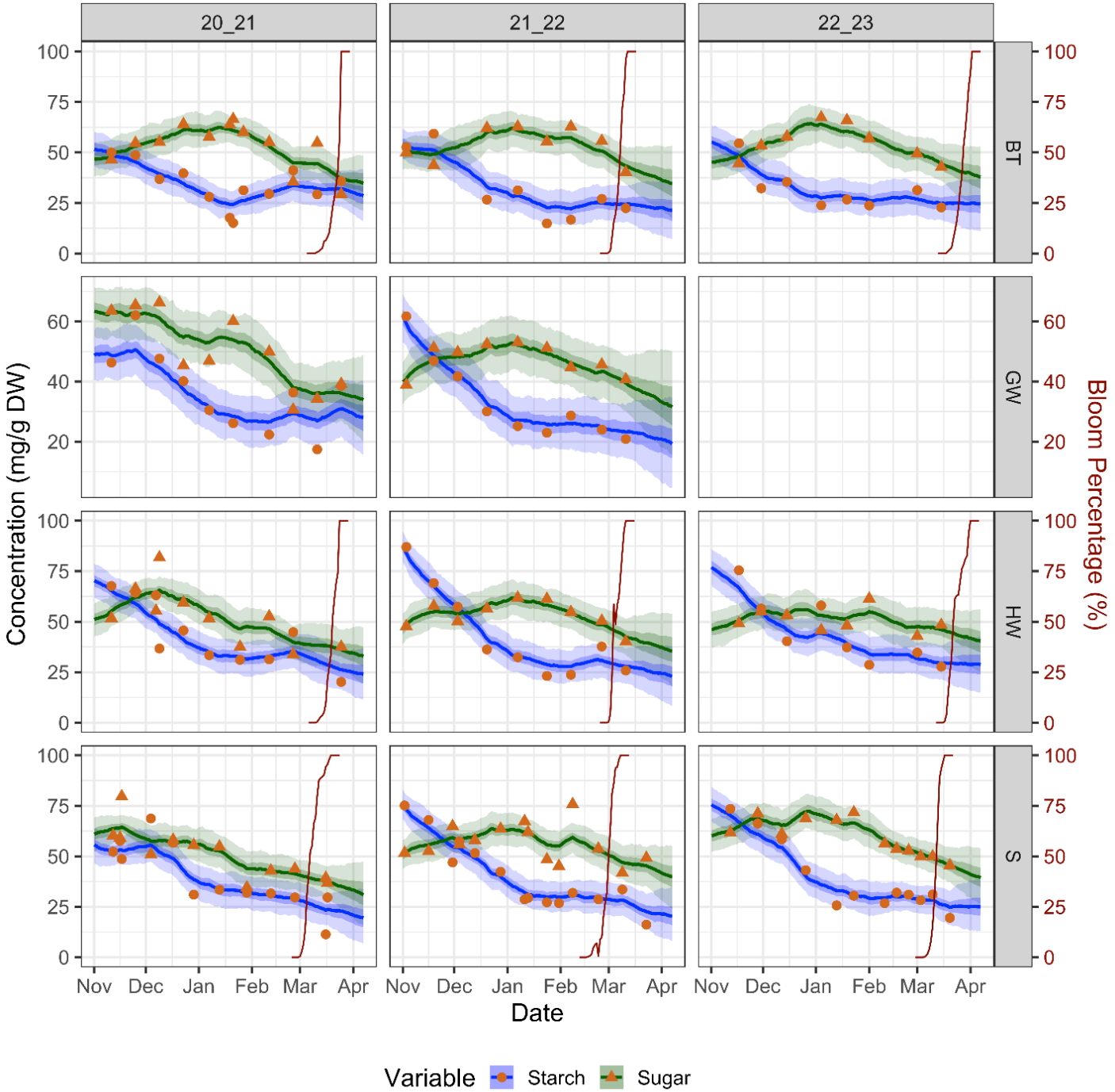
First year running we strongly welcome feedbacks!

- **Cherry Chill R Package (to be published before sharing)**
- **Cherry Chill Shiny App:** https://ucanr-igis.shinyapps.io/cherrychill/
- **Cleaned CIMIS Dashboard:** https://ucanr-igis.shinyapps.io/cleancimis_stats/

NSC Dynamics used to characterize dormancy progression



	WINTER PROGRESSION		
Paradormancy	Endodormancy	Ecodormancy	Bloom
Sugar ↗	Sugar →	Sugar ↘	Sugar ↘
Starch ↘	Starch →	Starch ↗	Starch ↘

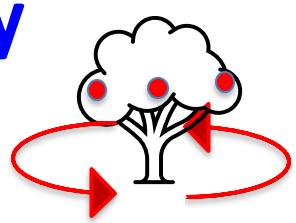

20_21
21_22
22_23
BT
GW
HW
S
Concentration (mg/g DW)
Bloom Percentage (%)
Nov
Dec
Jan
Feb
Mar
Apr
Date
Variable
Starch
Sugar

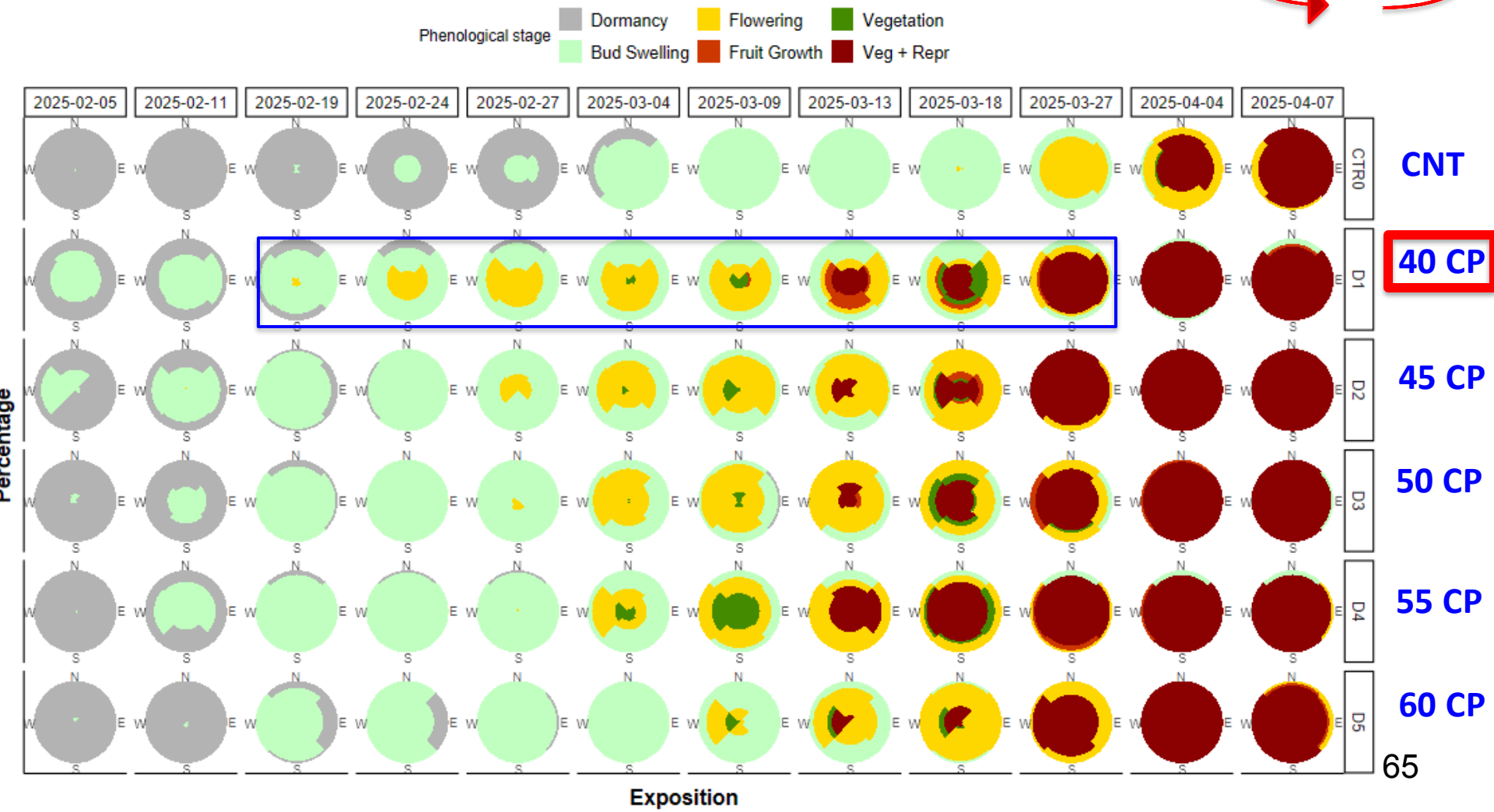
Phase 2- apply dormancy breaking agents based on the new framework – Year 1 = Dormex

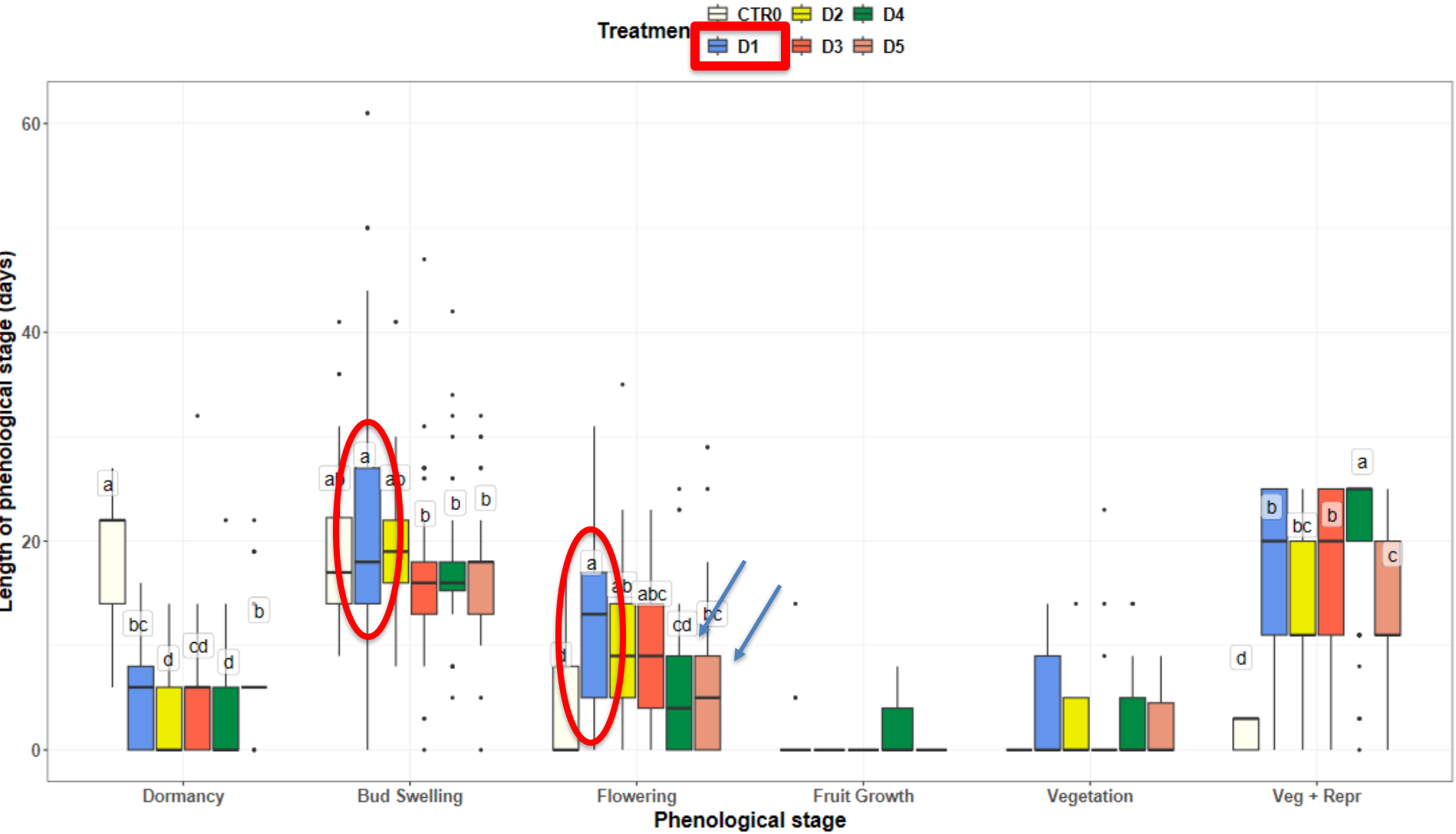
Treatment	Spray date	Air Chill portions	Tree Chill portions
D1	January 6	40	35
D2	January 14	45	40
D3	January 21	50	44
D4	January 28	55	48
D5	February 5	60	52
CTR	-	-	-

Objective 1 – Year 1 results for Dormex application

Bloom variability across tree canopy



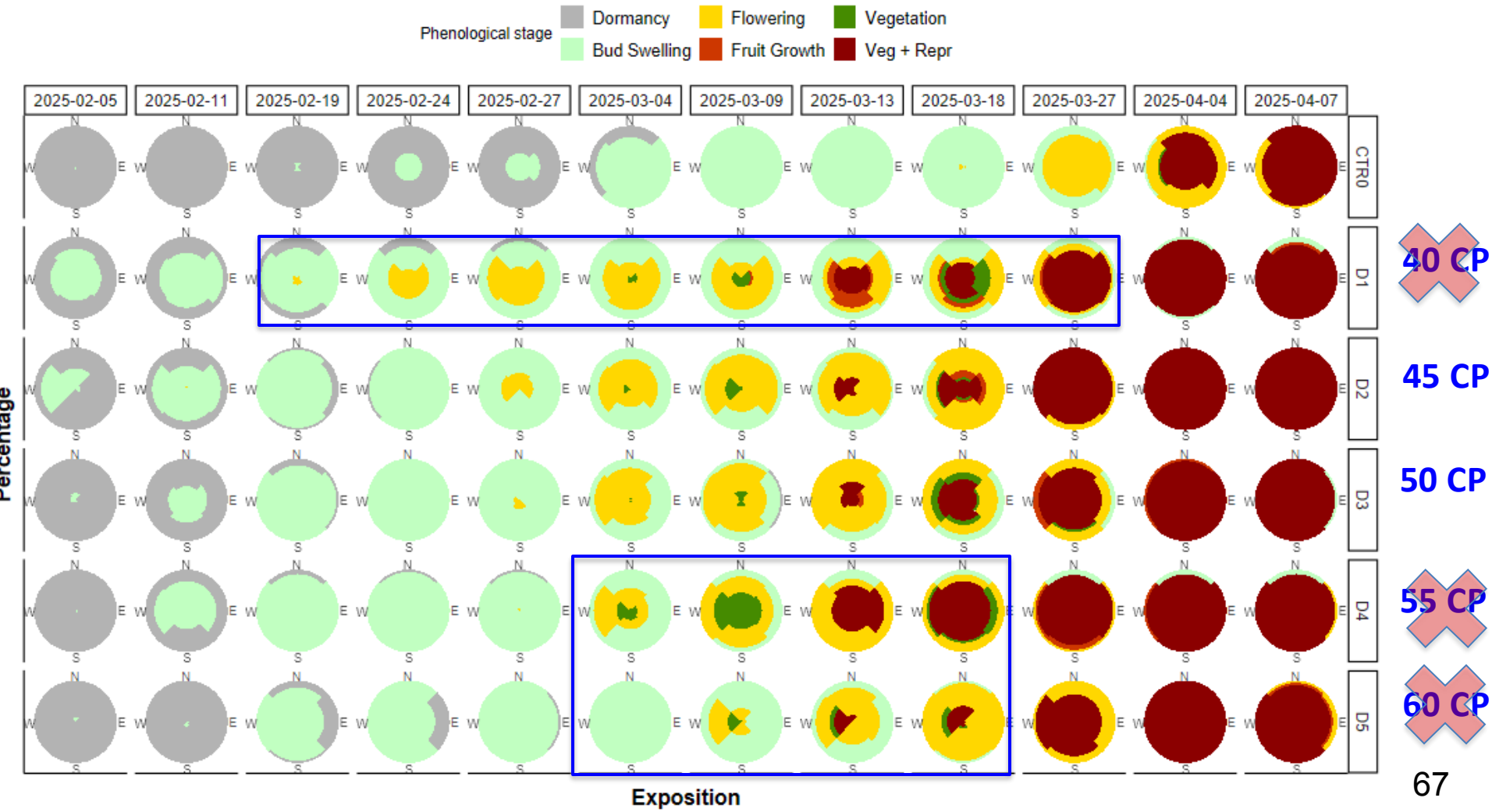


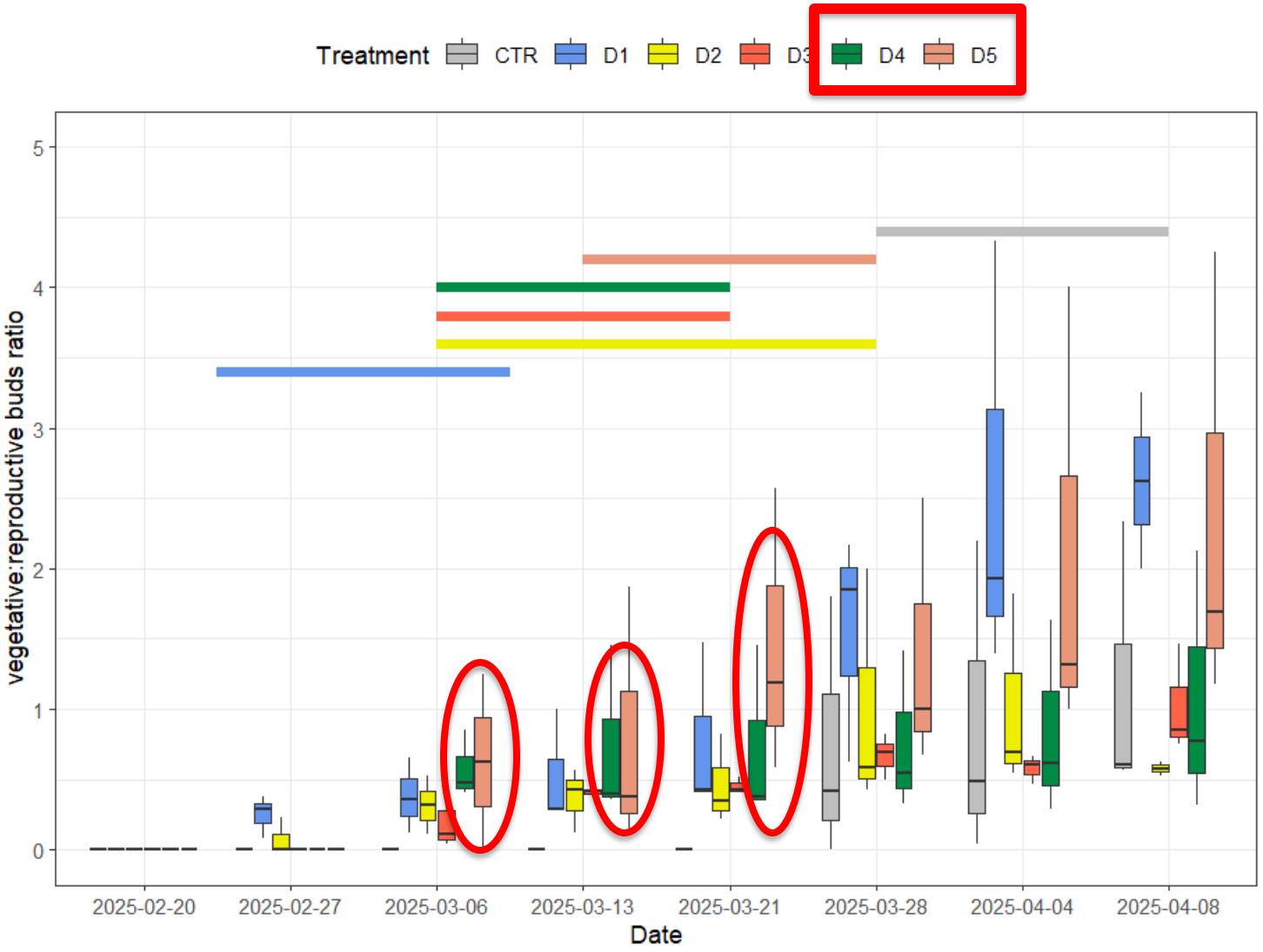


D1 (40 CP) had the earliest but most protracted bloom

D4 and D5 (55 and 60 CP) had very compacted bloom

Bloom variability across tree canopy

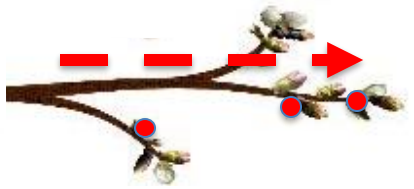


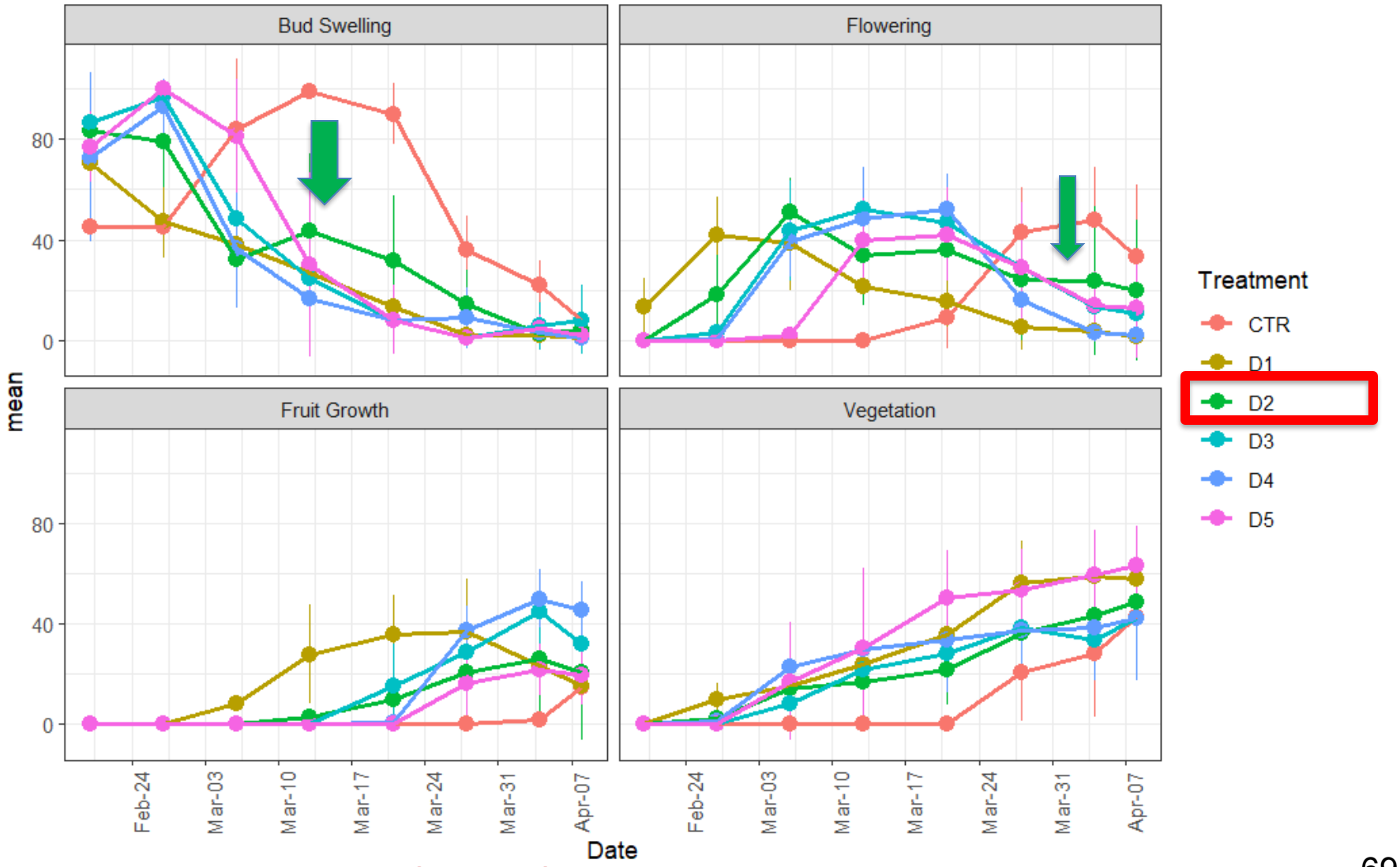


D4 and D5 (55 and 60 CP) had higher vegetative growth during early bloom

D3 (50 CP) had the lowest vegetative growth during early bloom

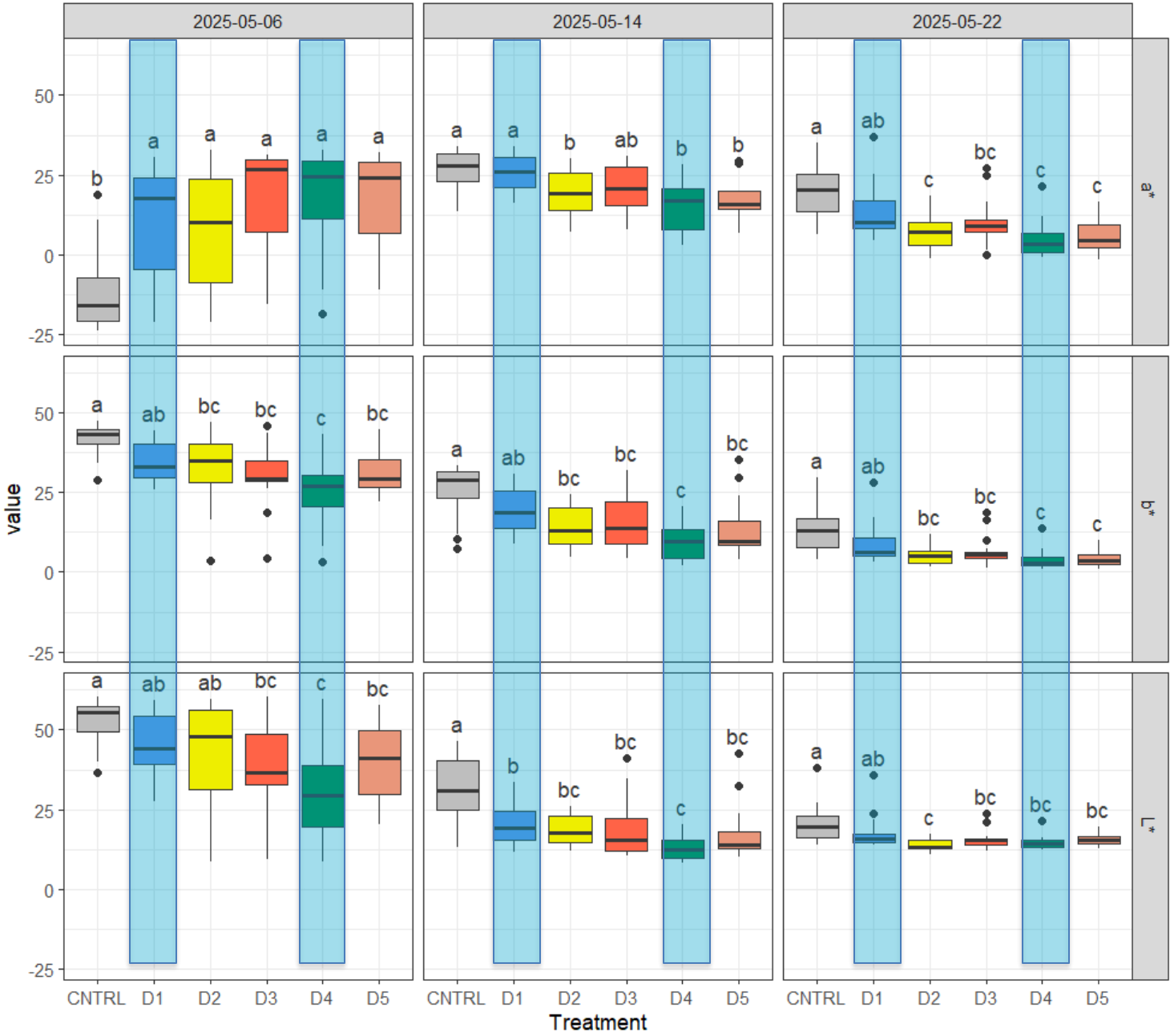
Bloom variability within branch



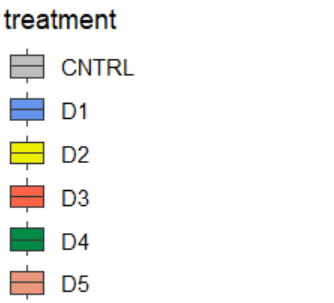


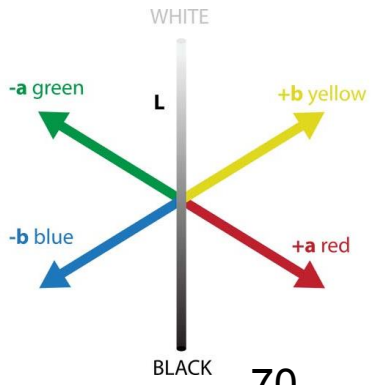
D2 (45 CP) had a spread full bloom

Fruit ripening progression



Red-green



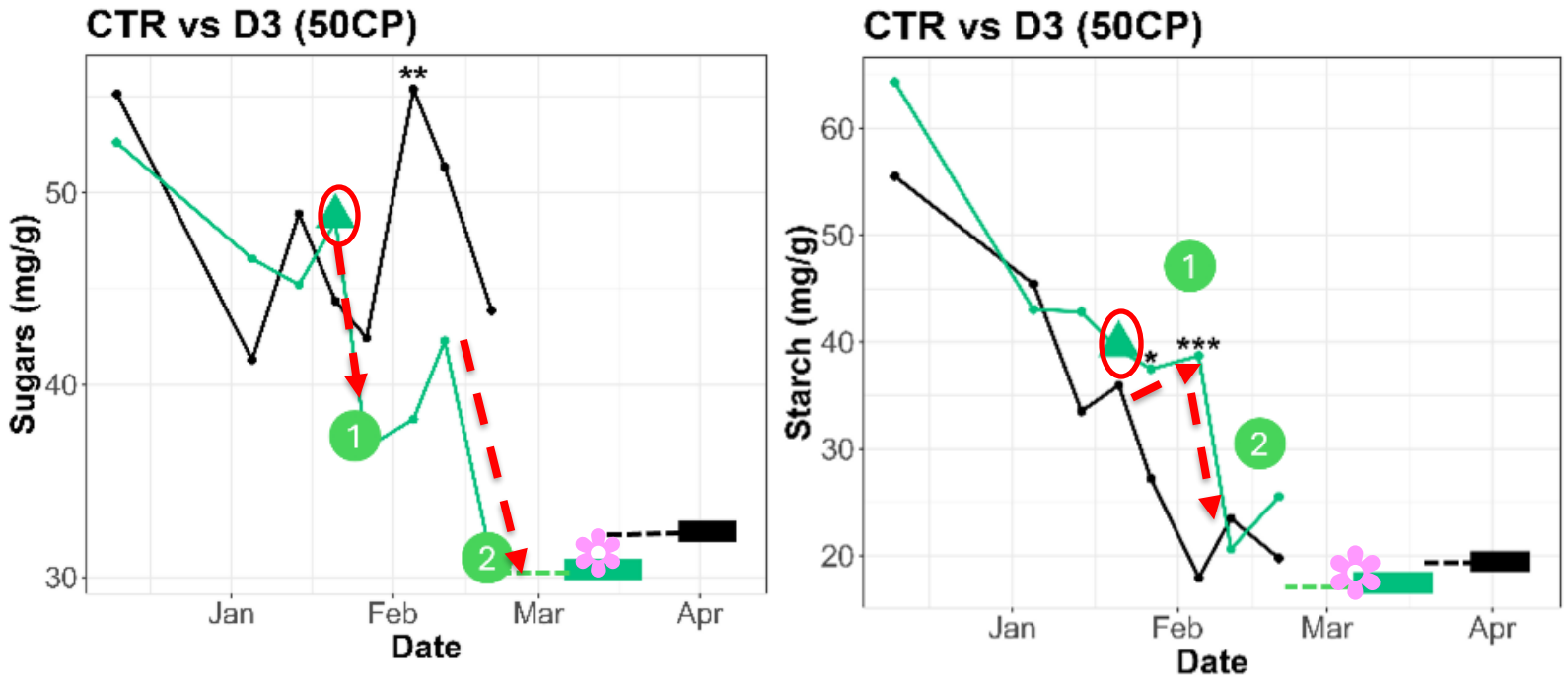


Summary

		February			March				April	
		week 2	week 3	week 4	week 1	week 2	week 3	week 4	week 1	week 2
X	D1			Feb 27						
X	D2					Mar 9				
V	D3						Mar 17			
X	D4						Mar 17			
X	D5						Mar 17			
	CNTR								Apr 4	

Treatment	Spray date	Air Chill portions	Tree Chill portions
D1	January 6	40	35
D2	January 14	45	40
D3	January 21	50	44
D4	January 28	55	48
D5	February 5	60	52
CTR	-	-	-

Dormex impact on NSC



All spray times show a sugars decrease and a starch increase after application, similar to what observed in natural condition in our original statewide trial

Cultivars chill requirement characterization

	January		February			
	week 3	week 4	week 1	week 2	week 3	week 4
Royal Lee						
Royal Lynn						
Black Pearl						
Rainier						
Royal Hazel						
Coral						
Brooks						
Air Chill (CP)	40	46	50	51	60	60
Tree Chill (CP)	33	36	40	42	46	46

Thank for your support and trust

Questions, please.

TREE SYSTEMS LAB

UC DAVIS

California Cherry Board

Rijal, Jhalendra

"Evaluation of Methyl Benzoate as Oviposition Deterrent & Repellent Against Spotted Wing Drosophila in Cherry Orchards"

CALIFORNIA CHERRY BOARD
RESEARCH REPORT

Institution/Organization: University of California Cooperative Extension-Stanislaus County

Project Year: 2025-26

Principal Investigator(s): Jhalendra Rijal, jrijal@ucanr.edu

Cooperating Personnel: Samaneh Sakaki (UCCE Stanislaus), Flint McGrath (UCCE Stanislaus), Aijun Zhang (USDA-ARS, Beltsville, Maryland)

Project Title: Evaluation of Methyl Benzoate as Oviposition Deterrent & Repellent against Spotted Wing Drosophila in Cherry Orchards

Background

Spotted Wing Drosophila (SWD), *Drosophila suzukii,* is the major pest insect of sweet cherry and other soft fruits in California. Unlike many other visually similar vinegar flies, SWD has a unique ability to incise the fruit with its serrated ovipositor and deposit eggs on healthy fruits. Larvae feed internally on the fruits, causing damage. The presence of larvae and damage in the fruit may not be realized before it goes into the consumer's hands; therefore, this pest's economic threshold is practically 'zero'. SWD has been established across the United States relatively short period due to its broad host range, high fecundity, and multiple generations per year. Because of the high-risk pest, growers rely on insecticide applications to control SWD. The most common insecticides for SWD management in California cherries are pyrethroid and spinosyn products. Recently, our studies showed good efficacy (Rijal et al. 2020) for a few diamide products (cyclaniliprole, cyantraniliprole) and added them to the list of rotational products, https://ipm.ucanr.edu/agriculture/cherry/spotted-wing-drosophila/#gsc.tab=0. Still, their use has not been widely adopted due to the higher costs associated with these products.

For SWD control, insecticides are applied several times during the ripening period (from straw-colored fruit stage to harvest) when cherry fruits are most susceptible. However, repeated use of these insecticides can have several negative consequences, including pest resistance, impacts on natural enemy populations, and potential outbreaks of secondary pests, such as scale insects (Rijal et al., 2016). Frequent use of the same insecticide active ingredient can compromise its efficacy if SWD builds resistance to it. SWD has developed resistance to spinosad and pyrethroids in caneberry (i.e., raspberry, blackberry, etc.) and strawberry fields on the central coast (Gress and Zalom 2018, Ganjisaffar et al. 2022a, Ganjisaffar et al. 2022b). One study reported that the LC50 of spinosad on SWD collected from the treated field was up to 7.7-fold higher than in unsprayed fields. Another study (Ganjisaffar et al. 2022b) reported that field-collected SWD populations are resistant to both Type I pyrethroids, including bifenthrin (Brigade 2 EC), and Type II pyrethroids, including zeta-cypermethrin (Mustang Maxx 0.8 EC). In recent years, California growers have reported reduced insecticide efficacy against SWD in

cherry orchards, which could be attributed to increasing tolerance to these commonly used insecticides. Therefore, we tested the potential resistance of SWD populations collected from cherry orchards in the northern San Joaquin Valley and Gilroy area (Santa Clara County). The study (reported in the 2023 Cherry Board Report, Rijal et al. 2023) showed that all four commercial cherry orchards showed higher tolerance levels for two insecticide group ingredients (average 68% SWD mortality on spinosad LC99 x 2 concentration; average 69% SWD mortality on zeta-cypermethrin, LC90 x 8 concentration), while 100% mortality was observed in lab-reared susceptible Wolfskill populations for both insecticides. This considerable discrepancy in mortality between field (68-69%) and susceptible (100%) populations strongly indicated pesticide resistance in field SWD populations.

Given the rise in pesticide resistance, exploring additional approaches to SWD management in cherry orchards is essential. One of the new products tested against many insects, including SWD, in recent decades is Methyl Benzoate (MB) (Mostafiz et al. 2022). Methyl benzoate is a naturally occurring volatile compound commonly found in various plants' essential oils (EOs) (Yang et al. 2020). MB has been approved and used as a flavoring agent for food applications in the United States and the European Union (Feng and Zhang 2017). Studies have demonstrated its efficacy against a range of arthropod pests, including brown marmorated stink bug, diamondback moth, mosquitoes, gypsy moth, and recently spotted wing drosophila (Feng and Zhang 2017, Feng et al. 2018, Mostafiz et al. 2018, 2020). A recent study (Gale et al., 2024) conducted across multiple blueberry orchards on the East Coast found that MB volatiles released from a dispenser reduced fruit damage through its presumed repellency and oviposition deterrent effects against SWD. Therefore, in the 2025 season, we evaluated methyl benzoate to assess its efficacy against SWD in California cherry orchards.

Research Objectives

- To assess the potential for methyl benzoate to function as a repellent and oviposition deterrent to protect the cherry crop from SWD damage
- To disseminate the existing and new research information to cherry growers and pest control professionals using multiple media- presentations, articles, and discussions.

Materials and Methods

Laboratory Experiments

Insect Source and Colony Maintenance. A laboratory colony of spotted wing drosophila (SWD), was established and maintained at the University of California Cooperative Extension–Stanislaus using a Jazzmix-based artificial diet. The diet was prepared by adding 10 g of Jazzmix to 70 mL of distilled water and boiling the mixture for approximately 2 min. The prepared diet was poured into Drosophila rearing vials and allowed to cool overnight. Approximately 10 adult flies (mixed sexes) were introduced into each vial for oviposition. Newly emerged adults were collected from the vials and used to maintain the colony and for subsequent experiments.

Insect and Fruit Preparation for Laboratory Experiments. Adult SWD flies aged 3–8 days were collected from the colony and used in laboratory assays. Cherry fruits were obtained from

local grocery stores and/or U-Pick farms. Fruits were washed thoroughly to remove surface debris and potential contaminants and then air-dried at room temperature for approximately 20 min. Only fresh cherries with intact pedicels and uniform ripeness, determined by visual inspection, were selected for experiments.

Dose–Response Experiment. Laboratory dose–response experiments were conducted using no-choice assays in collapsible insect rearing cages (12 × 12 × 12 inches). Six treatments were evaluated, including five methyl benzoate (MB) doses (200, 500, 1,000, 1,500, and 2,000 µL) and an untreated control (Control). Methyl benzoate (Alpha Scents, Inc., Canby, Oregon) was applied to a cotton ball, which was placed inside a polyethylene bag to serve as a dispenser.

For each treatment, one cage served as an experimental unit, and each treatment was replicated four times. Four repeated trials were conducted over a period of several weeks. Within each cage, a single cherry fruit was suspended, with one MB dispenser positioned adjacent to the fruit using duct tape. To prevent desiccation, each cage contained a petri dish with 30 mL of water saturated with two unrolled cotton balls.

Ten adult SWD flies (five males and five females), aged 3–8 days, were gently introduced into each cage and allowed to oviposit for 24 h. After the exposure period, cherries were collected and examined under a microscope to record oviposition activity, as indicated by oviposition scars on the fruit surface or visible white egg filaments (i.e., respiratory tubes) (Fig. 4).

Statistical Analysis. For the dose–response experiment, oviposition data were analyzed by comparing each MB concentration with the untreated control using pairwise Student's t-tests. Statistical significance was determined at $\alpha = 0.05$.

Fig. 1. Preparing miniature methyl benzoate dispensers and setting up lab experiments

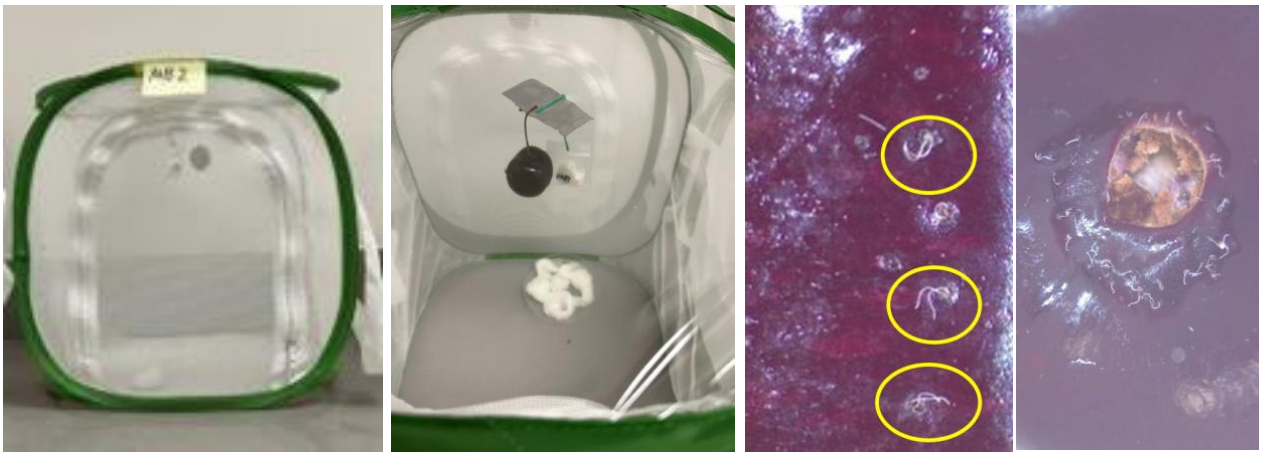


Fig. 2. Showing the final setup of the lab experiment in collapsible cages (left two photos), and SWD oviposition stings indicated by white filaments protruding from the cherry fruit surface (right two photos)

Field Experiments

Study Site and Experimental Design. The field experiment was conducted in a small, unsprayed commercial cherry orchard in the Stockton area, California, to evaluate the repellency of methyl benzoate (MB) against spotted wing drosophila (SWD). The study utilized four orchard rows. Within each row, 50% of the trees were assigned to the MB treatment (Treated), while the remaining 50% served as untreated controls (Control). In total, 46 cherry trees were included in the experiment. Treatments were arranged within each row to minimize positional effects.

Methyl Benzoate Dispensers and Deployment. Methyl benzoate dispensers were purchased from Alpha Scents, Inc. (Canby, Oregon). Each dispenser is a polyethylene pouch containing 100 mL of methyl benzoate and is designed for manual deployment in the orchard. MB dispensers were hung near cherry fruit clusters in medium-sized cherry trees at a rate of five dispensers per tree. Dispenser deployment occurred on 5 May, at the beginning of the fruit-ripening period. During the experiment period, dispensers that became broken or dried were replaced as needed to maintain consistent treatment exposure.

Fruit Sampling and Evaluation. From 27 May to 16 June, fruit sampling was conducted at regular intervals. From each row, 4-5 ripe fruits were randomly collected from both the Treated and Control trees during each sampling event. Collected fruits were transported to the laboratory in a cooler with an ice pack to preserve fruit quality during transport. In the laboratory, fruits were examined under a microscope to assess SWD oviposition by recording the presence and number of oviposition stings.

Statistical Analysis. The number of SWD oviposition stings per fruit was used as the primary response variable to evaluate treatment effects. Fruits collected from all four rows were combined for data analysis. Data were analyzed using a one-way analysis of variance (ANOVA) to compare oviposition between MB-treated and Control trees. Orchard row was considered the experimental unit. Statistical significance was determined at $\alpha = 0.05$

Fig. 3. Methyl benzoate dispensers installed in a cherry tree

Results

Laboratory Experiment Results

Five different rates of methyl benzoate were compared with an untreated control in laboratory bioassays to assess their effects on SWD oviposition. The highest mean number of ovipositions per fruit was observed in the control group (18.8 ± 3.5) (Fig. 4). Increasing the concentration of methyl benzoate led to a general reduction in egg-laying activity. Specifically, rates of 500 µL, 1000 µL, and 2000 µL significantly decreased oviposition compared to the control ($P<0.05$), with the lowest mean recorded at the 500 µL rate (10.8±1.5). While the 200 µL and 1500 µL treatments showed a downward trend in oviposition, they were not statistically different from either the control or the higher-dose groups (Fig. 4).

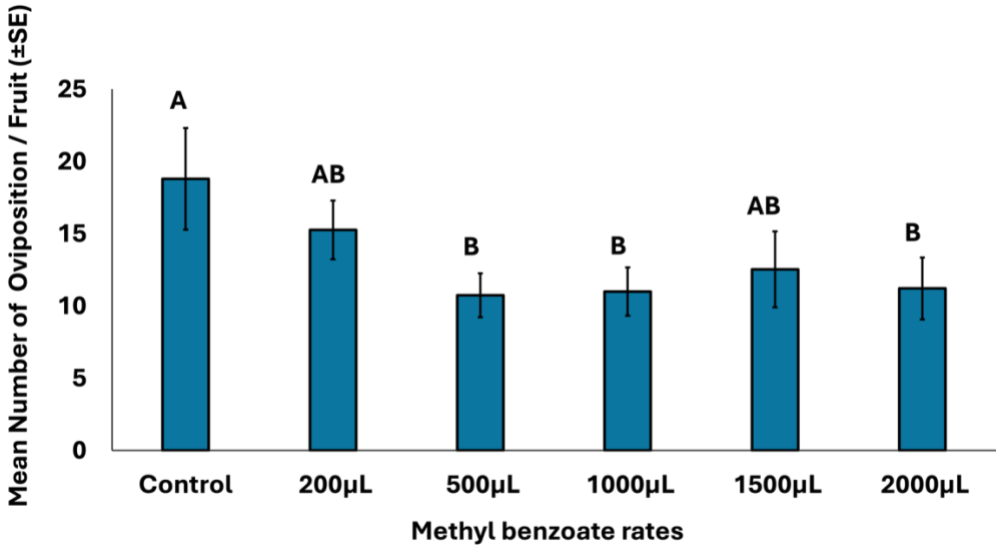


Fig. 4. SWD oviposition rates in cherries treated with five doses of methyl benzoate and an untreated control in a laboratory assay. Same letters on top of the bars indicate no statistical difference.

Field Experiment Results

When all data from all sampling collection dates were combined, the mean oviposition stings per fruit in MD-treated fruits were significantly (F = 8.137, p = 0.005) lower compared with the untreated control (Fig. 5).

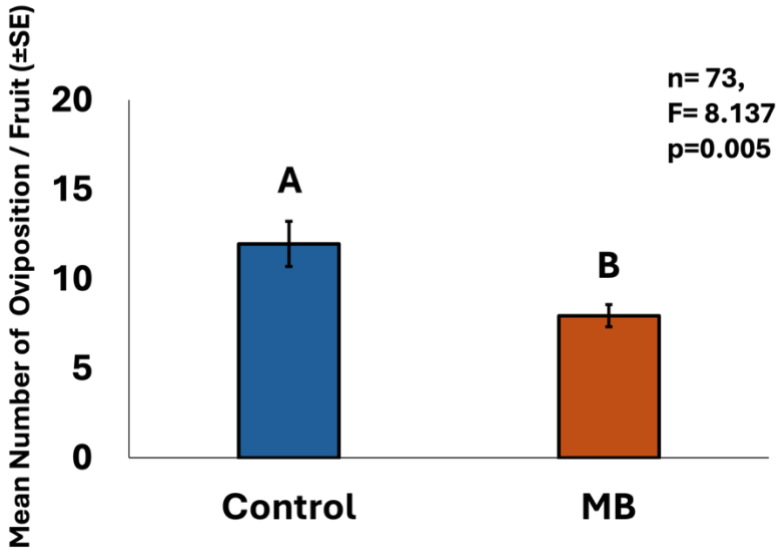
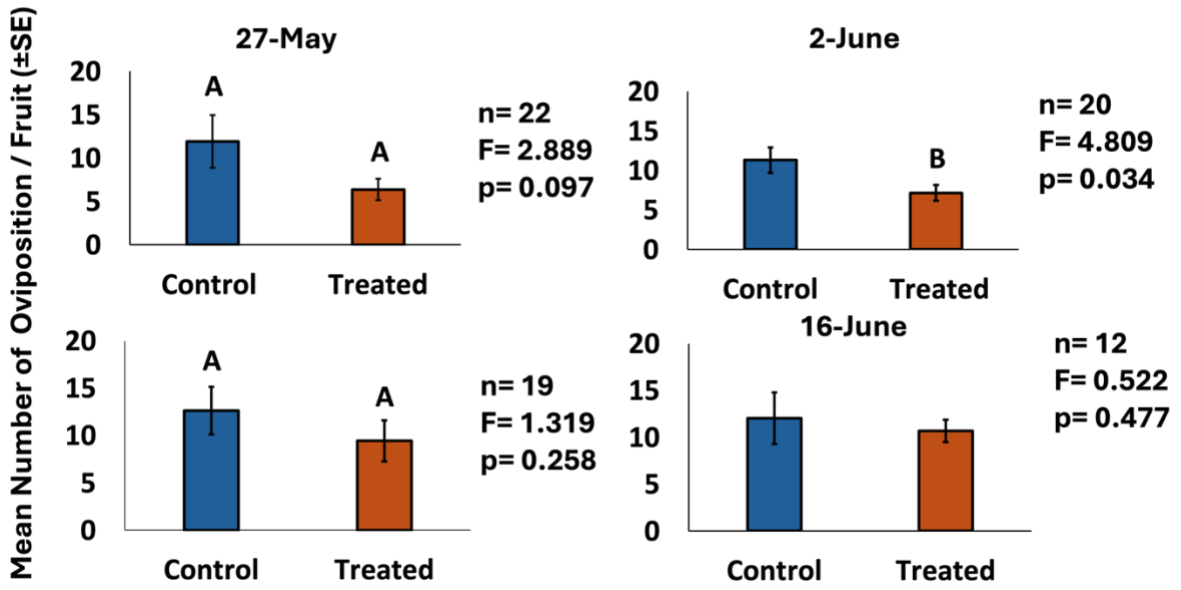


Fig. 5. SWD oviposition rates in cherry fruit collected from methyl benzoate–treated and untreated control trees under field conditions, Stockton, 2025

When examined by individual sampling dates, the MB-treated fruits always showed numerically lower average oviposition stings than the untreated control (Fig. 6). The second sampling date, June 2nd, showed a significantly lower number of oviposition stings compared to the untreated control.



On the first evaluation date (27 May), the overall reduction in oviposition was 41% lower in MB-treated than in the untreated control, and 34% on June 2. In contrast, the reduction was lower for late dates (6% for 9 June; 16% for 16 June).

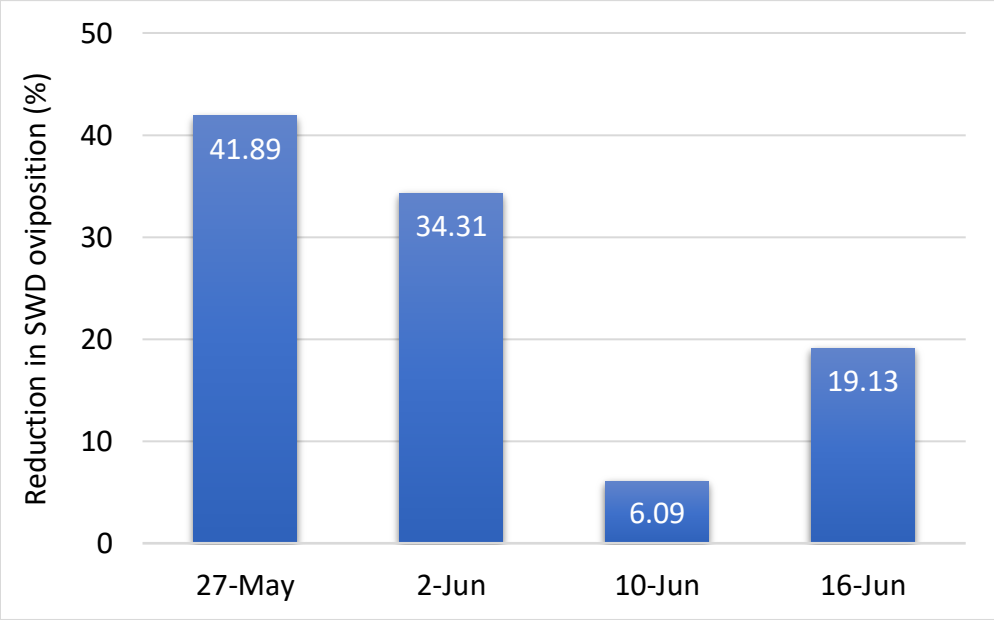


Fig 5. Overall reduction in oviposition by SWD in cherry fruits collected from trees treated with Methyl Benzoate in the field, Stockton, 2025

Discussions and Conclusions

The results of this study demonstrated that methyl benzoate (MB) reduced the oviposition activity of spotted wing drosophila in both laboratory and field experiments. In laboratory bioassays, all

MB concentrations showed a suppressive effect on SWD egg-laying behavior, with the untreated control group exhibiting the highest mean number of ovipositions (18.8 ± 3.5). Increasing the concentration of MB led to a general reduction in egg-laying activity, with rates of 500 µL, 1000 µL, and 2000 µL resulting in significantly lower oviposition than the control ($P<0.05$).

This deterrent effect is likely due to the volatile nature of methyl benzoate, which likely acted as a behavioral repellent or oviposition deterrent by signaling a suboptimal or toxic environment to female flies. Interestingly, the 500 µL rate yielded the lowest mean oviposition (10.8 ± 1.5), suggesting that intermediate concentrations of 500 µL or 1000 µL may be as effective as higher doses in a controlled environment. The lack of statistical significance for the 200 µL and 1500 µL treatments indicates that while a downward trend exists, these specific concentrations may fall near behavioral thresholds where the repellent signal is either insufficient or plateaued.

The field experiments corroborated these laboratory findings, showing that mean oviposition stings per fruit in MB-treated fruits were significantly lower than in the untreated control. The observed efficacy in the field suggests that the compound's volatility seems to be sufficient to create a protective zone around the fruit even in open-air conditions. However, the efficacy of MB was highly dependent on the time of evaluation. The greatest reductions were observed on the first two evaluation dates: the end of May (41%) and the first week of June (34%). This early-season success may be attributed to lower initial pest pressure and higher compound stability before cumulative environmental exposure, particularly as temperatures rise or UV exposure intensifies.

Despite this temporal variability, the MB application reduced oviposition relative to the control throughout the study period, indicating its potential as a suppressive tool in integrated pest management (IPM). However, given the best suppression was ~40%, this tool might not be a standalone protection tool for commercial cherry growers. Also, manually applying dispensers can be challenging and may not be practical unless different formulations, such as aerosol dispensers at a low per-acre rate, are used. Further research should explore integrating MB with reduced-risk insecticides to enhance overall control. Additionally, future studies should investigate "attract-and-kill" strategies, potentially pairing MB as a "push" repellent with other attractive products and lethal agents to more effectively manage SWD populations across the entire harvest window.

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UC Cooperative Extension
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Agriculture & Natural Resources

CALIFORNIA CHERRIES

Methyl Benzoate as Oviposition Repellent against Spotted Wing Drosophila in Cherry Orchards

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Coauthors:

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Samaneh Sakaki, Ph.D., and Flint McGrath, UCCE Stanislaus

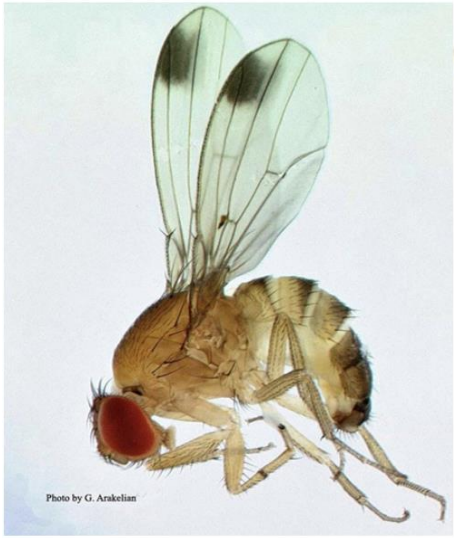
Cherry Research Review,
February 2, 2026; Stockton, CA

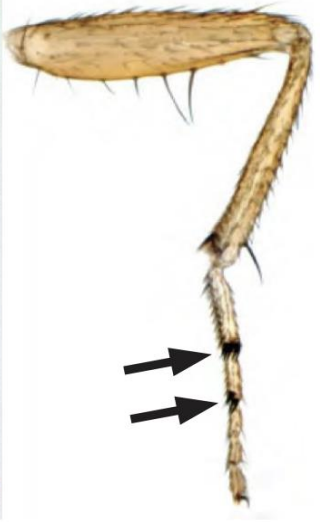
Spotted Wing Drosophila (SWD)

- Spotted wing drosophila (SWD), *Drosophila suzukii* (Matsumura), invasive pest
- First detected in California in 2008, now in 41 US states, Canada, Mexico, and many European countries
- Adult flies ~1/32 in (<6 mm), light brown with red eyes
- Females are uniquely devised with a ‘serrated’ ovipositor - capable of laying eggs on healthy fruits
- Male flies have a dark spot on the wing, and two “combs” on front legs

Female

Serrated ovipositor





Male

Photos: M. Hauser; https://extension.usu.edu/pests/research/spotted-wing-drosophila

SWD Damage in Caneberries and Cherries

- Fruits become susceptible to SWD damage as soon as fruit color begins to change,

  Blueberry: green to purple

  Cherry: green to pink/red

- Females lay eggs inside the fruit, and larvae feed on it internally.

- Infestation can lead to secondary pest/disease invasion

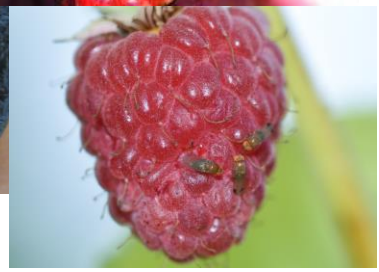


Photo: E. Burkness, D. Haviland; C. Teasdale, M. Hauser, UCIPM

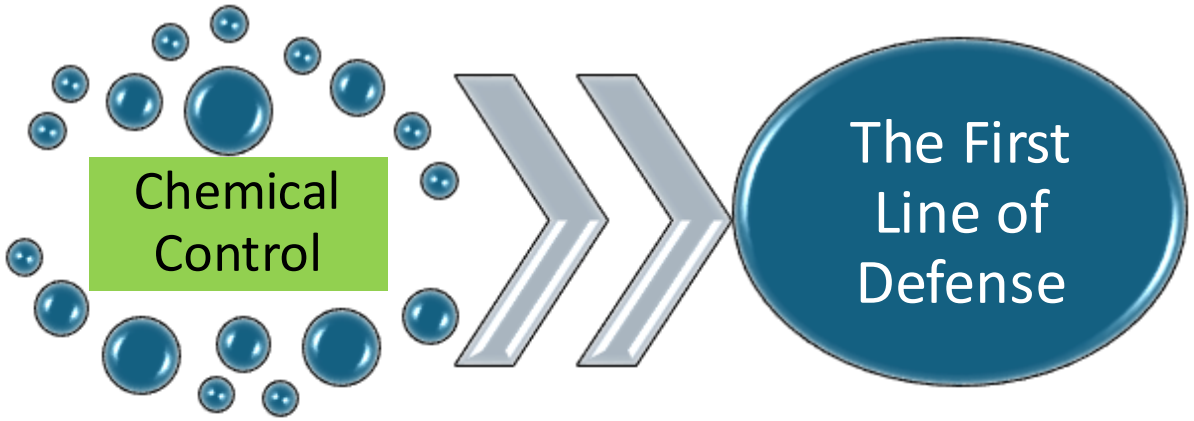
Challenges related to invasive species - SWD

They can spread rapidly.

They can be difficult to detect and identify; mistaken for native species.

Very adaptable and resilient to new climates and habitats

No biocontrol present in the new environment



SWD populations with reduced susceptibility

In Georgia, a significant decline in the susceptibility of *D. suzukii* adults to spinosad and malathion (Desi and Sial 2021)

In Michigan, reduction in SWD's susceptibility to malathion and spinetoram (Van Timmeren et al. 2019)

In California, Pesticide Resistant SWD in the Central Coast - Spinosad

Resistance Ratio (RR)

$$= \frac{\text{LC50 of resistant population}}{\text{LC50 of susceptible popultion}}$$

(RR >1 indicates that the pest population has built resistance to the particular insecticide)

2017-20 studies; spinosad:

- Extensive field studies showed widespread resistance of SWD populations with a Resistance Ratio (RR) from 10 to 17 folds.

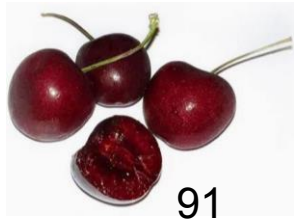
(Gress and Zalom 2018; Ganjisaffar et al. 2022b)

In California, Pesticide Resistant SWD in the Central Coast – Pyrethroids

Pyrethroid (bifenthrin, Type I; zeta-cypermethrin, Type II)

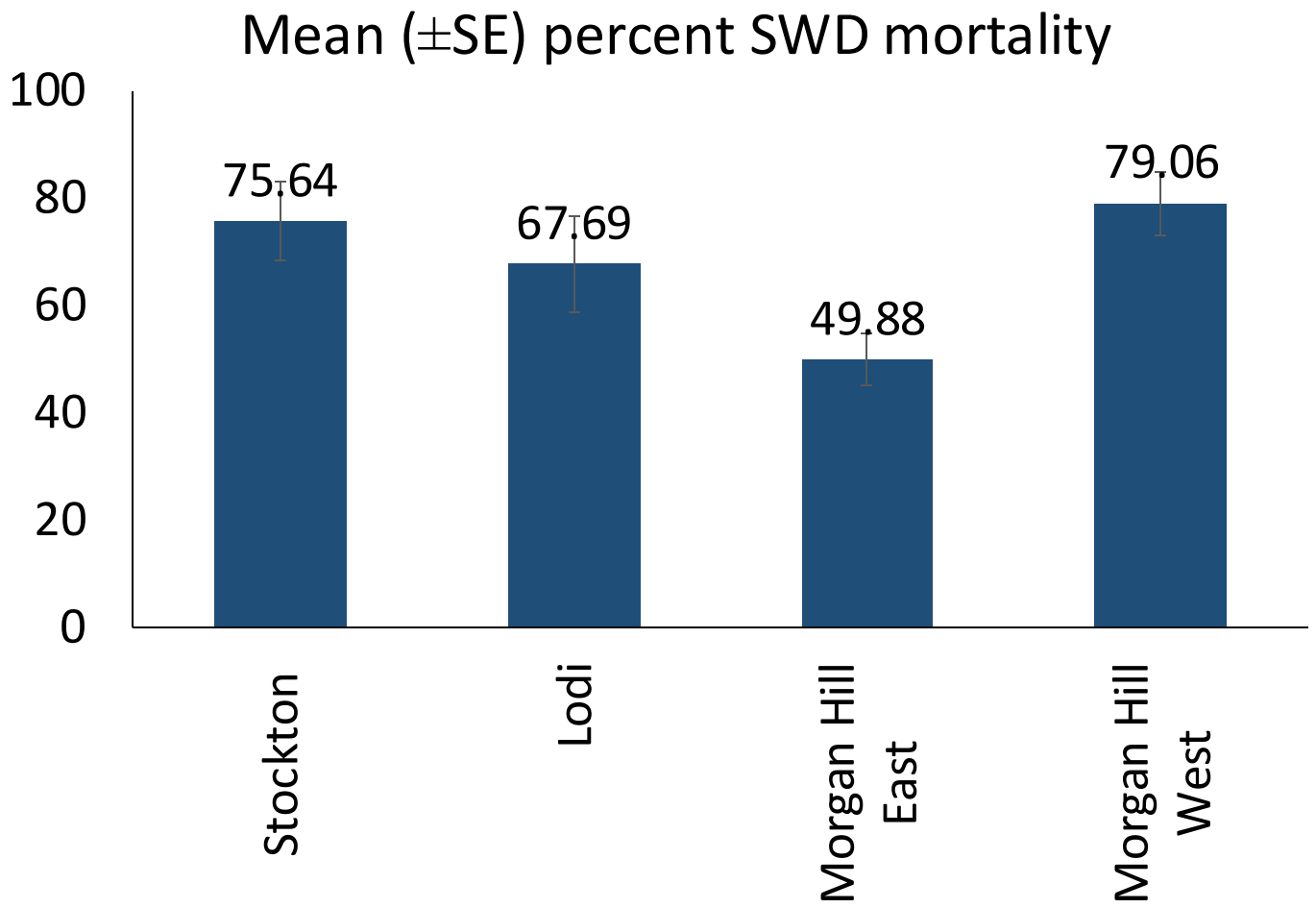
In 2020, The RR50 values were from **19.0- to 36.1 folds** for zeta-cypermethrin (Mustang Max) and from -**15.9- to 47.7** folds for bifenthrin (Brigade) (Ganjisaffar et al. 2022a)

What is the pesticide resistance status in California cherry orchards?



SWD Resistance Study -2023

Spinosad (LC99 x 2 dose): Average mortality of field-collected SWD

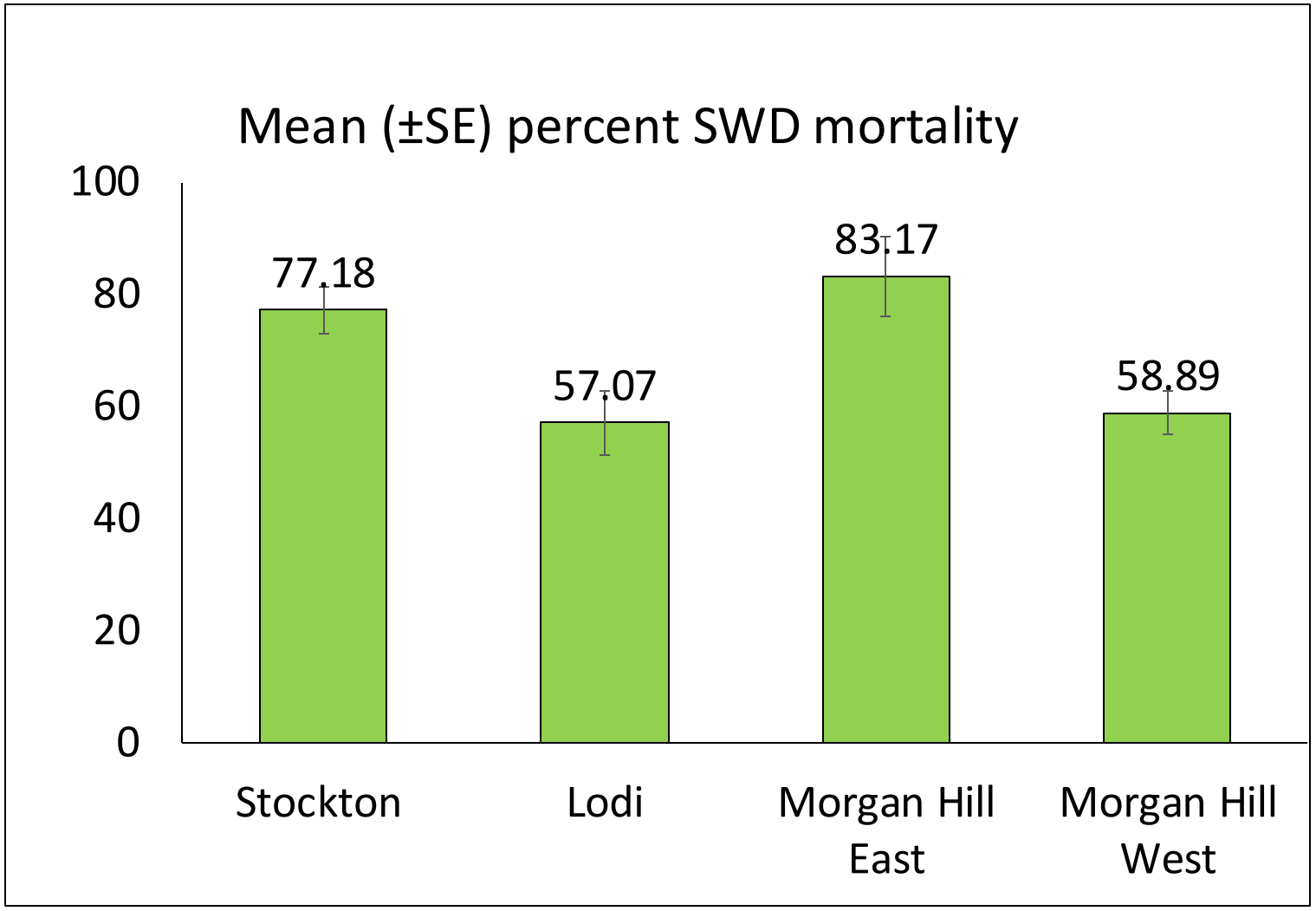


- ✓ **Treated mortality: 50-80%**
- ✓ **No mortality in Untreated Control**
- ✓ **100% mortality in the susceptible population**

Rijal and Sakaki, manuscript in prep.

SWD Resistance Study -2023

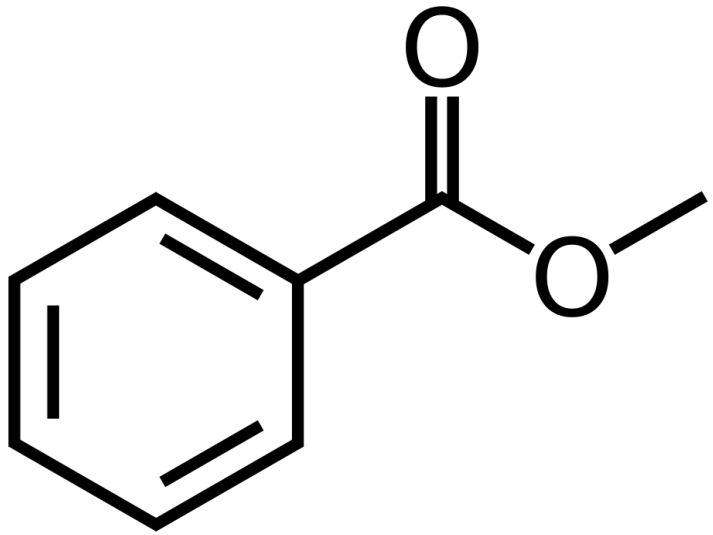
Pyrethroid/Cypermethrin (LC90 x 8 dose): Average mortality of field-collected SWD



- ✓ **Treated mortality: 57-83%**
- ✓ **No mortality in Untreated Control**
- ✓ **100% mortality in susceptible population**

Rijal and Sakaki, manuscript in prep.

An Emerging IPM Tool: Methyl Benzoate (MB)



- Naturally occurring compound
- Safe for human consumption, FDA approved
- Toxicity and repellency towards pest insects, including sweet potato whitefly *Bemisia tabaci (*Mostafiz et. al, 2018) and SWD (Feng & Zhang, 2017)
- Significantly reduced SWD oviposition in blueberries (Gale et. al, 2024).
- Eco-friendly and non-toxic for non-target organisms (Zhao et. al, 2022)

2025- Lab Bioassay

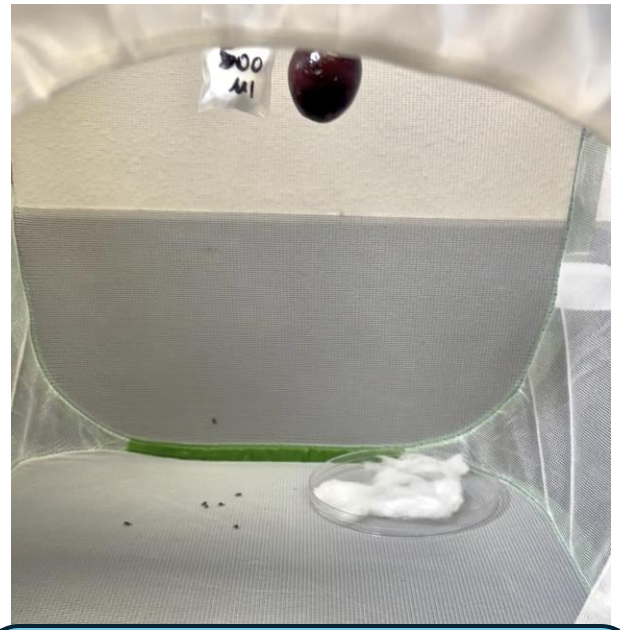
- Dose Response (No Choice):
- 200µL, 500µL, 1000µL,1500µL, 2000µL Methyl Benzoate , and Control
- Oviposition stings per fruit counted after 24 hours

Lab Bioassay Methods

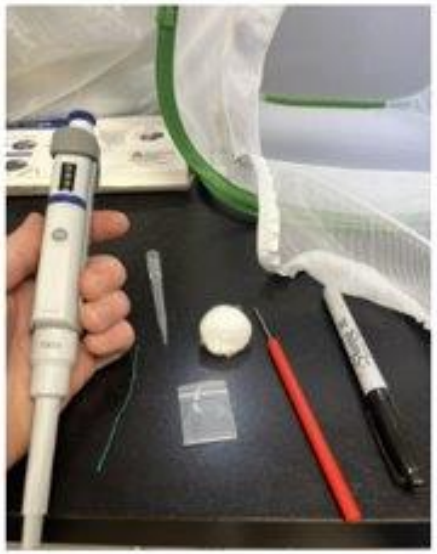
- Dose Response (No Choice):

200µL, 500µL, 1000µL,1500µL, 2000µL MB, and Control

- 4 repetitions/trials, 4 replications each
- Oviposition stings per fruit counted after 24 hours
- Data analysis: Each Pair, Student's t-test

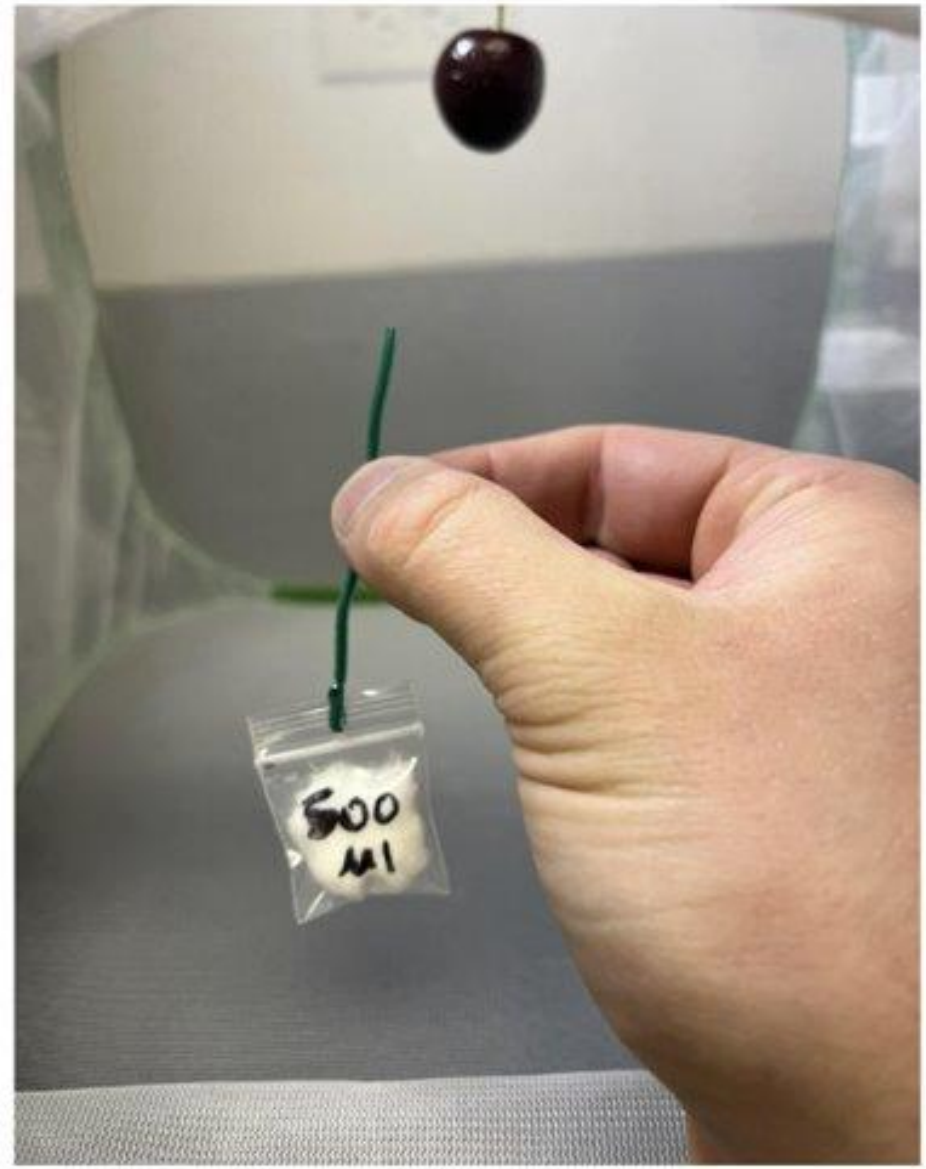


12x12x12 inch Cage
10 flies released:
5M, 5F – age 3-8 days

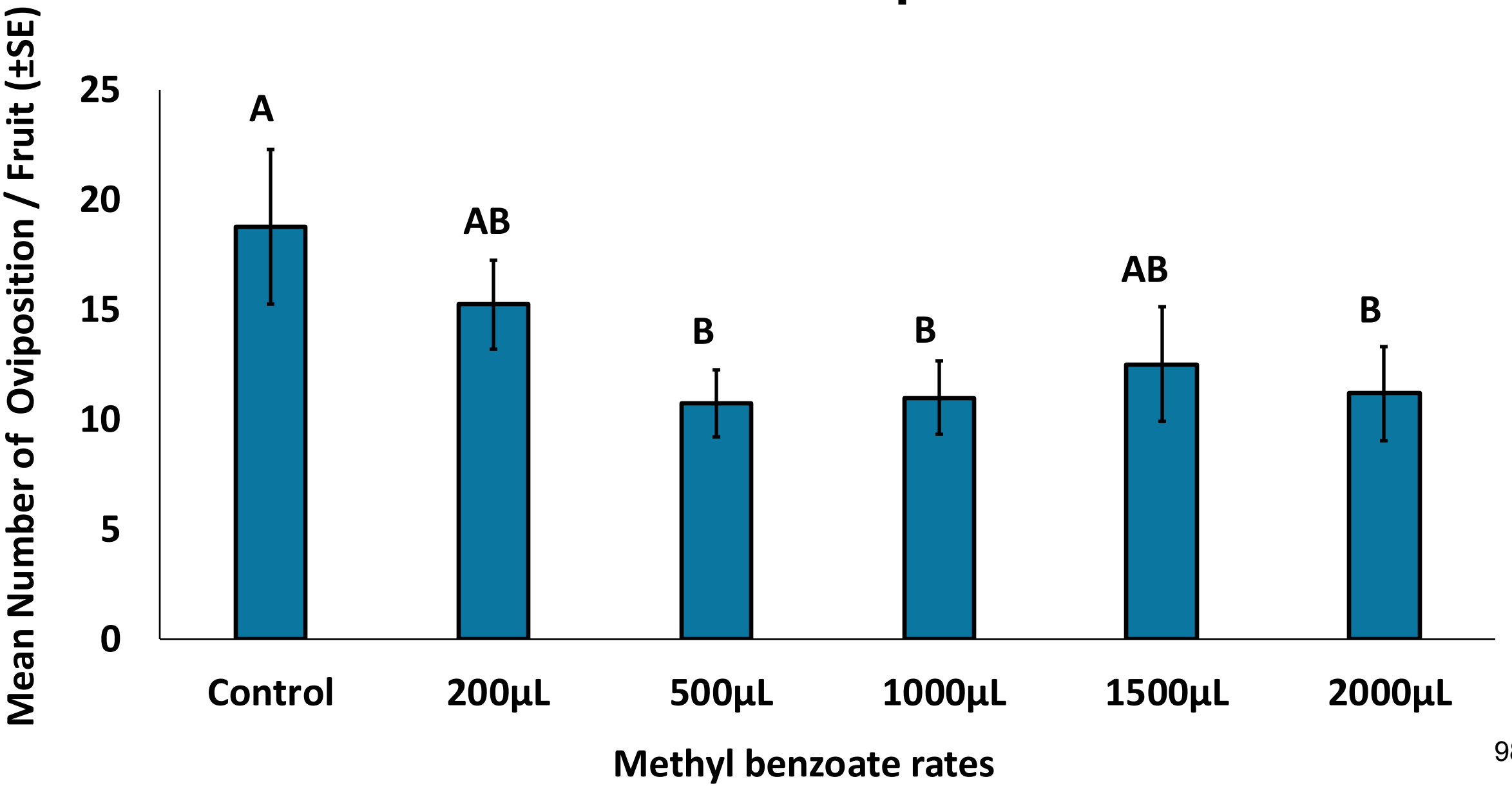






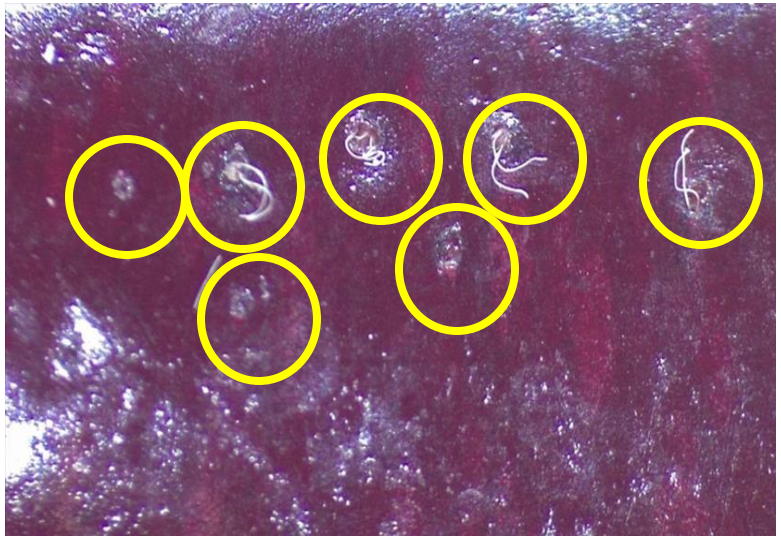


Lab Results: Dose Response Test

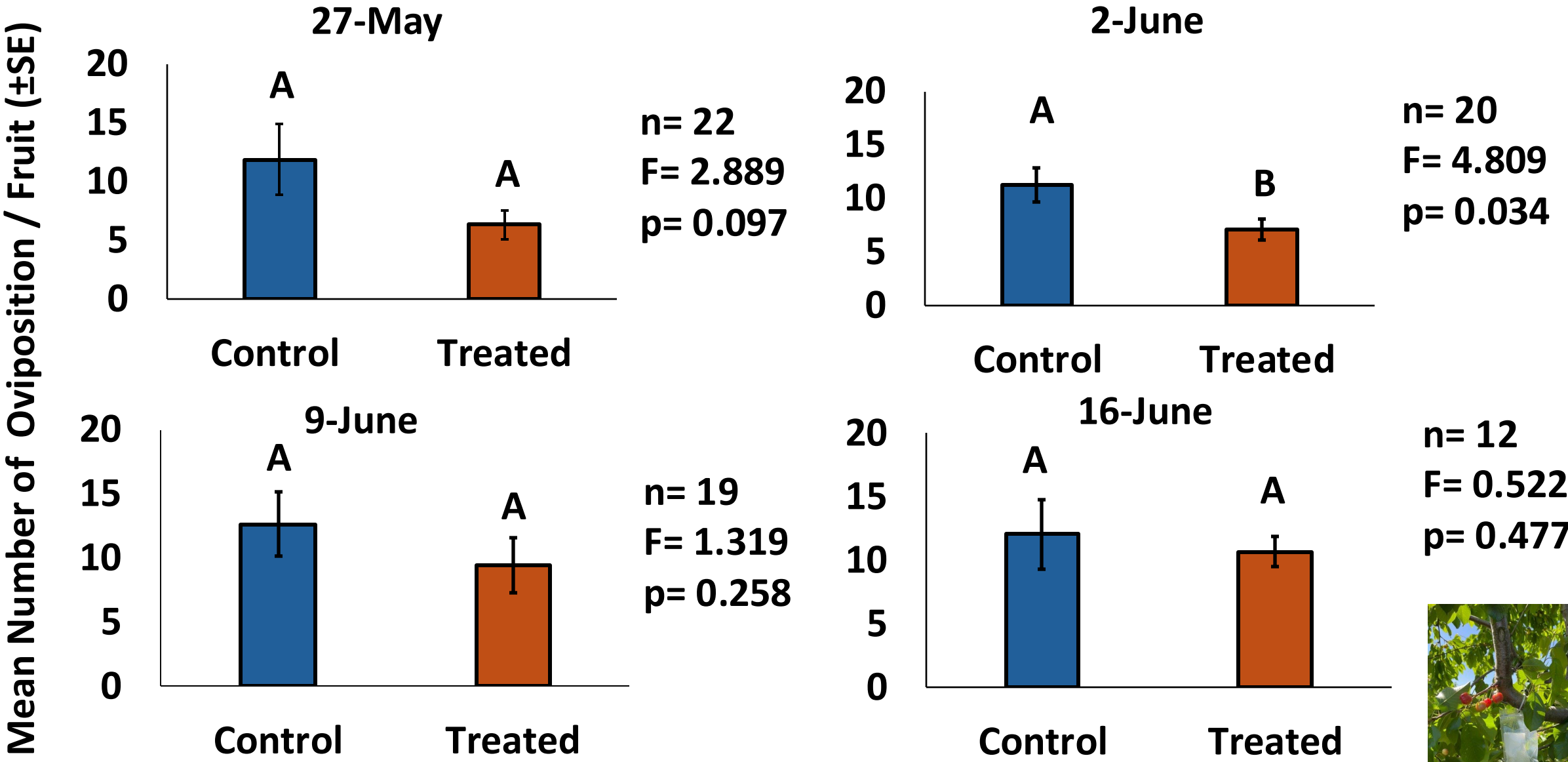


Field Study Methods

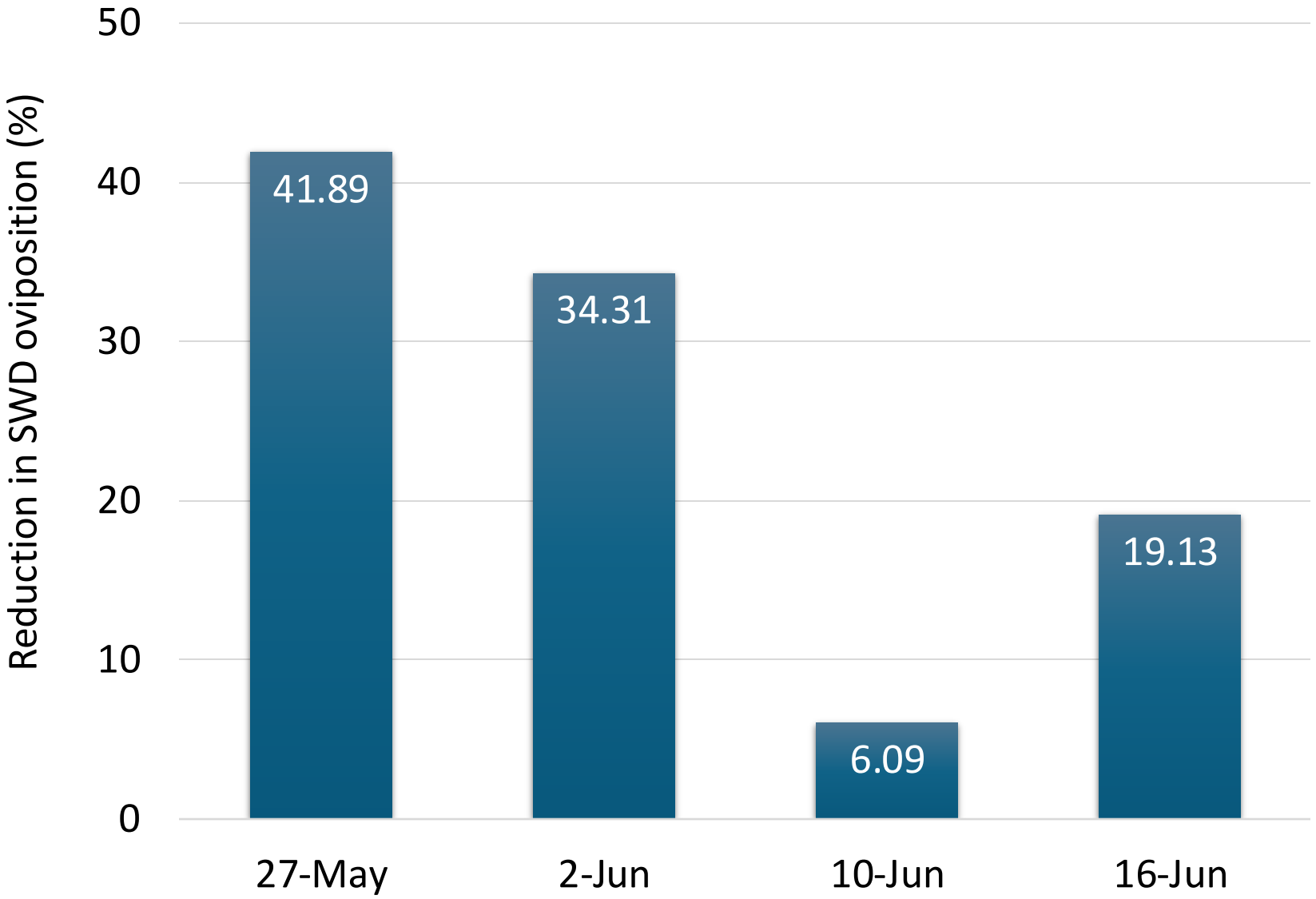
- An unsprayed section of a cherry orchard in Stockton, CA
- Four rows (replications)
- Each row contained an equal number of Treated (MB) & Control trees
- 5 MB dispensers per tree
- 4 weeks of data collection
- Oviposition stings per fruit recorded at the lab
- Data analysis: One-way ANOVA



Field Results- Weekly Oviposition Rate

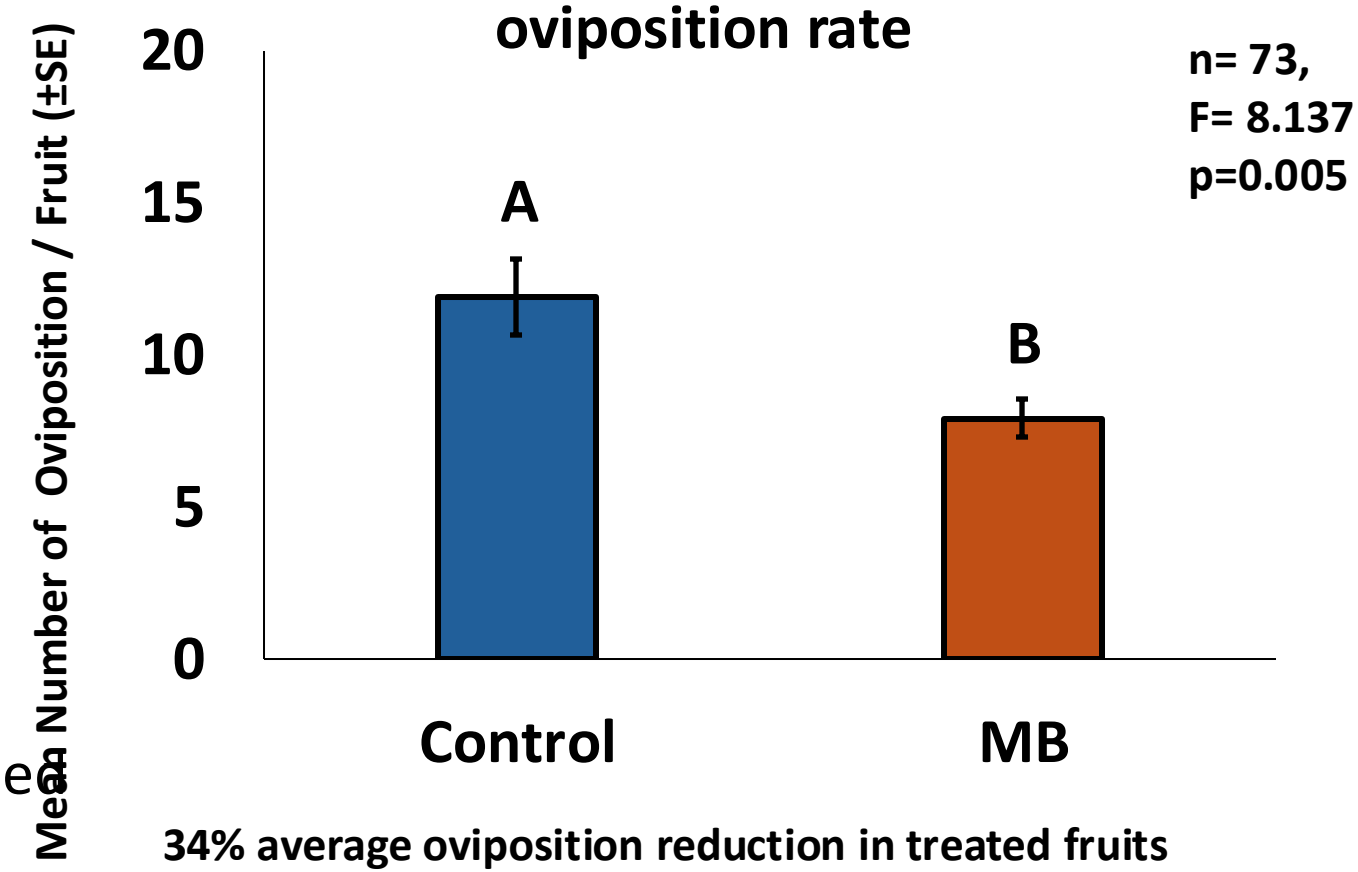


Oviposition reduction in MB-treated fruits over Control



2025- Field Study (Seasonal Combined)

- 5 MB dispensers per tree
- 4 weeks of data collection
- Oviposition stings per fruit recorded at the lab



34% average oviposition reduction in treated fruits

Summary

- Dose Response test: significant oviposition reduction compared to control and with 500, 1000, and 2000 µL MB doses.
- Field test: significant oviposition reduction (34%) in fruits from treated trees (whole season average)
- Future research will focus on combining MB with insecticides and on testing a few new baits to reduce the amount of insecticide.
- Testing a few new active ingredients, and new formulations

California Cherry Board

Trouillas, Florent

"Assessing Disease Risk for an Integrated Management of Bacterial Blast of Sweet Cherry"

Annual Report January 2026

Project Title: Assessing disease risk for an integrated management of bacterial blast of sweet cherry

Principal investigator: Florent Trouillas, Cooperative Extension Specialist, UC Davis.
Email: flotrouillas@ucanr.edu
Location: Kearney Agricultural Research and Extension Center, Parlier, CA 93648

Collaborators, cooperators:
Dr. Tawanda Maguvu, UC KARE
Rosa Jaime Frias, UC KARE
Dr. Mohammad Yaghmour, UCCE Kern County

Summary of major outcomes

During a survey of sweet cherry orchards in California's San Joaquin Valley, we isolated and characterized over 200 fluorescent *Pseudomonas* isolates from both symptomatic and asymptomatic cherry tissues, including leaves, flowers, bark, fruit, and buds. From this collection, 96 isolates were selected for whole-genome sequencing and analysis. Comprehensive phylogenomic analysis revealed that most sweet cherry isolates from California belonged to the *Pseudomonas syringae* species complex. Within this species complex, we identified five distinct putative pathogenic *Pseudomonas* species: *P. syringae* pv. *syringae* (35 isolates), *P. cerasi* (6 isolates), *P. viridiflava* (11 isolates), *P. syringae* (3 isolates), and one unnamed species designated as A (2 isolates). Additionally, we commonly found non-pathogenic pseudomonads in cherry trees.

From the genomic sequences, we searched for phytotoxins and virulence genes to identify potential phytopathogens within the *P. syringae* species complex, as well as ice nucleation protein (INA) encoding genes, which play a crucial role in the blast phase of the disease. Genes encoding INA were present in all isolates of *P. syringae* pv. *syringae*, *P. syringae*, *P. cerasi*, and species A. In contrast, only 36% of *P. viridiflava* isolates possessed INA encoding genes. The presence of these genes suggests that most of the newly identified isolates could contribute to the bacterial blast of sweet cherries. We also examined genes that confer resistance to commonly used bactericides in California for managing bacterial blast and bacterial canker. The gene ctpV, which confers copper resistance, was found in 46% of *P. syringae* pv. *syringae* isolates and 35.5% of *P. viridiflava* isolates. Additionally, several genes conferring resistance to tetracyclines were detected in more than 50% of all isolates. However, no isolates contained genes that conferred resistance to kasugamycin.

The genotypic antibiotic resistance data was complemented by phenotypic antibiotic resistance tests, showing a positive correlation. In vitro antibiotic tests revealed that no isolates from our collection were resistant to kasugamycin and oxytetracycline, indicating their potential effectiveness in controlling bacterial blast. However, all isolates carrying the ctpV gene were

resistant to copper in laboratory assays, suggesting that copper cannot be effectively used to manage bacterial blast and canker in sweet cherries.

Based on phytotoxin and virulence gene combinations in the genome sequences, we selected 39 isolates from six *Pseudomonas* species for pathogenicity testing. Results from a pathogenicity assay conducted in November 2023 indicated that *P. syringae* pv. *syringae* and *P. syringae* could cause substantial cankers in the branches of sweet cherries. Another assay conducted in March 2024 showed that *P. syringae* pv. *syringae*, *P. cerasi*, *P. syringae*, and *P. viridiflava* caused cankers in sweet cherries, indicating that temperature may significantly influence bacterial pathogenicity.

In April 2024, we observed severe fruit rot in several sweet cherry orchards with a history of bacterial blast. From these fruit rot samples, we frequently isolated *P. syringae* pv. *syringae*. Inoculating immature cherry fruits with *P. syringae* pv. *syringae* isolates produced fruit rots similar to those observed in the field, meeting Koch's postulates. Fruit rot caused by *P. syringae* pv. *syringae* is concerning as it can lead to fruit drop in orchards. We also conducted leaf/blast pathogenicity tests in the field, which indicated that only isolates of *P. syringae* pv. *syringae* could cause significant leaf spots. Overall, our results indicate that *P. syringae* pv. *syringae* is the main pathogen responsible for bacterial blast and fruit rot in sweet cherry trees in California.

We also developed a PCR assay and sampling protocol for the detection and quantification of the inoculum of *P. syringae* pv. *syringae* from buds of sweet cherry trees. Using the established PCR protocol, population dynamics of *P. syringae* pv. *syringae* were monitored from three different orchards located in Tulare, Hanford, and Parlier. Results of this study indicated that the population of *P. syringae* pv. *syringae* increases at the onset of flower opening. This finding has significant practical implications for the management of bacterial blast. To effectively manage the blast phase of the disease, the application of bactericides should coincide with this specific time.

Objectives:

Objective 1: to identify main *Pseudomonas* species and pathovars associated with bacterial blast and canker of sweet cherry (Completed).

Objective 1 has been completed, and the results were included in the January 2024 report. In summary, we identified five potential phytopathogenic *Pseudomonas species* based on genomic analyses and the presence of virulence factors. These species are *P. syringae* pv. *syringae*, *P. cerasi*, *P. viridiflava*, *P. syringae*, and a newly designated species referred to as Species A.

Objective 2: to determine the pathogenicity of *Pseudomonas* species and pathovars associated with sweet cherry and recognize the main pathogen groups (Completed).

Objective 2 has been completed, and the results were included in the August 2024 report. In summary, *P. syringae* pv. *syringae* is the primary pathogen responsible for bacterial blast and bacterial canker in sweet cherry. Additionally, we found that *P. syringae* pv. *syringae* also causes significant fruit rot, leading to fruit drop. In contrast, *P. cerasi, P. viridiflava*, and genomospecies A are considered opportunistic pathogens and are not a major concern.

Objective 3: to determine the baseline sensitivities of pathogenic *Pseudomonas* species to copper, kasugamycin and oxytetracycline in populations (Completed).

Objective 3 has been completed, and the results are included in the January 2024 report. In summary, no pathogenic strains showed resistance to Kasugamycin in vitro. In contrast, 45.7% of *P. syringae* pv. *syringa*e and 45.5% of *P. viridiflava* exhibited resistance to copper. These results suggest that copper may not be effective for managing bacterial blast and bacterial canker. Mapping copper resistance across all cherry-producing counties in California can provide valuable insights into the extent and geographic distribution of this resistance. Furthermore, we conducted in vitro sensitivity tests for oxytetracycline, the results of which are detailed below.

Materials and Methods

All 35 isolates belonging to the *P. syringae* pv. *syringae* species were tested for their sensitivity to oxytetracycline, a bactericide used (pending registration approval) to manage bacterial blast in California. To evaluate the toxicity of oxytetracycline (Mycoshield®, Nufarm Americas, Inc.), the agar dilution plate method was employed. Nutrient agar was amended with 150 µg/mL oxytetracycline, which is the labeled rate of the product. Unamended plates served as controls. Aliquots of 2 µL of bacterial suspensions were inoculated onto both control and bactericide-amended plates. The plates were then incubated for 48 hours at 25°C and visually inspected for bacterial growth. Growth on the amended plates was considered a sign of resistance.

Results

None of the isolates were able to grow in the presence of 150 µg/mL oxytetracycline, the label-recommended rate. These results indicate that all *P. syringae* pv. *syringae* isolates in our collection are susceptible to oxytetracycline, suggesting that this compound could be effectively used for the management of bacterial blast. Although genome mining revealed that some of the isolates contained genes conferring resistance to tetracyclines, these genes do not confer resistance to oxytetracycline, as evidenced by the phenotypic tests. Therefore, they likely confer resistance to other tetracyclines instead.

Objective 4: to develop and validate a real-time PCR assay for the specific detection and quantification of *P. syringae* pv. *syringae* directly from cherry tissues (Completed).

Objective 4 was successfully completed, and the results were detailed in the reports from January and August 2024. We identified *P. syringae* pv. *syringae* as the primary pathogen responsible for bacterial canker and bacterial blast. To facilitate specific detection and quantification of *P. syringae* pv. *syringae* directly from cherry tissues, we designed targeted primers and confirmed their effectiveness. Our lab currently uses these primers for diagnostic purposes as well as to address Objective 5

Objective 5: to identify main inoculum reservoir, determine the seasonal population dynamics of *P. syringae* pv. *syringae* in sweet cherry orchards and assess disease risk for bacterial blast (Completed)

In the August 2024 report, we identified buds as the main source of inoculum. Here we report the results from our population dynamic study, highlighting an increase in bacterial populations during bloom, regardless of the level of inoculum present in the fields during winter and fall. This led us to hypothesize that while the general inoculum level in the field is important, the increase in bacterial populations in orchards depends on the phenological stage of flower

development. To investigate this further, we conducted a comprehensive population dynamics study, as detailed in the Materials and Methods section below. Additionally, experiments were conducted to determine the bacterial threshold levels for disease occurrence.

Materials and Method

For our population dynamics studies, we selected three orchards with varying levels of inoculum load: 1) High level of inoculum load (Location: Tulare; Variety: Royal Lynn/Hazel); 2) Moderate to low level of inoculum load (Location: Hanford; Variety: Royal Lynn/Hazel); 3) Low level of inoculum load (Location: Parlier; Variety: Bing). From each location, we randomly selected 10 tree replicates for sampling buds and flowers from fall 2024 to spring 2025. Sampling was conducted on a bimonthly basis. For each tree replicate, we randomly collected and pooled 10 buds or flowers into a single sample for genomic DNA extraction. Samples were collected in zip lock bags and immediately placed in a cooler for transport to the laboratory for processing. Most samples were processed right away; however, if immediate processing was not possible, they were stored at -80°C. Genomic DNA was extracted and purified directly from the pooled buds/flowers using the FastDNA® SPIN Kit (MP Biomedicals, Irvine, CA), following the manufacturer's protocol. The quality and quantity of the extracted DNA were assessed using a NanoDrop Spectrophotometer (ND-100, NanoDrop Technologies Inc., Wilmington, DE, USA). Using the extracted DNA, quantitative PCR (qPCR) was performed on 96-well plates. PCR reactions for each sample were conducted in duplicate, containing 1 µL of normalized DNA (20 ng/µL), 0.2 µM of each forward and reverse primer, SYBR Green, and nuclease-free water to yield a total volume of 25 µL. The thermal cycling conditions were set as follows: pre-denaturing at 95°C for 60 seconds, initial denaturing at 95°C for 15 seconds, followed by 40 cycles of amplification at 95°C for 30 seconds, annealing at 65°C for 30 seconds, and extension at 72°C for 60 seconds. For relative quantification of samples in colony-forming units (CFUs), a standard calibration curve was generated using serial dilutions of pure *P. syringae* pv. *syringae* DNA. The DNA concentration was expressed as the log number of cells per µL.

Additionally, we conducted experiments to determine the bacterial threshold level for bacterial blast occurrence in spring 2025. Blooming shoots, each with at least eight flowers of the Bing cultivar, were cut and placed in holding tubes containing distilled water. The shoots were inoculated with *P. syringae* pv. *syringae* at concentrations of 1×10^2 to 10^8 CFU and were immediately placed in a cold room at - 2°C for periods ranging from 30 minutes to 2 hours. After this, the shoots were returned to room temperature. Uninoculated shoots, which were also placed in the cold room for the same duration, served as controls. The occurrence of blast was observed visually and recorded as either present or absent for up to seven days.

Results and Discussion

In the 2023-2024 season, we conducted monthly sampling in eight orchards, which revealed a general increase in bacterial populations at bloom (reported in August 2024, Fig. 1). As a result, we hypothesized that this increase in bacterial populations was dependent on the phenological stage of the trees. However, the monthly frequency of our sampling during this period was insufficient to draw robust conclusions. Consequently, in the 2024-2025 season, we selected three orchards for continuous bimonthly sampling.

One of the orchards, Tulare, had a history of bacterial blast and demonstrated a higher inoculum load based on our previous studies of population dynamics. The second orchard, Hanford, had a moderate to low inoculum load, while the third orchard, Parlier, had a lower inoculum load. Results from the 2024-2025 season indicated that the Tulare orchard had relatively low bacterial populations from September to November ($< 1 \times 10^2$ CFU) (Fig. 2). A slight increase was observed in December, averaging 1×10^3 CFU, but this figure dropped back to ($< 1 \times 10^2$ CFU) until about February 11. Subsequently, a peak in bacterial populations was observed from February 26 until the last sampling day on March 10. Notably, this peak in bacterial population coincided with the transition from the onset of flower opening (pink bud) to full bloom (Fig. 2). This observation was consistent with the trends noted in the 2023-2024 season.

The Hanford orchard exhibited a similar trend, with bacterial populations remaining below 1×10^2 CFU from October 14 until February 11. A peak was again noted from February 26 to March 10 (Fig. 3). In contrast, the trends in the Parlier orchard were less clear. During the early sampling stages, we did not detect any bacteria; however, lower quantities were sporadically detected ($< 1 \times 10^2$ CFU) during the stage of flower opening. These findings suggest that the flowering period is favorable for the growth and development of *P. syringae* pv. *syringae*.

Our results were corroborated by Chilean researchers who are also studying bacterial canker in sweet cherry. The findings have significant practical implications for the management of bacterial blast. To effectively manage the blast phase of the disease, the application of bactericides should coincide with these specific time periods. These findings support the current timing recommendation by Adaskaveg, highlighting that early sampling is not suitable for risk prediction. Flowering is the main and consistent trigger of high population loads in orchards, making the development of a model unnecessary.

We were unable to determine the threshold level for disease occurrence, as all our experimental units, including the control, were symptomatic (brown and necrotic petals). We suspect that the shoots used already had elevated levels of *P. syringae* pv. *syringae*. According to research findings from Chile, disease occurrence typically requires a population of approximately 1×10^5 CFU.

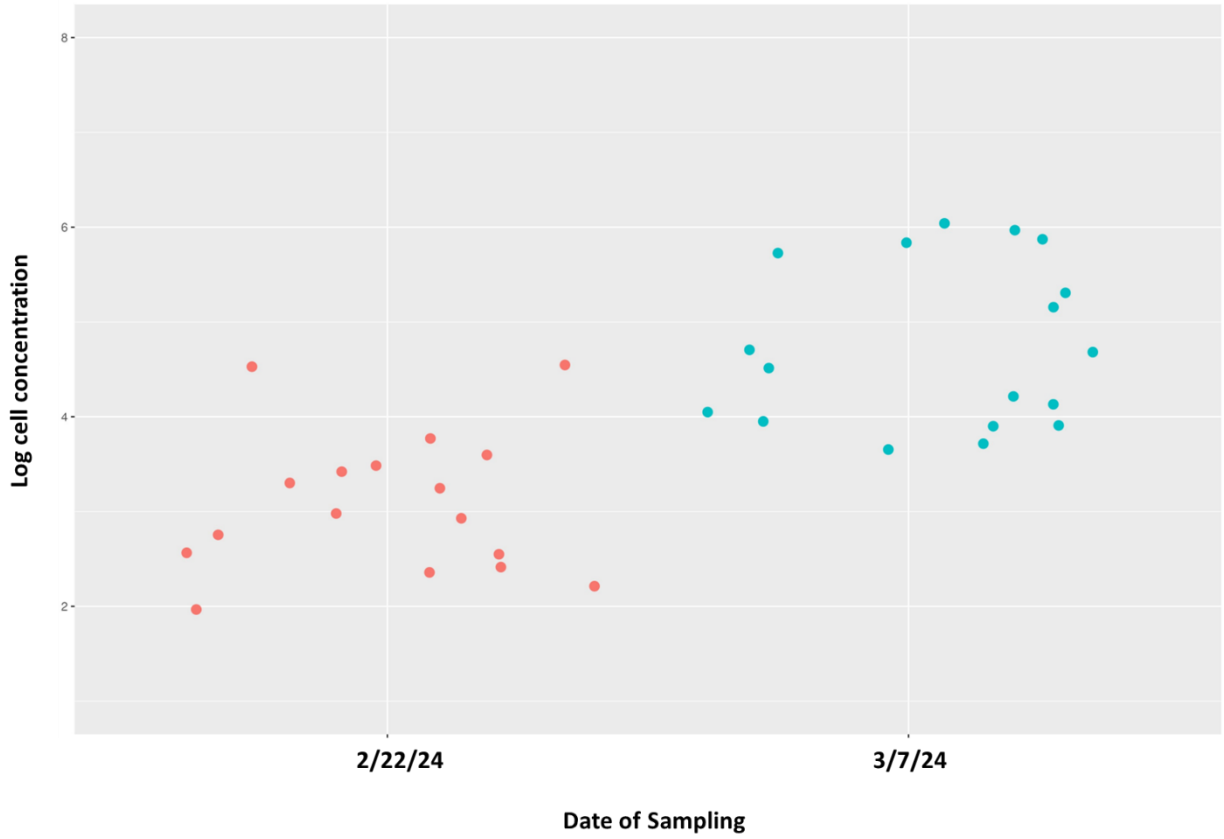


Figure 1 illustrates the population dynamics of *Pseudomonas syringae* pv. *syringae* in cherry buds from the Hanford orchard during the 2023-2024 season. The pathogen load was relatively low in February, prior to flower opening, and an increase in population was observed at full bloom in March.

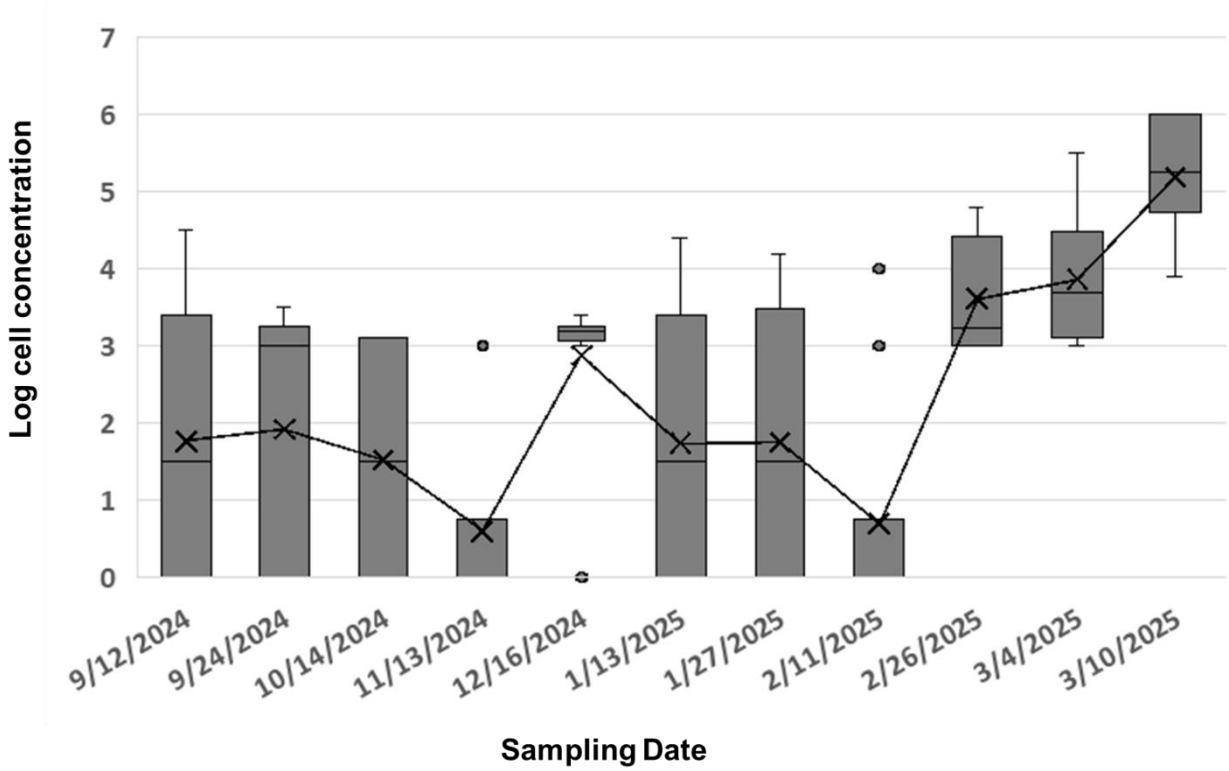


Figure 2 illustrates the population dynamics of *Pseudomonas syringae* pv. *syringae* in the Tulare orchard. The pathogen load remained relatively low from September until February 11, just before the flowers began to open. An increase in the population was observed starting on February 26, coinciding with the onset of flower opening, continuing until full bloom in March. The × symbol connected by a continuous line represents the average log CFU for the sampling date. The horizontal line indicates the median value, while the box and whiskers illustrate the quartile range. Outliers are represented by dot points that fall outside the quartile range.

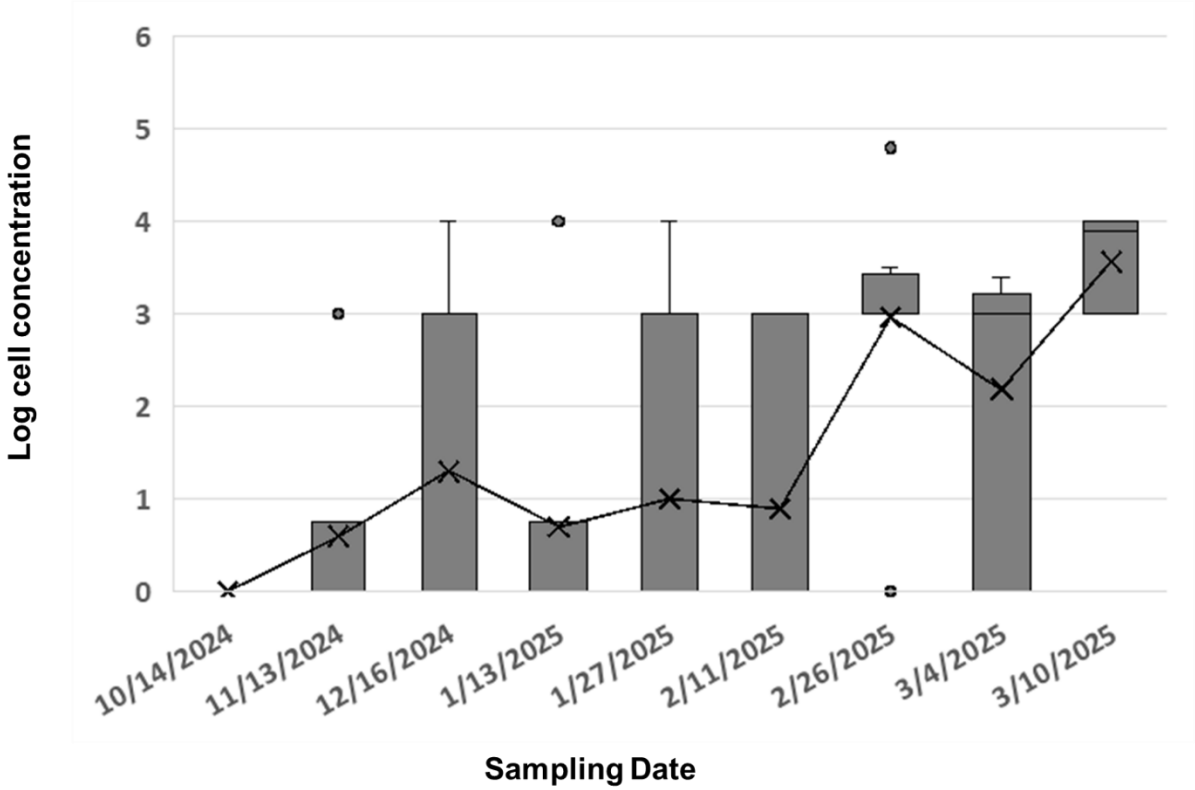


Figure 3 illustrates the population dynamics of *Pseudomonas syringae* pv. *syringae* in the Hanford orchard. The pathogen load remained relatively low from October until February 11, just before the flowers began to open. An increase in the population was observed starting on February 26, coinciding with the onset of flower opening, continuing until full bloom in March. The × symbol connected by a continuous line represents the average log CFU for the sampling date. The horizontal line indicates the median value, while the box and whiskers illustrate the quartile range. Outliers are represented by dot points that fall outside the quartile range.

Conclusion

Pseudomonas syringae pv. *syringae* was the most frequently isolated species within *the P. syringae* species complex, accounting for 60% of the isolates classified in this group. More importantly, it was the only species that caused symptoms in the field on both leaves and fruits, indicating that it is the primary pathogen responsible for bacterial blast and bacterial fruit rot in sweet cherries. Based on the results of this study, *P. viridiflava*, *P. cerasi*, and *P. syringae* appear to be of less economic importance. However, these species can still contribute to bacterial canker after springtime infections and bacterial fruit rot in fruits damaged by insects, such as green sting bugs. Importantly, no isolates of the various bacteria showed resistance to kasugamycin and oxytetracycline, suggesting that these antibiotics can be effectively used to manage bacterial blast and bacterial canker in sweet cherries. Conversely, copper resistance is common in cherry orchards, indicating that copper is not suitable for managing bacterial blast and bacterial canker in California. In addition, we observed that *P. syringae* pv. s*yringae* populations naturally increase at the onset of flower opening. To effectively manage the blast phase of the disease, the application of bactericides should coincide with this specific time period. Given that *P. syringae* pv. *syringae* can

multiply by as much as 20-fold within 12 hours, applying bactericides before the onset of flowering can reduce the inoculum load; however, it may not necessarily protect the flowers from blossom blast. Thus, our findings support the current recommendation by Adaskaveg.

IMPROVED MANAGEMENT OF BACTERIAL BLAST AND BACTERIAL CANKER OF SWEET CHERRY and ASSESS DISEASE RISK IN ORCHARDS

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Statement of problem - Rationale

- ❑ The disease is very active in California, the pathogen *Pseudomonas syringae* is ubiquitous in cherry orchards
- ❑ A complex disease, with t**wo distinct phases:** bacterial blast and bacterial canker
- ❑ **Few studies in sweet cherry in California**
  - Little, E.L., Bostock, R.M. and Kirkpatrick, B.C., 1998. Genetic characterization of *Pseudomonas syringae pv. syringae* strains from stone fruits in California. *Applied and Environmental Microbiology*, *64*(10), pp.3818-3823. **4 strains from cherry**
  - *WILSON, E.E., 1931. A comparison of Pseudomonas prunicola with a canker-producing bacterium of stone-fruit trees in California. Phytopathology, 21(12).*
- ❑ **Little knowledge about the disease biology and epidemiology in California**
- ❑ Gaps in knowledge can make disease management difficult

HYPOTHESES:

- ❑ We can improve disease management by gaining knowledge of disease biology and epidemiology

- ❑ Bacterial populations of *Pseudomonas syringae* that overwinter in dormant buds provide the primary inoculum for blossom blast

- ❑ Determining the **population levels** of *P. s.s.* in dormant buds prior to bloom may help predict disease risk in orchards

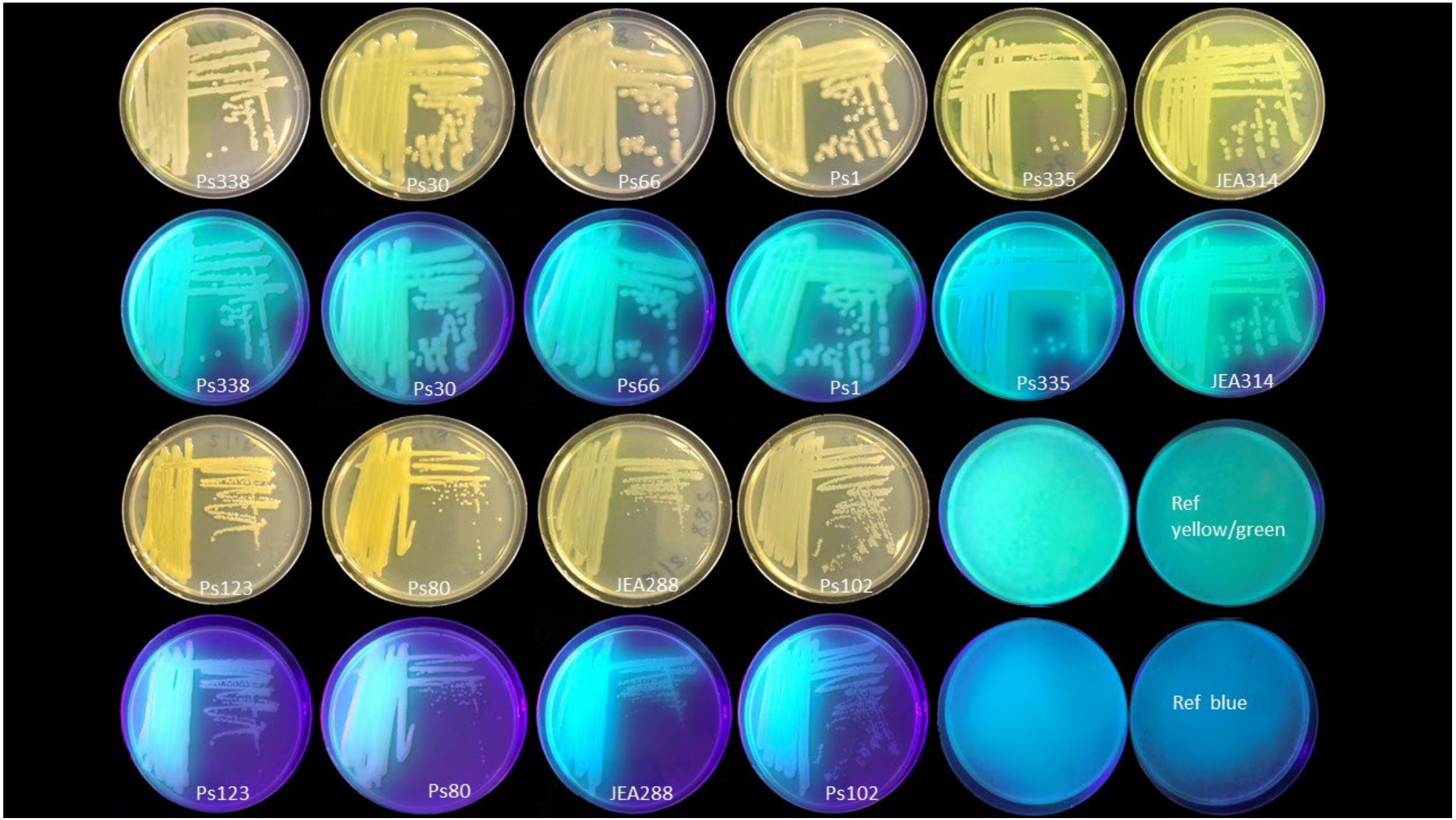
BLOSSOM BLAST: symptoms

- ❑ Many localized and sometime widespread events of blast in 2018, 2019, 2020, 2021, and 2023
- ❑ New early varieties seem very susceptible
- ❑ Royal Hazel, Royal Lynn, Coral Champagne and Chelan cvs.

BACTERIAL CANKER: symptoms

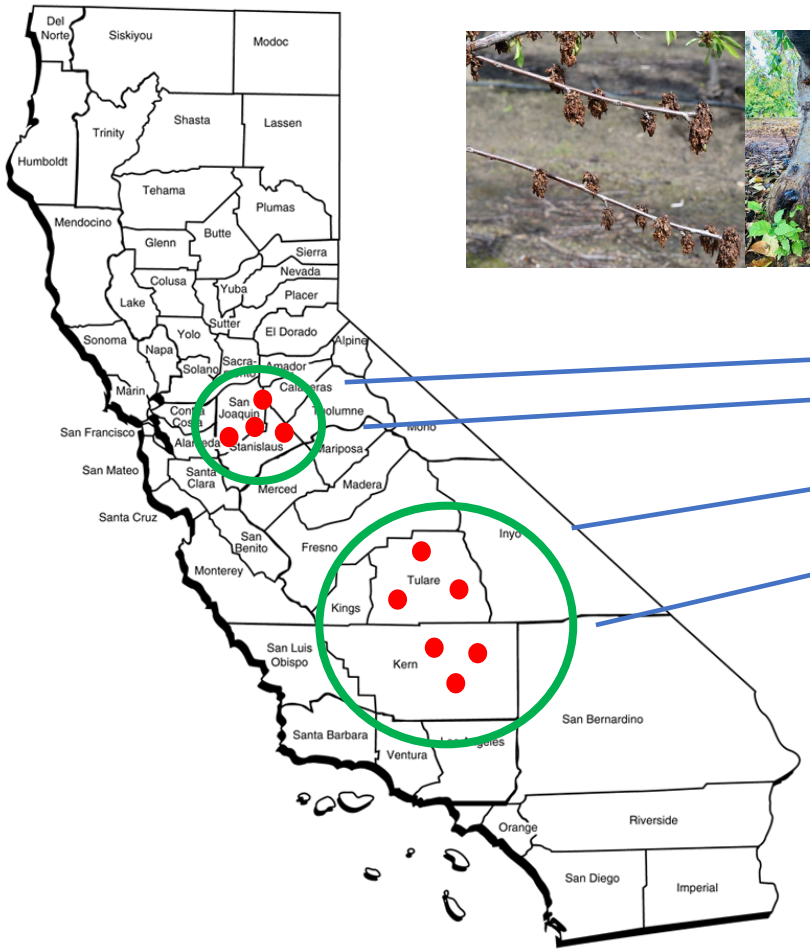
Outcome 1:
Improving disease diagnosis
(gaining knowledge of the causal agents involved)

Species Identification: isolation on King's B medium and fluorescence



STATEWIDE SURVEYS FOR PSEUDOMONAS:

Statewide survey



sweet cherry

Laboratory isolations

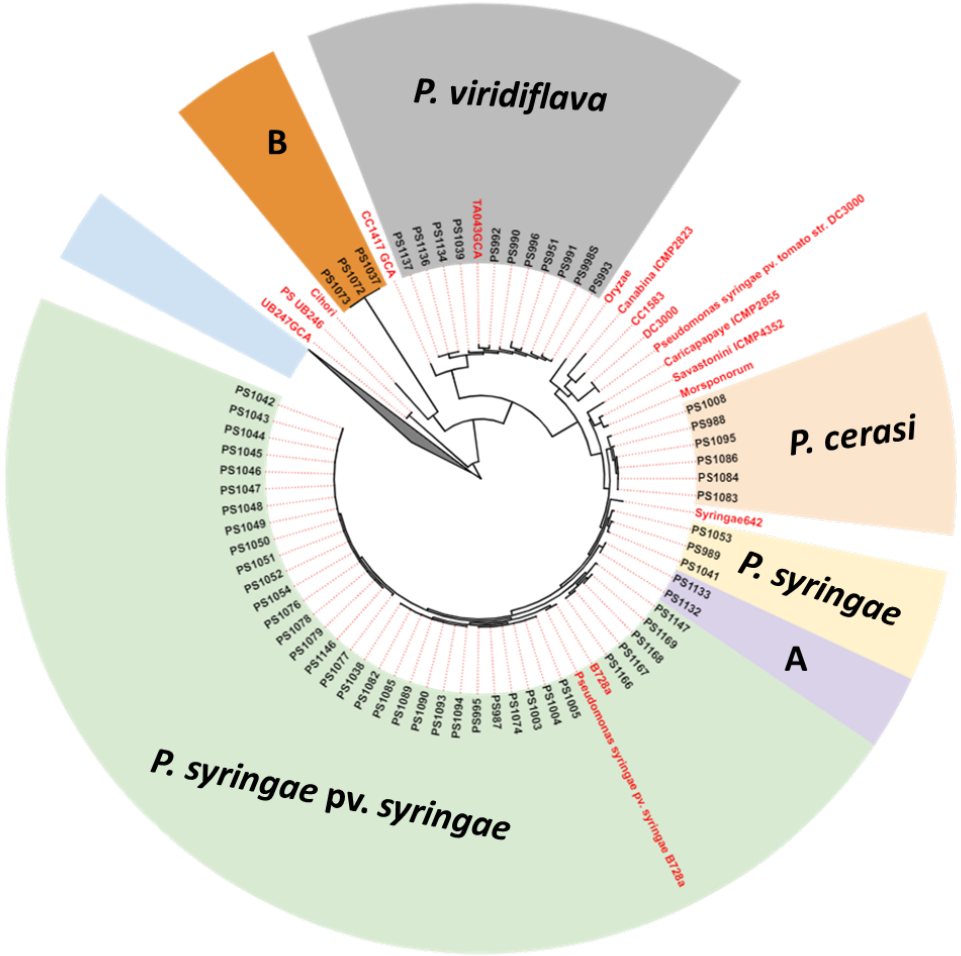
Isolate collection

King's B medium

More than 300 isolates of Pseudomonas were collected from symptomatic and asymptomatic cherry tissues

Improved diagnostic and pathogen ID:

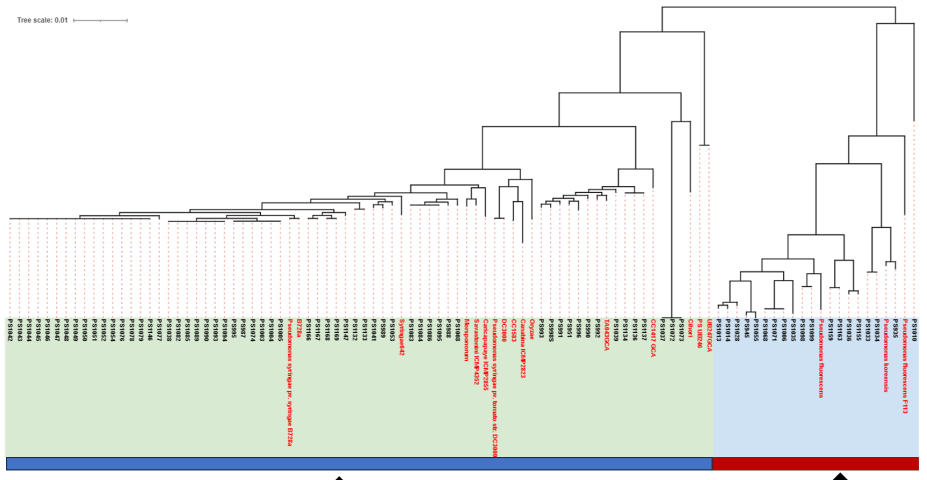
- About a dozen Pseudomonas species were isolated from sweet cherry trees
- **6 genomospecies** within the *P. syringae* species complex were identified from symptomatic and asymptomatic cherry tissue
- **At least 4 putative plant pathogens** identified based on whole genome sequencing



We designed specific primers for disease diagnosis

Table 1. Primers to be used for detection of specific species or group

Primer Name	Primer Set	Target	Reference
G1	G1_m16F: 5′-CCGYTGATCTTCGTCGATCT-3′ G1_R: 5′-CGGTAATGCTGTCGCCAAAA-3′	*Pathogenic pseudomonads*	Visnovsky *et al.*, 2020
PsAVRE	PsAVRE_F: 5′-GACTGGTAGGTCTGAACGCC-3′ PsAVRE_R: 5′-TGCTGCTCAGCGTGTAAAGA-3′	*Pseudomonas syringae pv. syringae*	This study
PcAVRE	PcAVRE_F: 5′-GGACTACTGGCCTGGCTTTT-3′ PcAVRE_R: 5′-CGCGCTTCATAGGTTTCGTG-3′	*Pseudomonas cerasi*	This study
PvhrpR	PvhrpR_F: 5′-CATATCCTCAACCGGCTGCT-3′ PvhrpR_R: 5′-GCCGTGGAATACCCAGTTCA-3′	*Pseudomonas viridiflava*	This study



Pseudomonas syringae species complex

Other fluorescent pseudomonads

Improved diagnostic and pathogen ID:

- We validated a PCR assay for the rapid and reliable detection of *Pseudomonas* pathogens

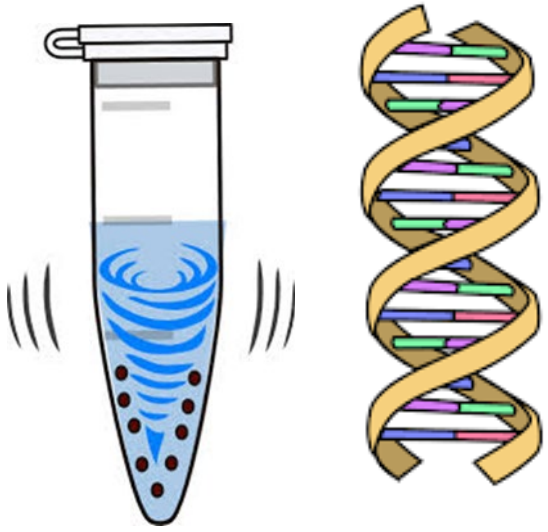
Diseased samples



or

Healthy tissues


1:

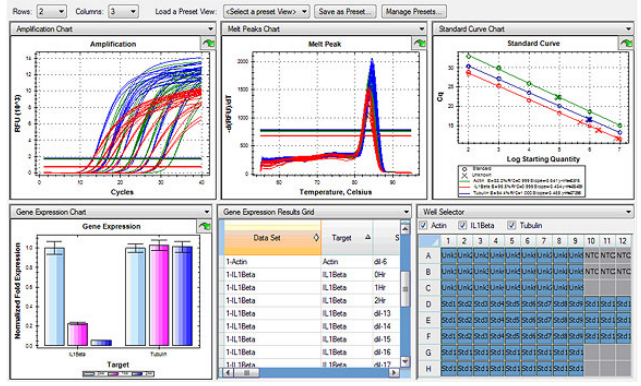


DNA Extraction directly from plant tissue

2:

Real time PCR

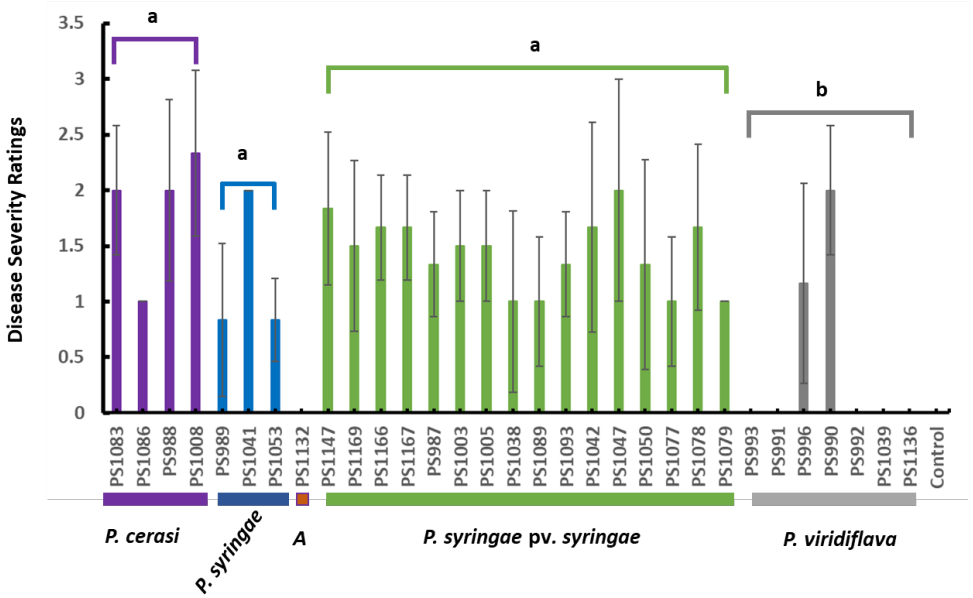
3:



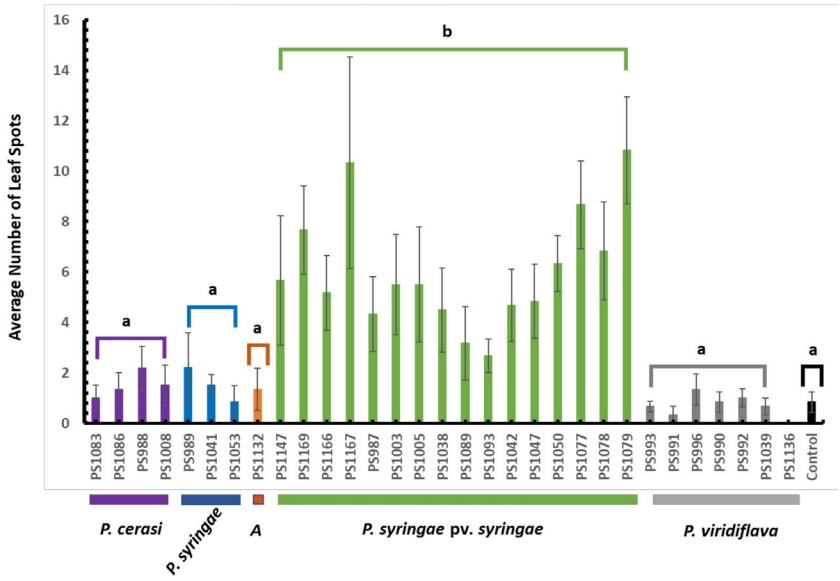
Results within 8 hrs

Pathogenicity studies: Canker and blast

Canker disease severity



Blast disease severity



Outbreak of fruit rot in 2024 in orchards affected with blast in 2023:

- Fruit rot leading to fruit drop caused by *P. syringae* pv. *syringae* (this is NOT hail damage!)

Outcome 2: We validated assay that can be used to rapidly test control agents or products

Pathogenicity assays under field conditions:



Canker phase



Blast phase

Tools to test and register new products:

nativa BIOINSUMOS

BioSafe Systems

VM Agritech

Outcome 3: Improve disease management, including resistance management

Testing for antibiotic resistance:

GENE PREDICTION

using genome sequence data to predict drug resistance

Summary

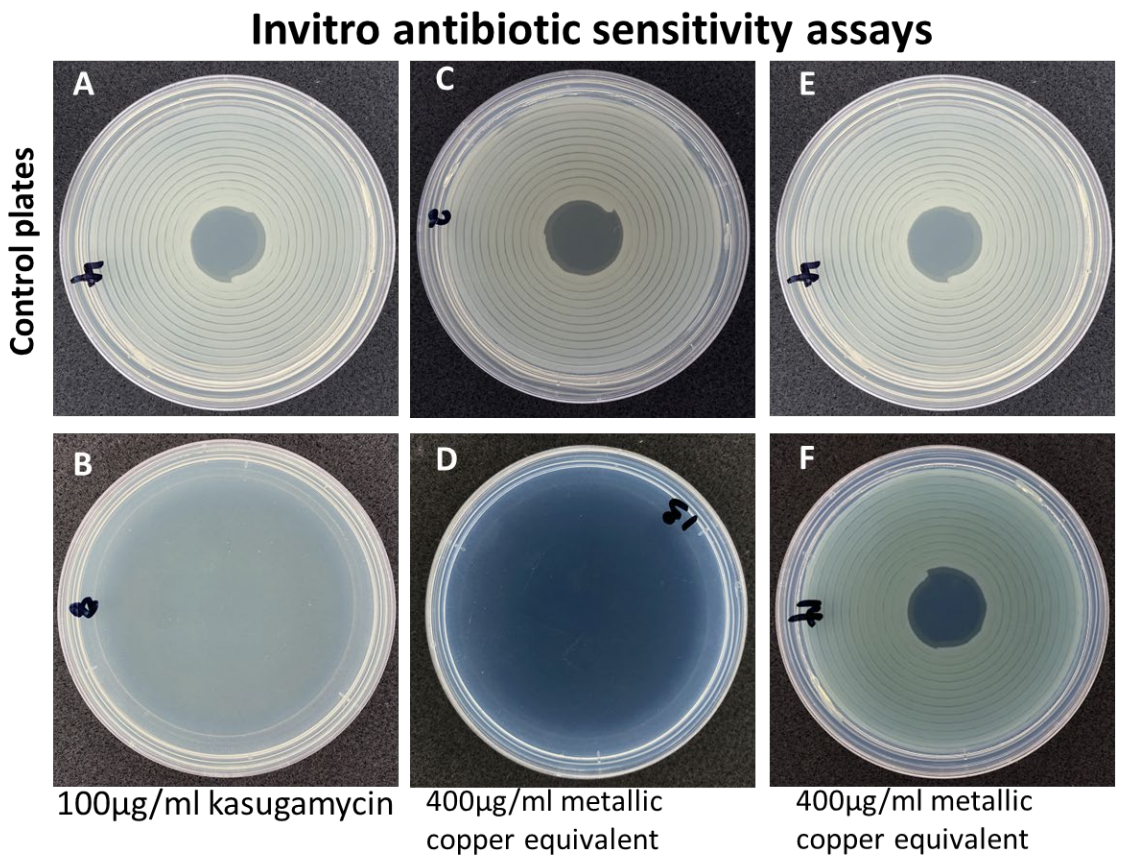
Filename	Date (UTC)	RGI Criteria	# Perfect Hits	# Strict Hits	# Loose Hits	Download
PS850SPAdes.Assembly	October 27, 2022 16:00:56	Perfect, Strict, complete genes only	0	6	0	Download

Results

Search:

RGI Criteria	ARO Term	SNP	Detection Criteria	AMR Gene Family	Drug Class	Resistance Mechanism	% Identity of Matching Region	% Length of Reference Sequence
Strict	Acinetobacter baumannii AbaQ		protein homolog model	major facilitator superfamily (MFS) antibiotic efflux pump	fluoroquinolone antibiotic	antibiotic efflux	72.73	100.69
Strict	adeF		protein homolog model	resistance-nodulation-cell division (RND) antibiotic efflux pump	fluoroquinolone antibiotic, tetracycline antibiotic	antibiotic efflux	42.22	98.58
Strict	adeF		protein homolog model	resistance-nodulation-cell division (RND) antibiotic efflux pump	fluoroquinolone antibiotic, tetracycline antibiotic	antibiotic efflux	66.29	100.38
Strict	adeF		protein homolog model	resistance-nodulation-cell division (RND) antibiotic efflux pump	fluoroquinolone antibiotic, tetracycline antibiotic	antibiotic efflux	42.45	98.96
Strict	APH(3")-Ib		protein homolog model	APH(3")	aminoglycoside antibiotic	antibiotic inactivation	99.63	100.00
Strict	APH(6)-Id		protein homolog model	APH(6)	aminoglycoside antibiotic	antibiotic inactivation	99.64	100.00

BASELINE SENSITIVTY STUDIES



Testing for antibiotic/copper resistance:

- ❑ 46% (16/35) of *P. syringae* pv. *syringae* isolates tested had the ctpV gene which is known to confer resistance to copper
- ❑ None of the 60 isolates from the *P. syringae* species complex had a gene or mutation that conferred resistance to kasugamycin
- ❑ No resistance to oxytetracycline

Phylogenomic Species	pathogenicity locus probable regulatory protein hrpR	Ice nucleation (INA+) genotype	Syringomycin biosynthetic genes	Syringopeptin biosynthetic genes	Phaseolotoxin biosynthetic genes	Copper resistance genotype (ctpV gene)	Copper resistance phenotype	Kasugamycin resistance genotype	Kasugamycin resistance phenotype
P. syringae pv. syringae	100%	100%	100%	100%	0%	45.7%	45.70%	0%	0%
Genomospecies A	100%	100%	0%	0%	0%	0%	0%	0%	0%
P. syringae	100%	100%	100%	100%	0%	0%	0%	0%	0%
P. cerasi	100%	100%	100%	100%	16.70%	0%	0%	0%	0%
P. viridiflava	0%	50%	0%	0%	0%	35.5%	35.5%	0%	0%
Genomospecies C	0%	0%	0%	0%	0%	0%	0%	0%	0%

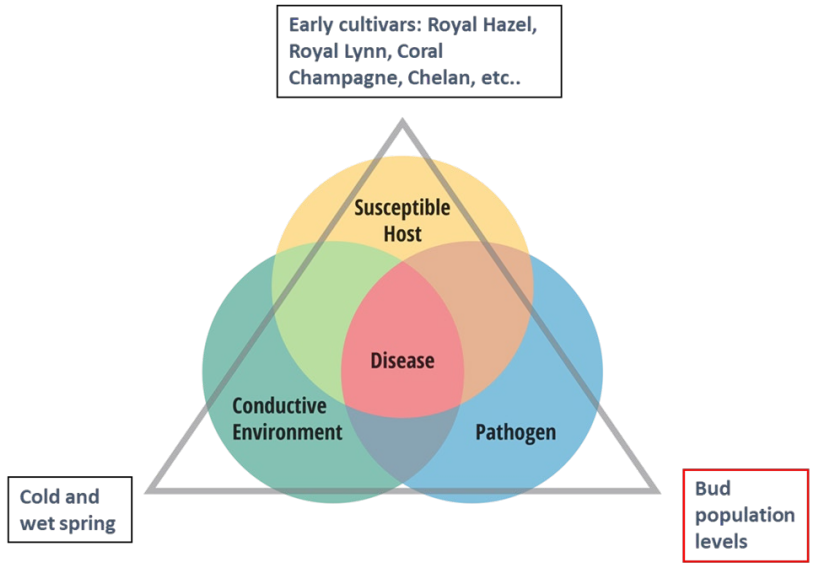
Objective 4: Assess disease risk

Determine bacterial population temporal dynamic from buds:

Bacterial population levels in bud prior to budbreak

Can we establish a correlation?

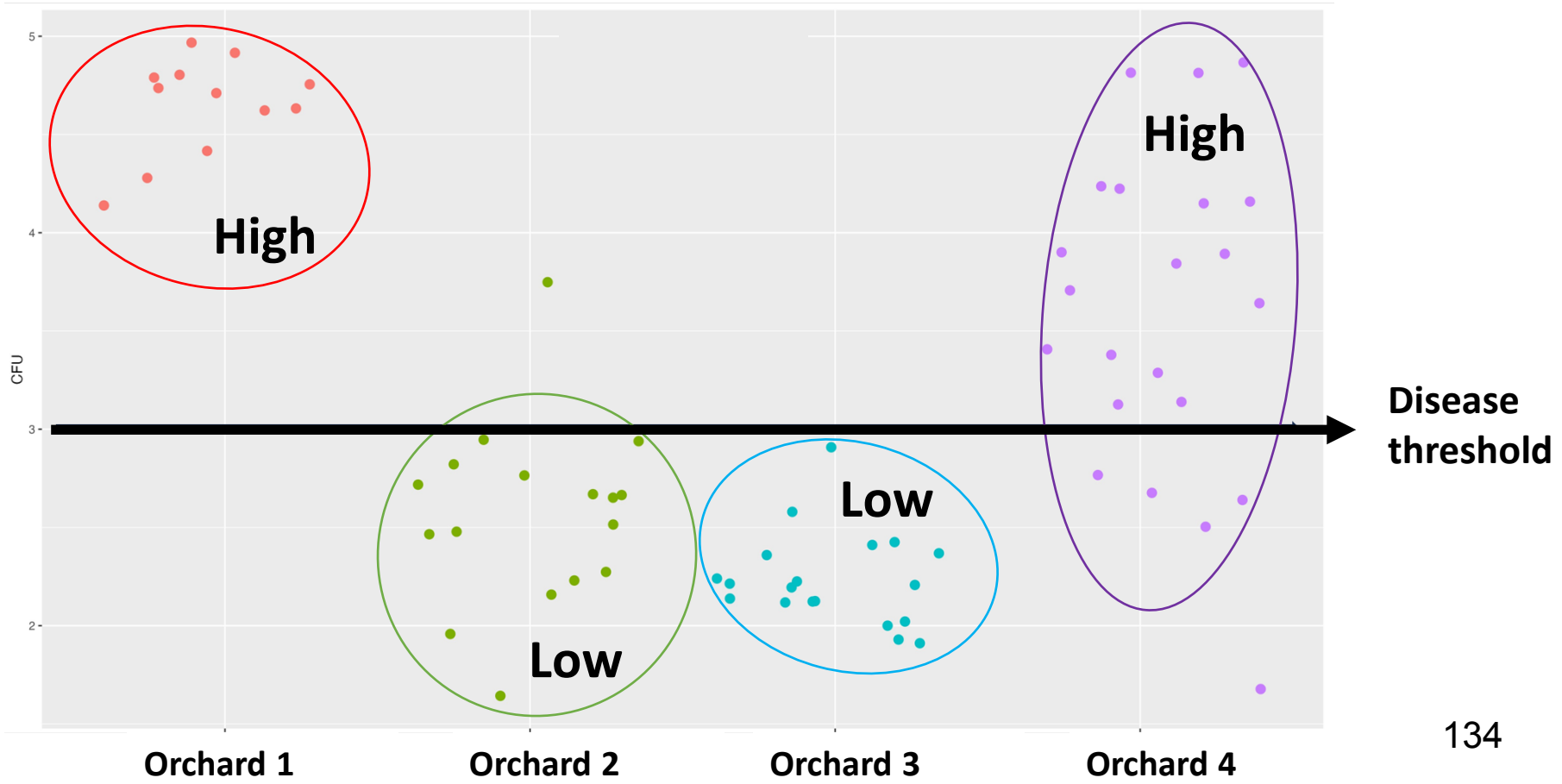
Blast disease occurrence during cold and wet bloom



Assess disease risk in orchards:

Using real time q-PCR assay (highly specific)

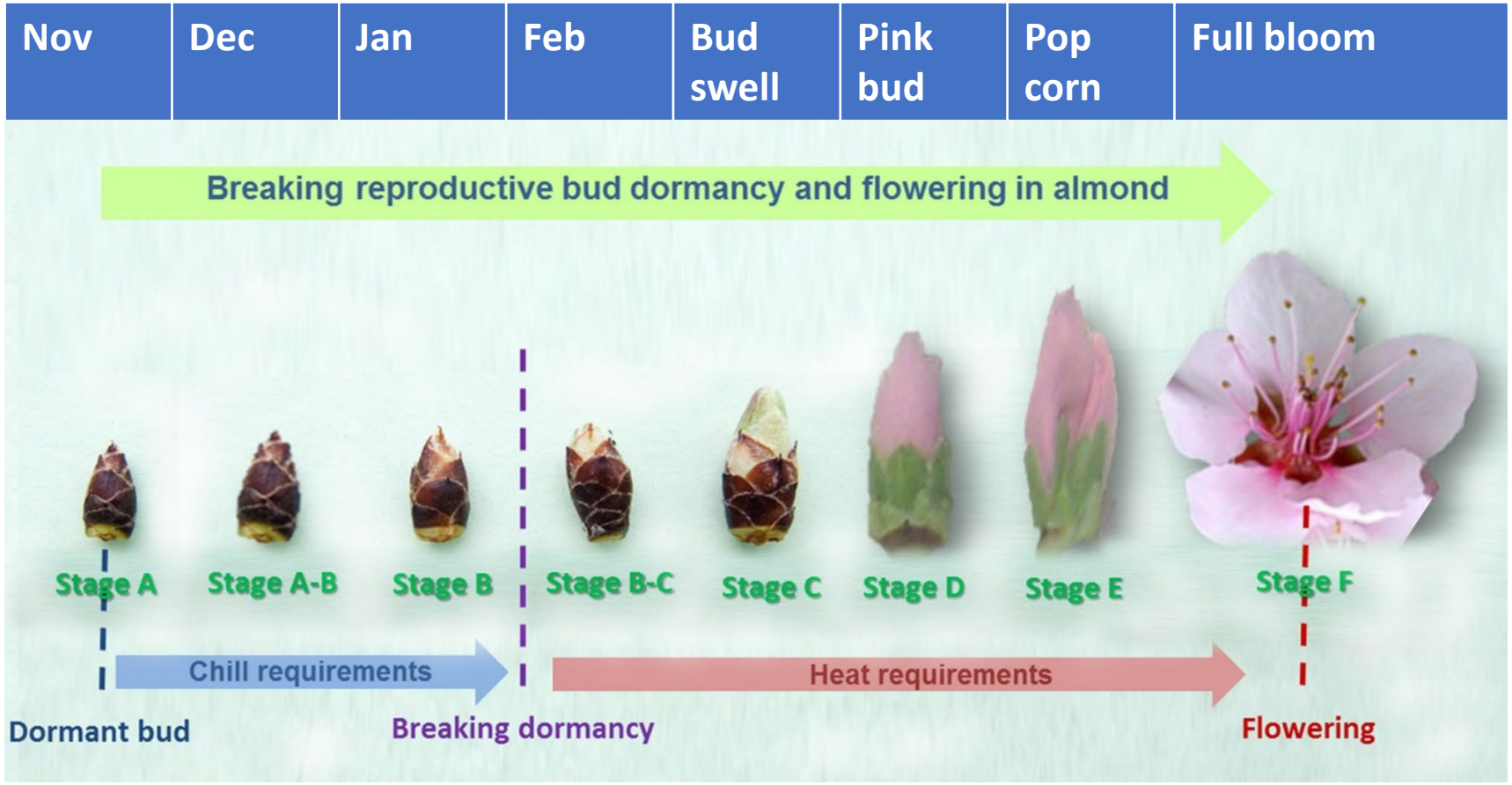
- ❑ Monitoring bacterial population levels in dormant buds to assess disease risk during bloom
- ❑ High vs Low levels



Determine bacterial population temporal dynamic from buds:

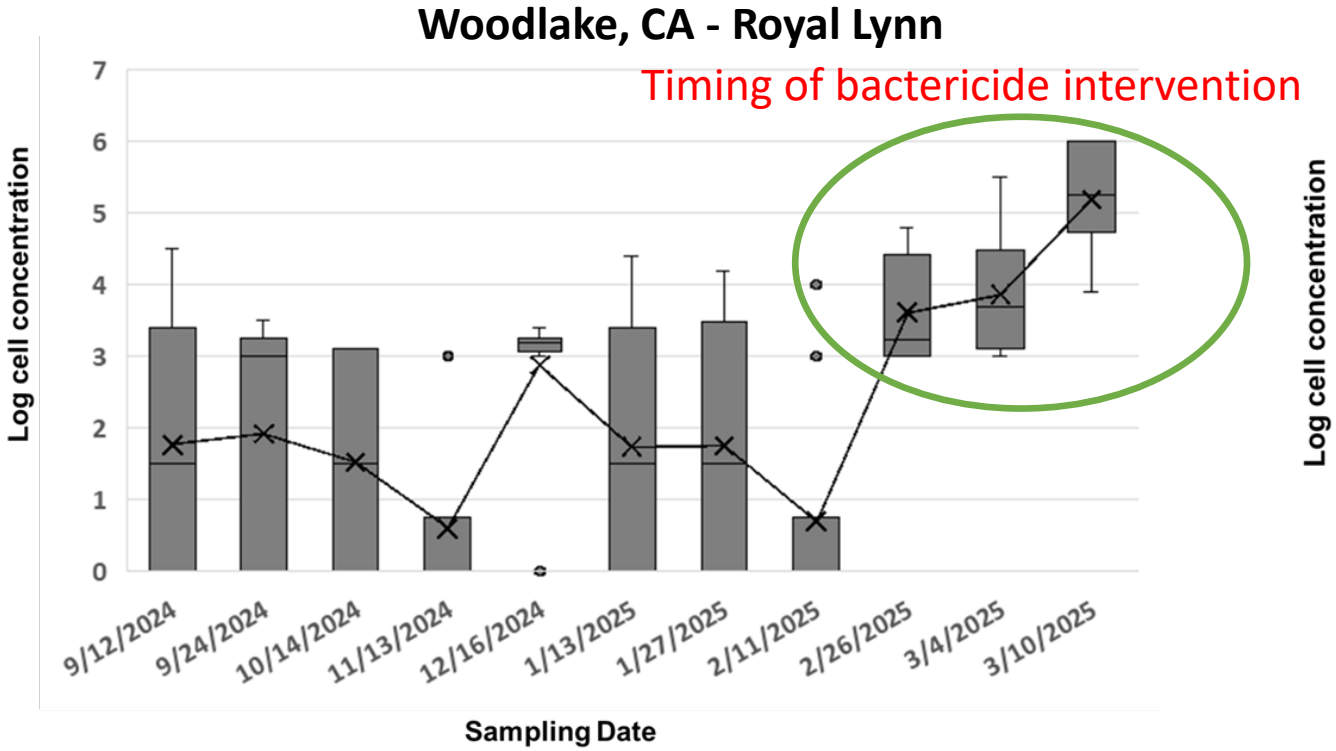
- **What is the best sampling time or bud stage for disease risk prediction**
  - From dormant buds to flowers
  - Once a month to every 2 weeks
  - 3-4 sampling locations, multiple cvs.

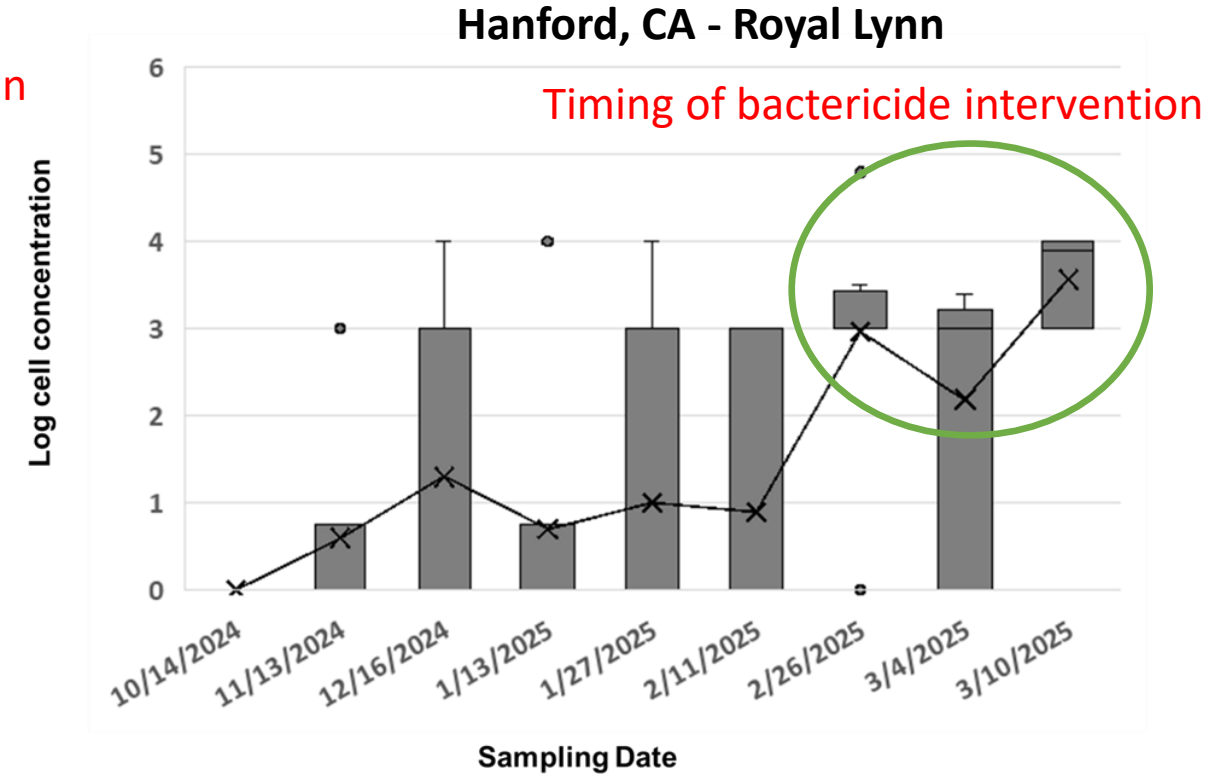
Sampling times



Pseudomonas population dynamics in orchards:

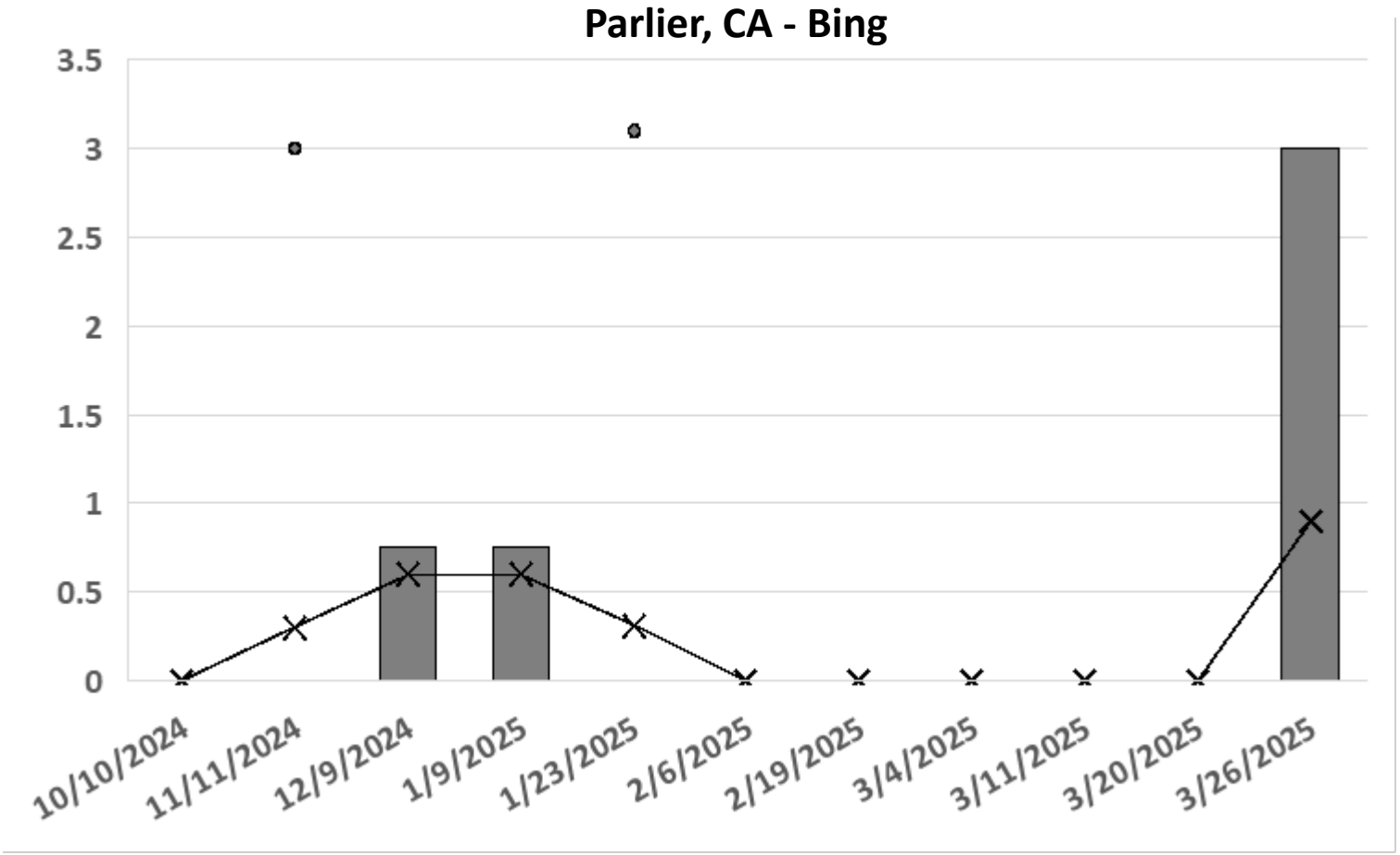
- We could not determine any correlation between winter populations in dormant buds and spring population in flowers
- **However, we observed that populations start increasing at the popcorn stage and confirmed the best period for bactericide interventions (from popcorn to full bloom stage)**





Pseudomonas population dynamics in orchards:

- We could not determine any correlation between winter populations in buds and spring population in flowers
- **No population increase in less susceptible cultivars**



Summary of main outcomes

1- We confirmed that ***Pseudomonas syringae*** **pv.** ***syringae*** is the main bacterial pathogen associated with bacterial canker and blossom blast

2- Two to three additional species were associated with cankers (***P. cerasi*** **and** ***P. viridiflava***)

3- Many similar-looking *Pseudomonas* species can be isolated from sweet cherry, but **we developed a PCR assay with specific primers for accurate identification of the true causal agent of bacterial blast and canker**

4- Improved disease diagnosis

5- Inoculation assays are now available for **new product efficacy testing (2 to 3 weeks turnaround)** – this will facilitate **new product registration**

6- Baseline sensitivities were obtained for copper, Kasugamycin and Oxytetracyclin

7- Widespread resistance to copper were detected – no resistance detected for Kasugamycin and Oxytetracyclin

8- We confirmed that **flower buds serve as main inoculum sources** for the disease

9- We confirmed that **popcorn stage to full bloom is the critical window for bacterial population expansion** and timing of bactericide applications

10- No correlation between bacterial population levels in dormant buds during winter and population levels in flowers during bloom

Thank you!

CALIFORNIA
CHERRIES

California Cherry Board

Adaskaveg, Jim
"Management and Epidemiology of Pre- and Postharvest Diseases of Sweet Cherry"

Annual Report - 2025

Prepared for the California Cherry Advisory Board

Project Title: Management and Epidemiology of Pre- and Postharvest Foliar and Fruit Diseases of Sweet Cherry

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SUMMARY

In 2025, we continued our efforts in developing new management strategies for major foliar, fruit, and root/crown diseases of sweet cherry in California including bacterial blast and canker caused by *Pseudomonas syringae* pv. *syringae*, powdery mildew caused by *Podosphaera cerasi* (formerly *Pd. clandestine*), blossom blights and fruit rots caused by *Monilinia* and *Botrytis* spp., postharvest decays, as well as Phytophthora and Phytopythium root and crown rots.

1) **Bacterial blast and canker**:
   a. Environmental conditions during bloom time again were not favorable for bacterial blast this year, and our studies were not successful.
   b. Bacterial canker: In two field studies, treatments containing Kasumin resulted in the smallest cankers, and the 8L organic formulation performed similar to the conventional 2L formulation. The addition of Vacciplant or Syllit to Kasumin improved performance in one study. Ɛ-poly-L-lysine mixed with Seican and Manniplex Zn, as well as NUP (new, high formulation of oxytetracycline) + Syllit, also significantly reduced canker length from the control in both studies.
   c. Kasumin is fully registered on cherry in California and the United States since 2018. A registration of oxytetracycline on sweet cherry with support of the registrant through the IR-4 program has been pending at EPA for several years. Based on our latest communications, the EPA removed PRIA dates and will evaluate oxytetracycline under new guidelines (Note: Unlike kasugamycin, oxytetracycline is used in human medicine and as such, its registration is controversial).
2) In a **powdery mildew** study in San Joaquin Co., with a high incidence of disease, treatments with the highest efficacy were Luna Sensation (FC 7/11), Miravis Prime (FC 7/12), and the new FRAC Code (FC) 29 Omega. The other treatments evaluated were much less effective on inside shoots, but all fungicides including the plant extracts Cinnerate and BTS 100 significantly reduced powdery mildew on outside shoots where disease pressure was lower. The powdery mildew-specific fungicide proquinazid that is in the IR-4 program again did not perform well. Proquinazid and quinoxyfen are both FC 13 fungicides, and resistance to quinoxyfen is present at some locations.
3) In evaluation of new fungicides for control of gray mold blossom blight, the disease developed at a high natural incidence on collected flower petals from control trees. In two studies, field treatments with Cevya (FC 3) and Elysis (FC 3/7) resulted in the lowest incidence, whereas the new V6M-5-14 (FC 7/21) was highly effective only in one trial.
4) Two field studies on the evaluation of **preharvest treatments for management of fruit decays** were conducted using season-long program with the last application 6 days preharvest.
   a. **Brown rot**: Among the 13 preharvest applied treatments, Cevya, Elysis, and Miravis Prime reduced brown rot of non-washed fruit after wound inoculation to the lowest levels. Cevya and Elysis were the only very effective treatments after postharvest washing of fruit that simulated a hydrocooler treatment, supporting the local systemicity of mefentrifluconazole. Regev and Cinnerate were moderately effective on non-washed fruit but were not effective on washed fruit. Absolute Maxx, Luna Sensation, and V6M-5-14 were effective after non-wound inoculation only.
   b. **Gray mold.** None of the treatments was highly effective after wound-inoculation of fruit. After non-wound inoculation of non-washed or washed fruit, Axios, Miravis Prime, Elysis, Merivon, and V6M-5-14 were the most effective.

5) **Postharvest studies** were conducted in the laboratory.
   a. Mixtures of the organically approved biofungicides natamycin (i.e., BioSpectra or Uniguard) and polyoxin-D (i.e., Oso) reduced the incidence of brown rot, gray mold, and Rhizopus rot to zero or very low levels, similar to Scholar or Chairman. This mixture would provide an effective postharvest decay management strategy for the organic sweet cherry sector. Unfortunately, the registrant of Oso is hesitant on a postharvest registration, and a new registrant has to be identified.

   b. A federal label was approved for Oso as an organic postharvest treatment along with natamycin for sweet cherry but the registrant has not marketed the product. The natamycin formulations BioSpectra and Cerafruta are certified by OMRI for organic postharvest use in the United States.

   c. New postharvest treatments evaluated were Miravis and Miravis Prime. Miravis Prime was highly effective due to its fludioxonil component. The second component, Miravis (FC 7) was not effective. Therefore, Miravis Prime will only be considered as a pre-harvest treatment.

6) **Management of Phytopythium and Phytophthora root rots**.

   a. In a greenhouse study with potted Mahaleb plants, Elumin, Orondis, and Ridomil Gold were the most effective in reducing root rot caused by *Phytopythium vexans,* whereas for root rot caused by *Phytophthora cambivora*, Orondis, Presidio, and Ridomil Gold reduced root rot incidence to the lowest levels, whereas ProPhyt, Elumin, and Revus were slightly less effective.

   b. Our manuscripts in Plant Disease on the use of these new fungicides for managing *Phytophthora* diseases of sweet cherry and on baseline sensitivities have been accepted.

   c. IR-4 residue studies with Orondis have been completed and registration of this fungicide on sweet cherry in the United States is pending in 2026. Elumin and Presidio are in the IR-4 program as of 2022 and 2023, respectively. Syngenta submitted a deciduous tree nursery registration for Revus in 2024 to the EPA to expand the nursery registration of this fungicide from container citrus to deciduous trees. The registration is expected in 2026.

INTRODUCTION

Management of bacterial blast and canker. Bacterial canker and blast with the main pathogen *Pseudomonas syringae* pv. *syringae* (*Pss*) can impact sweet cherry production and can have long-term effects on tree health. Cold, wet conditions favor both phases of the disease. After infection of twig and branch wounds, cankers develop with gumming around the infected, sunken bark tissue after several weeks to months. In contrast, blossom blast develops rapidly after infection, and flowers become dark to black, wilt, and die. Bacterial blast is commonly found on early-blooming varieties and on trees where rest-breaking treatments are applied that induce early flowering when cold, wet spring environments may be present. Bud death, spots on leaves and developing fruit, and spur cankers are additional symptoms of the blast phase of the disease.

Because copper resistance in pathogen populations is widespread in California, potential alternatives are being evaluated in this project. We demonstrated that kasugamycin (Kasumin), an antibiotic not used in animal or human medicine, can significantly reduce bacterial blast of sweet cherry and consistently reduce the severity of bacterial canker of inoculated branches. Based on our efforts, Kasumin was registered for management of these diseases of sweet cherry in early 2018. Studies with bacterial blast are difficult to do because favorable environmental conditions for disease are not always present at bloom time. Two studies were conducted on bacterial canker in 2024/25. We evaluated the new organic 8L formulation of Kasumin and obtained very good results. We are also pursuing oxytetracycline (Mycoshield), however, registration of this antibiotic on sweet cherry has been postponed by EPA without a new PRIA date but will be eventually evaluated under new regulations. Two GRAS antibacterial food additives (i.e., nisin and ε-poly-L-lysine - EPL) showed promising results in some studies previously, and EPL mixed with Seican and Manniplex Zn significantly reduced canker size as compared to the control in both 2025 studies. In collaboration with the Summit Agro chemical company, agrochemical formulations are being designed for nisin and EPL, and these are being tested. Still, new products are available for

testing in 2026. None of the other alternatives that we evaluated surpassed the efficacy of kasugamycin. These included the biocontrols Actinovate (fermentation product of *Streptomyces lydicus*), Blossom Protect/Botector (*Aureobasidium pullulans*), and YSY (*Papiliotrema* sp.), copper-enhancing compounds, inhibitors of the type III bacterial secretion system, a nano-particle zinc compound, Cinetis, a nutritional stress reducer, oxidizing sanitizers (e.g., Oxidate, Perasan), and various plant extracts.

Management of powdery mildew, blossom blight, and fruit rot. Fungicides and bactericides evaluated in 2025 for management diseases of sweet cherry are listed in Table 1. Powdery mildew of sweet cherry is a chronic problem in California because warm temperatures with low rainfall and high humidity from dews or irrigation are highly favorable for the disease. Flower sepals, leaves, and fruit may be infected. Symptomatic fruit need to be removed during sorting, or the lot is downgraded. Powdery mildew can also provide entry points for infection of fruit decay organisms. Additionally, powdery mildew is a quarantine disease in some export markets, and fruit for shipment may have to be certified as disease-free. With decreased sensitivity to some fungicides at some locations, new highly effective materials are needed to prevent the selection of resistant populations. Alternative fungicides that we evaluated previously include those in FRAC Codes (FCs) FC 3 - DMIs, FC 7 - SDHIs, FC 11 – QoIs, FC 13 – Quinolines, and FC 19 - polyoxins, pre-mixtures of FC 3/7, FC 3/11, FC 7/11, FC 7/12 (pending registration), as well as biological treatments in FCs 19 (e.g., Oso), BM 01 (e.g., ProBlad, Gargoil), and BM 02 (e.g., Serifel). In 2025, we evaluated the new powdery mildew fungicide Talendo (FC 13 - proquinazid) and the FC 29 Omega that were both nominated into the IR-4 program, and we also included the FC 53 Axios in our evaluations. In addition to conventional fungicides, we also included two new FC BM 01 products, BTS 100 and Cinnerate.

For management of brown rot and gray mold blossom blight and fruit rot caused by *Monilinia* spp. and *Botrytis cinerea,* selected fungicides belonging to FCs 3, 7, 9, 11, 12, 17, and 19 are effective. The pre-mixtures Quadris Top (FC 3/11), Luna Experience, Miravis Duo, and Elysis (Mibelya) (all FC 3/7), as well as Luna Sensation and Merivon (both FC 7/11) represent some of the best treatments for brown rot along with tank mixtures of FC 3 and 7 fungicides. Still, more new fungicides are being developed. They generally belong to the same FCs as previously registered compounds, but their activity against fungal pathogens is often different due to their different affinity to fungal target sites. Thus, the newer FC 7 Miravis (pydiflumetofen) and the FC 3 Cevya (mefentrifluconazole) have extremely high in vitro activities. Cevya and the new pre-mixtures Miravis Prime (FC 7/12) and Regev (FC 3/BM 01), the new FC 52 Axios, and the new experimental V6M-5-14 were included in our evaluations in 2024 and 2025. Gray mold blossom blight and fruit decay caused by *Botrytis cinerea* are much more difficult to manage. The DMI fungicides generally need to be complemented with other materials to obtain high efficacy. In our studies in 2025, Cevya, Regev, Miravis Prime, and Elysis showed activity against blossom blight, and preharvest treatments with Axios, Elysis, Miravis Prime, Merivon, and V6M-5-14 significantly reduced gray mold decay when treated fruit were non-wound inoculated. Additionally, Miravis Duo showed good efficacy as in previous years.

Management of postharvest fruit decay with postharvest treatments. We continue our efforts to provide effective and economic treatments for management of postharvest fruit decays caused by brown rot, gray mold, and Rhizopus rot. Currently, five FCs are registered as postharvest fungicides on sweet cherry in the United States as shown in Table 2. Judge (fenhexamid) FC 17 was withdrawn from postharvest use in the US several years ago. Natamycin is the first postharvest biofungicide that is exempt from tolerance in the United States, it has been approved for organic use, and it is certified by OMRI. Another organic OMRI-listed biofungicide that showed good efficacy especially when mixed with natamycin is Oso (polyoxin-D), however, the registrant currently does not want to pursue a postharvest registration. All of these fungicides are effective against brown rot and gray mold, but Penbotec and Oso are not active against Rhizopus rot. The DMI propiconazole (Mentor) is also effective against sour rot, a less common decay on sweet cherry. Chairman has the broadest spectrum of activity and is effective against all four decays. Of the compounds registered, Tebucon and Mentor are conventional fungicides, whereas Scholar and Penbotec are classified as ‘reduced-risk’ fungicides. Scholar, Penbotec, and Mentor received Food Additive Tolerances (FAT) in Japan, but the FAT for natamycin in Japan is still pending. Thus, continued studies on how to use these fungicides most efficiently for the Japanese and other Asian export markets are critical to the industry as we move toward organically approved products.

Table 1: Fungicides and bactericides used in 2025 studies*

Category	FRAC Code	Trade name	Active ingredient
Single active ingredients	M01	CS2005	Cu-sulfate pentahydrate
	3	Cevya	mefentrifluconazole
	4	Ridomil Gold	mefenoxam
	7	Miravis	pydiflumetofen
	12	Scholar	fludioxonil
	13	Talendo	proquinazid
	19/BM 01	Oso	polyoxin-D
	22	Elumin	ethaboxam
	29	Omega	fluazinam
	40	Revus	mandipropamid
	43	Presidio	fluopicolide
	48	BioSpectra, Uniguard	natamycin
	49	Orondis	oxathiapiprolin
	52	Axios	ipflufenoquin
	U12	Syllit	dodine
	P07 (33)	ProPhyt	potassium phosphite
Antibiotics	24	Kasumin 2L, 8L	kasugamycin
	41	NUP	oxytetracycline
Biologicals	BM 01	Cinnerate	cinnamon oil
	BM 01	Seican	cinnamaldehyde
	BM 01	BTS	*Quillaja saponaria* extract
	BM 01	PureCrop	soybean and corn oils
	Food additive	Nisin	nisin
	Food additive	EPL	ε-poly-L-lysine
	Plant defense inducer	Vacciplant	Laminarin
	Fertilizer	ManniPlex Zn	nitrate and urea nitrogen, zinc
Premixtures	3 + BM 01	Regev	difenoconazole + tea tree oil
	3 + 7	Elysis (Mibelya)	mefentrifluconazole + fluxapyroxad
	3 + 11	Absolute Maxx	tebuconazole + trifloxystrobin
	3 + 12	Chairman	propiconazole + fludioxonil
	7 + 11	Luna Sensation	fluopyram + trifloxystrobin
	7 + 11	Merivon	fluxapyroxad + pyraclostrobin
	7 + 12	Miravis Prime	pydiflumetofen + fludioxonil
	7 + 21	V6M-5-14	not disclosed

* - Chemicals are sorted by Fungicide Resistance Action Committee (FRAC) code or mode of action. Some treatments were used with adjuvants such as DyneAmic.

Table 2. Postharvest fungicides registered or pending registration on sweet cherry

				Performance*			
Trade names	Active ingredients	FRAC Code	FAT	Brown rot	Gray mold	Rhizopus rot	Sour rot
Tebucon, Teb	tebuconazole	3	no	+++	++	++	-
Mentor	propiconazole	3	yes	+++	++	++	+++
Scholar	fludioxonil	12	yes	+++	+++	+++	-
Chairman	fludioxonil/propiconazole	3/12	yes	+++	+++	+++	+++
BioSpectra**, Cerafruta	natamycin	48	no	++	++	++	+
Penbotec	pyrimethanil	9	yes	+++	+++	-	-
Oso**,***	polyoxin-D	19	no	+++	++	-	-

*- Performance is from +++ = excellent to 0 = no efficacy.
**- Organically certified by OMRI.
***- Federally labeled for preharvest use. Registrant currently does not support postharvest use.

Etiology and Management of Phytophthora root and crown rot. We identified new fungicides with different modes of action for managing Phytophthora root and crown rot diseases of tree fruit crops. Oxathiapiprolin (Orondis, FC 49), mandipropamid (Revus, FC 40), fluopicolide (Presidio, FC 43), and ethaboxam (Elumin, FC 22) are now registered on selected crops, and we are seeking registration on cherry, other stone fruit crops, and on almond with the registrants (i.e., Syngenta and Valent) through the IR-4 program. We determined the in vitro toxicity of these new fungicides to isolates of *Phytophthora* spp. from cherry, and we demonstrated their efficacy and evaluated their systemic properties in several field trials using inoculated trees. We also evaluated if the Oomycota fungicides are fungitoxic or fungistatic, and we demonstrated soil binding of Orondis in laboratory studies. In collaboration with growers, field studies with Orondis were successfully conducted in naturally infested orchards. These data were presented in previous reports and have been accepted for publication in Plant Disease.

In our surveys of causal pathogens of cherry tree decline, we often found *Phytopythium vexans* to be associated with declining trees. This Oomycota organism has also been described from several other tree crops in recent years. In greenhouse studies, we confirmed its pathogenicity to cherry roots, and in 2025, we again evaluated the new Oomycota fungicides as soil treatments for their efficacy against this new disease. Because the Oomycota fungicides vary in efficacy against Phytophthora and Phytopythium diseases, and moreover, mandipropamid is not effective against *Ph. vexans*, it is important to properly identify the causal agent of tree decline.

Our goal is to characterize and develop efficacy data for the new Oomycota fungicides so they can be made available to the sweet cherry industry, and best treatment strategies can be identified. This will allow for the development of resistance management programs with rotation and mixtures of different fungicides. Systemic action will benefit treatment performance because roots and crowns are protected from infection for extended periods. In cooperation with Syngenta, we are seeking mandipropamid registration for nursery production of tree fruit crops.

Objectives:

1. Evaluate new products against bacterial blast in flower inoculation studies and against canker in twig inoculation studies.
   a. Biocontrols/natural products (e.g., Blossom Protect, new formulations of nisin and ε-poly-L-lysine, natural plant products such as Problad and Seican without and with selected adjuvants): small-scale field trials.
   b. Antibiotics – kasugamycin, oxytetracycline: small- and large-scale trials if favorable environments are present and trials to improve penetration into plant tissue. These studies are needed to support registration of oxytetracycline.
2. Evaluate under field conditions bloom and preharvest applications of new conventional compounds: Cevya, Axios, Omega, new premixtures (Miravis Duo, Miravis Prime, Regev, Elysis, Absolute Maxx, V6M-5-14) for control of brown rot and Botrytis blossom blight, powdery mildew, and preharvest brown rot and gray mold fruit decay; and natural products (e.g., Oso, Cinnerate) for the control of powdery mildew.
3. Evaluate new fungicides as postharvest treatments:
   a. Continue to evaluate Chairman and support Scholar-natamycin mixtures for approved or pending (i.e., natamycin) food additive tolerance (FAT) in Japan, respectively.
   b. Continue to monitor for postharvest fungicide resistance in target pathogen populations.
   c. Continue to evaluate new and ‘exempt from tolerance’ biofungicides that are OMRI-approved for postharvest use. Evaluate Oso (polyoxin-D) mixtures with natamycin products in different ratios.
4. Evaluate new fungicides for managing Phytophthora root and crown rots of cherry
   a. Continue surveys on causal agents of cherry trees declining from apparent *Phytophthora* spp. infection. Collect root, crown, and rhizosphere soil from declining trees and isolate the causal pathogens by direct plating or pear baiting and identify pathogens based on morphology and DNA sequencing.
   b. Continue to establish in vitro baseline sensitivities to oxathiapiprolin, mandipropamid, fluopicolide, and ethaboxam (and possibly others like picarbutrazox) for newly collected isolates

of *Phytophthora* and *Phytopythium* spp. These will be used for future references in detecting potential resistance in the pathogens.

c. Conduct studies in the greenhouse and in commercial orchards in collaboration with growers.
    i. Conduct greenhouse studies with selected cherry rootstocks (e.g., Mazzard and Mahaleb) to characterize mobility of mandipropamid inside plants and support registration of mandipropamid for use in greenhouse container plants and tree propagation in nurseries.

5. Evaluate water sanitation treatments including VirusShield (non-oderiferous chlorine dioxide) and Oxidate 5.0 (PAA) for their efficacy to inactivate propagules of *P. cactorum*.

MATERIALS AND METHODS

Evaluation of new products against bacterial canker in twig inoculation studies. To evaluate bactericides (*see* Fig. 1 for the list of treatments), 1- to 2-year-old branches of cv. Coral cherry trees at UC Davis and in a commercial field in San Joaquin Co. were puncture-wounded laterally in Dec. 2024 using a nail to expose the cambium and wood (3 wounds/branch). Wounds were spray-treated and inoculated with *Pss* (4 x 10^7 cfu/ml) after air-drying. Branches were evaluated for gumming and canker formation in May 2025. A blast trial was initiated but disease did not develop.

Evaluation of new fungicides for control of powdery mildew. In a field trial in San Joaquin Co., treatments were done on at 20% bloom (3-19-25, Omega and Luna Sensation only), and at 80% bloom, 2 weeks after petal fall and 5 weeks after petal fall (all fungicides). These applications were targeted to provide protection from primary ascospore inoculum from overwintering chasmothecia and from infection by secondary conidial inoculum. Biological treatments, single fungicides, pre-mixtures, and three numbered experimentals were evaluated (see Fig. 2). Evaluation was done on 5-21-25. For this, 10 random terminal shoots each from inside or outside of the tree were rated for the severity of disease using the following scale: 0=healthy, 1=1-3 lesions, 2=<25%, 3=up to 50%, and to 4=>50% of leaf area diseased. Disease intensity was calculated as the multiplication product of disease incidence and severity rating.

Evaluation of new fungicides for control of gray mold and brown rot blossom blight. Fungicide applications for control of blossom blight were evaluated in a commercial orchard in San Joaquin Co. and at UC Davis. Treatments were applied on 3-19 and 3-25-25 in San Joaquin Co. and on 3-27 and 4-2-25 at UC Davis. Gray mold was evaluated on flower petals that were collected on 3-25-25 (San Joaquin Co.) or 4-2-25 (UC Davis) and incubated on moist vermiculite in the laboratory. Incidence of gray mold was based on ca. 40 petals for each of 4 treatment replications. For brown rot, open flowers were collected after the second fungicide application, placed onto moist vermiculite, and inoculated with *M. fructicola* (40,000 spores/ml). The incidence of diseased stamens was determined after 6 days of incubation at 20 C.

Evaluation of new fungicides for control of brown rot and Botrytis fruit decay. Preharvest fungicide applications for control of fruit decay were evaluated in a commercial orchard in San Joaquin Co. and at UC Davis. Treatments were applied at timings as indicated in Figs. 5-7 using a back-pack sprayer calibrated to deliver 100 gal/A. Fruit (8 fruit from each of four single-tree replication) were harvested, wounded with a glass rod (1 x 1 x 0.5 mm), and inoculated with 20 µl of a conidial suspension of *M. fructicola* or *B. cinerea* (30,000 or 40,000 spores/ml) or were non-wound drop-inoculated with *M. fructicola* or *B. cinerea* (300,000 spores/ml in 50% cherry juice) or non-wound spray-inoculated with *M. fructicola* (40,000 spores/ml). A sub-set of fruit was postharvest washed before inoculation, and this was done by gently agitating fruit in running water for 2 min. Fruit were incubated for 5-10 days at 20-24°C, >95% RH. Incidence of infection was determined as the number of fruit infected of the total number of fruit evaluated.

Efficacy of new and registered postharvest treatments for managing brown rot, gray mold, Rhizopus rot, and sour rot of sweet cherry. In laboratory studies, Oso, natamycin (Uniguard or BioSpectra), BTS 100, Miravis, and Miravis Prime were compared to Scholar or Chairman (*see* Figs. 8,9). Fruit were wound-inoculated with *M. fructicola, B. cinerea,* or *R. stolonifer* (40,000 spores/ml) as described above and treated after 12 h using an air-nozzle sprayer. After treatment, fruit were incubated for 4-7 days at 20°C, >95% RH.

Incidence of decay in these studies was determined as the number of infected fruit of the total number of fruit evaluated.

***Evaluate new fungicides for managing root rot caused by* P. cambivora *or* Ph. vexans.** In greenhouse studies, 8- to 12-week-old Mahaleb seedlings were planted into infested soil, and the soil was treated with selected fungicides. Fungicide rates were based on field rates that were proportionally reduced based on pot surface area. After 4 weeks, roots were plated onto a selective *Phytophthora* isolation medium, and the incidence of root rot was calculated based on the number of colonized root pieces of the total number of pieces plated.

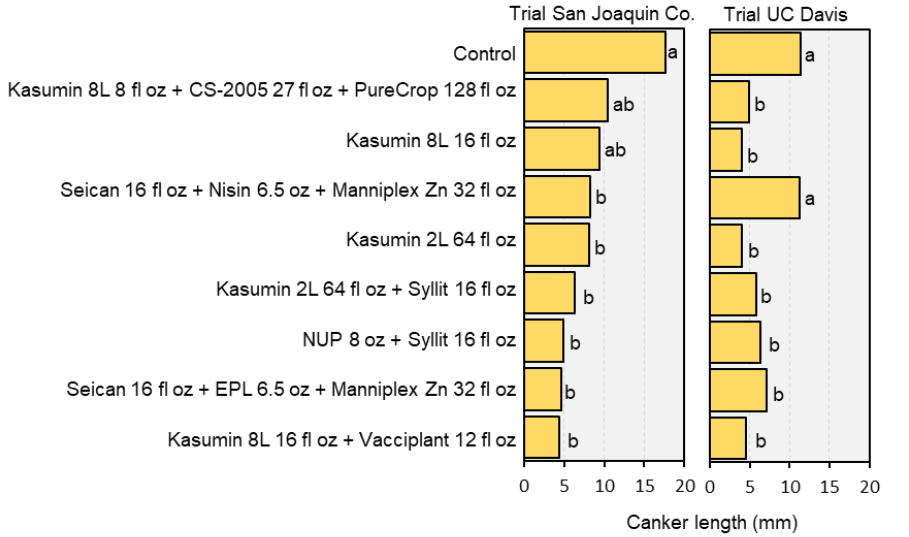
Statistical analyses. Data from the experiments described above were analyzed using analysis of variance and mean separation procedures of SAS 9.4.

RESULTS AND DISCUSSION

Evaluation of treatments for control of bacterial canker. In two trials on bacterial canker focused on the use of antibiotics with emphasis on the new organic 8L formulation of Kasumin and on mixtures containing EPL or nisin. Overall, treatments containing Kasumin resulted in the smallest cankers, and the 8L formulation performed similar to the 2L formulation (**Fig. 1**). The addition of Vacciplant or Syllit to Kasumin improved performance in one study but not the addition of the copper product CS-2005 and PureCrop. EPL mixed with Seican and Manniplex Zn as well as NUP+Syllit significantly reduced canker length from the control in both studies. The overall high efficacy of Kasumin 8L makes this a promising treatment for organic production. Kasumin previously showed good efficacy in reducing bacterial canker, and was also very effective in reducing the incidence of bacterial blast. Registration of the NUP product (oxytetracycline) is still being pursued on cherry with support of the registrant through the IR-4 program. The PRIA date was postponed several times by EPA, and currently, there is no new date provided by EPA. Because oxytetracycline is used in human medicine, new registrations on plants such as cherry are controversial and difficult. New agricultural formulations of EPL-Seican are still being developed by the potential registrant of this biological treatment.

Evaluation of new fungicides for control of powdery mildew of sweet cherry. Environmental conditions were favorable for powdery mildew development at our trial site in the spring of 2025. In late May, 100% of evaluated leaves on inside and outside shoots of control trees were diseased, but disease severity on shoots inside the canopy was higher. Mildew sequentially develops on 1) leaves of inside

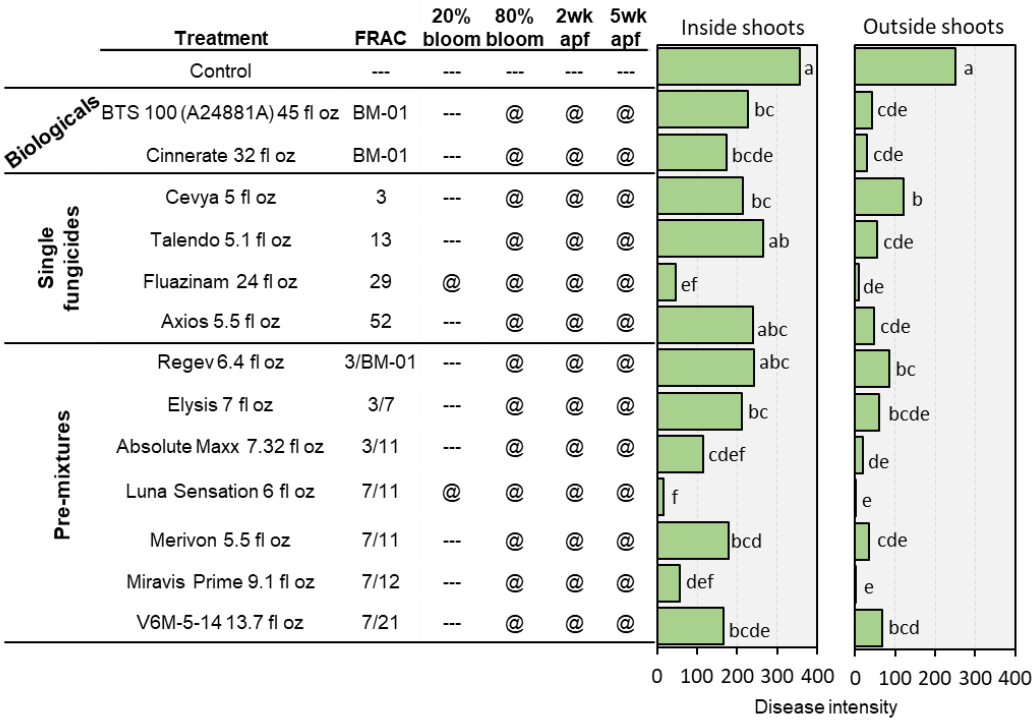
Fig. 1. Evaluation of antibacterial treatments for protection of cv. Coral cherry branches from bacterial canker - 2025



On 12-17-25 (UC Davis) or 12-27-24 (San Joaquin Co.), 1- to 2-year-old branches were wounded (3 wounds/branch; 2 mm deep, 2 mm in diameter) on the tree, sprayed with selected treatments using a hand sprayer, and spray-inoculated with *Pseudomonas syringae* (4×10^7 cfu/ml) after air-drying. Disease was evaluated in May 2025, and canker length was measured after removing the bark.

shoots (water sprouts); 2) leaves of outer shoots; 3) green stems of fruit; and 4) ripening fruit after color break. Young leaves are more susceptible than older ones, and the disease has not been found on green fruit. In our trial, treatments with the highest efficacy were Luna Sensation, Miravis Prime, and the new FC Omega (**Fig. 2**). Luna Sensation and Omega were applied four times in this trial based on an IR-4 protocol for Omega, whereas the other treatments were applied three times starting at full bloom. Earlier bloom applications may be necessary to obtain high efficacy. The other treatments evaluated were much less effective on the inside shoots, but all fungicides including the plant extracts Cinnerate and BTS 100 significantly reduced powdery mildew on the outside shoots where disease pressure was lower.

Fig. 2. Evaluation of preharvest fungicide treatments for management of powdery mildew of Bing cherry in San Joaquin Co. 2025



Applications were done using an airblast sprayer at 100 gal/A starting on 3-19-25 (20% bloom). DyneAmic (6 fl oz /A) was added to treatments in the third and fourth applications except for Cinnerate, Regev, and Miravis Prime. Evaluation was done on 5-21-25. For this, 10 random terminal shoots each from inside or outside of the tree were rated for the severity of disease using a scale from 0=healthy to 4=>50% of leaf area diseased. Disease intensity is the multiplication product of disease incidence and severity rating.

The new powdery mildew fungicide proquinazid (Talendo) was again among the least effective on inside shoots, likely because the pathogen at the trial location is resistant to FC 13 compounds that also includes quinoxyfen (Quintec).

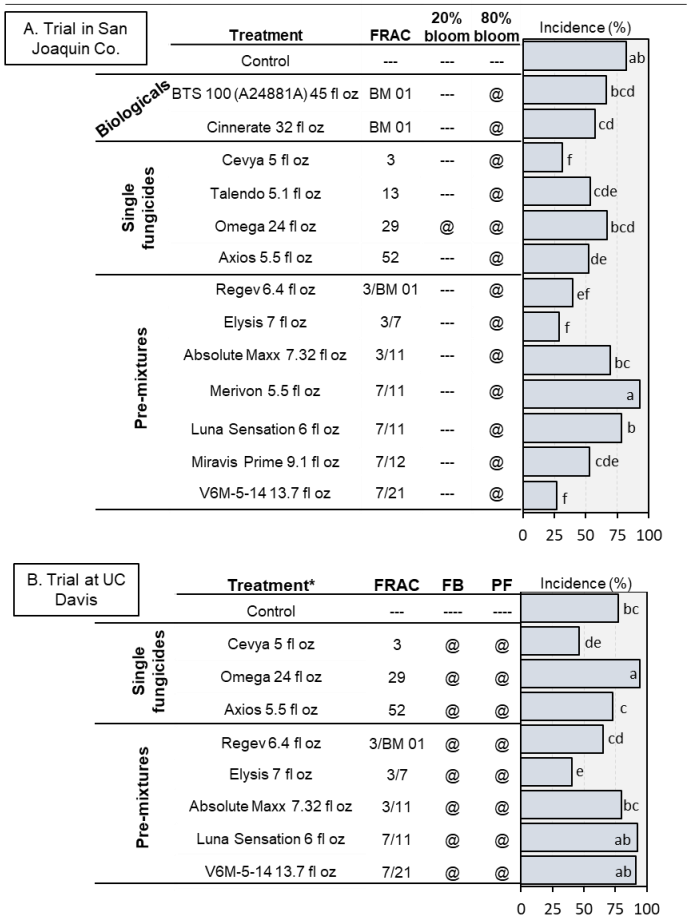
Our research demonstrates excellent activity of several registered and experimental compounds against powdery mildew and that the disease can be reduced to acceptable levels by properly timed applications. Effective treatments include several FCs with DMIs, SDHIs, and QoIs known to have high activity against powdery mildews. These can be used as pre-mixtures and/or in rotations with biological products such as Cinnerate as an anti-resistance strategy. This limits the use of any single-site mode of action fungicide (i.e., single FCs) and reduces the pressure for selecting for fungicide resistance. Limiting the number of applications of any one mode of action (i.e., FC) will also reduce the residue and ensure that MRLs are not exceeded with any of the trade partners of the cherry industry. Under conditions where fungicides need to be used as post-infection treatments when visible symptoms are already present on fruit, we showed previously that Ph-D can be used with a multi-site fungicide like Kaligreen or with FC 3 fungicides like Procure for effective suppression of the disease.

Evaluation of new fungicides for control of gray mold and brown rot blossom blight. Gray mold developed at a high natural incidence on collected flower petals from control trees (**Fig. 3**). In both studies, field treatments with Cevya and Elysis resulted in the lowest incidence, whereas the new V6M-5-14 was high effective only in the trial in San Joaquin Co. Miravis Prime, Axios, and Regev were also quite effective in the San Joaquin trial, but Axios and Regev were less effective in the UC Davis study (Miravis Prime was not included in the UC Davis study). For brown rot blossom blight where detached field-treated flowers were inoculated, Omega was compared to Luna Sensation as part of an IR-4 efficacy study. In both trials, Luna Sensation was significantly more effective than Omega, and Omega significantly reduced the incidence of infected stamens only in the UC Davis trial (**Fig. 4**).

Evaluation of preharvest treatments for management of fruit decays. Preharvest treatments that were mostly applied 6 days before harvest (a different timing was done for Omega and Luna Sensation as part of an IR-4 efficacy study) were evaluated on cv. Bing cherry in a commercial orchard in San Joaquin Co. Fruit were not washed or were washed before inoculation to simulate a hydrocooler treatment and subsequent inoculation during postharvest handling. Fungicide persistence after a postharvest hydrocooler treatment is important in an integrated pre- and postharvest decay management program, but especially if no postharvest fungicide treatment can be done. Harvested fruit were wound- or non-wound inoculated with *M. fructicola* or *B. cinerea*.

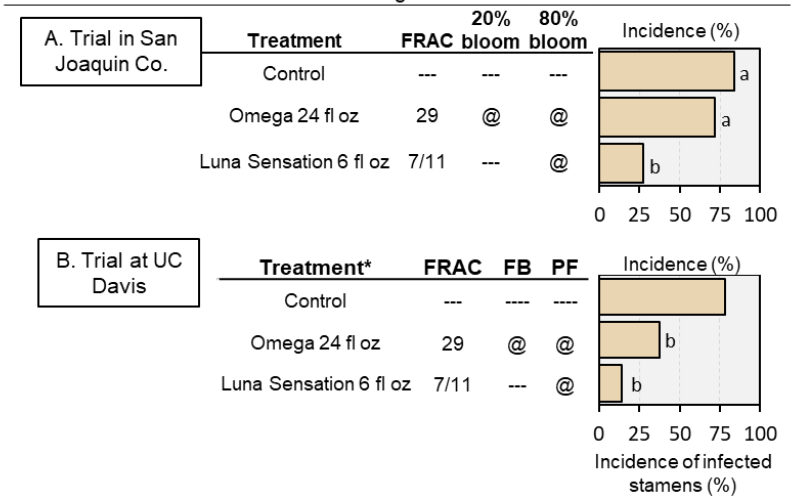
Among the 13 preharvest applied treatments, Cevya, Elysis, and Miravis Prime reduced brown rot of non-washed fruit after wound inoculation to 15.6% incidence or less as compared to 71.9% of the control (**Fig. 5**). Thus overall, as in 2023 and 2024, Cevya and Elysis had among the lowest decay incidence, and these two treatments were the only very effective ones after postharvest washing that simulated a hydrocooler treatment, supporting the local systemicity of mefentrifluconazole. Regev and Cinnerate were

Fig. 3. Efficacy of fungicide applications to Bing sweet cherry in the field for control of gray mold blossom blight of detached flowers - 2025



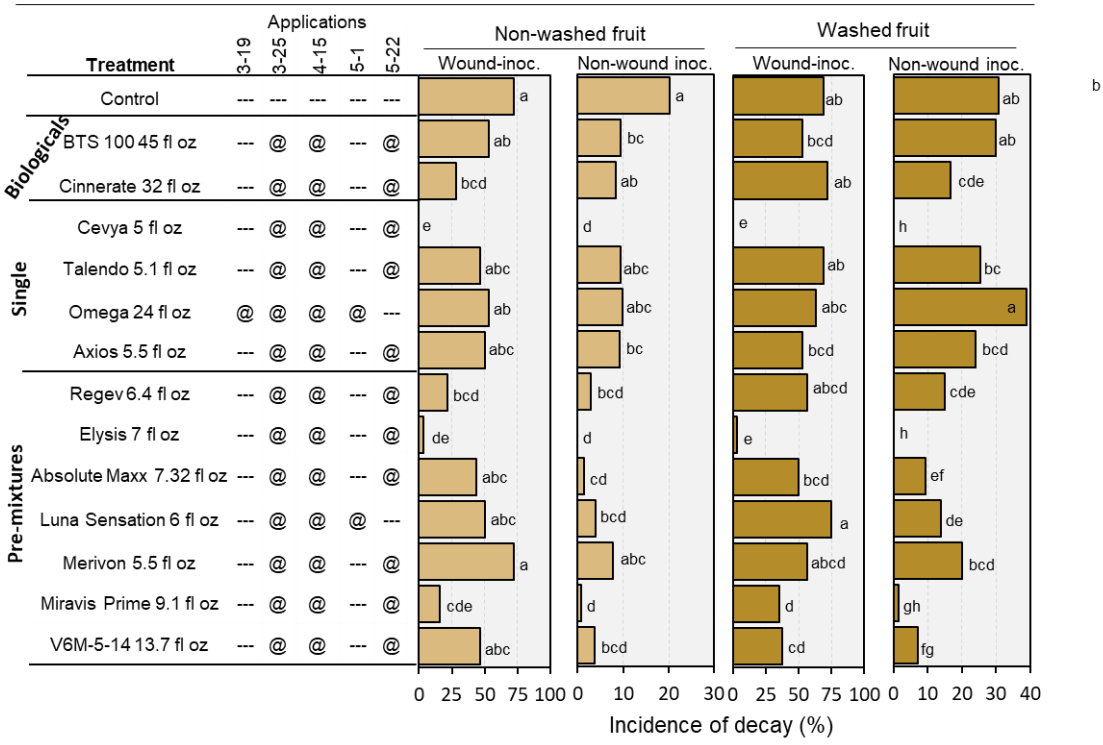
Applications were done using an airblast sprayer at 100 gal/A on 3-19 and 3-25-25 in San Joaquin Co. and on 3-27 and 4-2-25 at UC Davis. Gray mold was evaluated on flower petals that were collected on 3-25-25 (San Joaquin Co.) or 4-2-25 (UC Davis) and incubated on moist vermiculite in the laboratory.

Fig. 4. Efficacy of fungicide applications to Bing sweet cherry in the field for control of brown rot blossom blight of detached flowers - 2025



Applications were done using an airblast sprayer at 100 gal/A on 3-19 and 3-25-25 in San Joaquin Co. and on 3-27 and 4-2-25 at UC Davis. Open flowers were collected after the second fungicide application, placed onto moist vermiculite, and inoculated with *M. fructicola* (40,000 spores/ml). The incidence of diseased stamens was determined after 6 days of incubation at 20C.

Fig. 5. Efficacy of preharvest fungicide treatments for management of postharvest brown rot of Bing cherries - San Joaquin Co. 2025



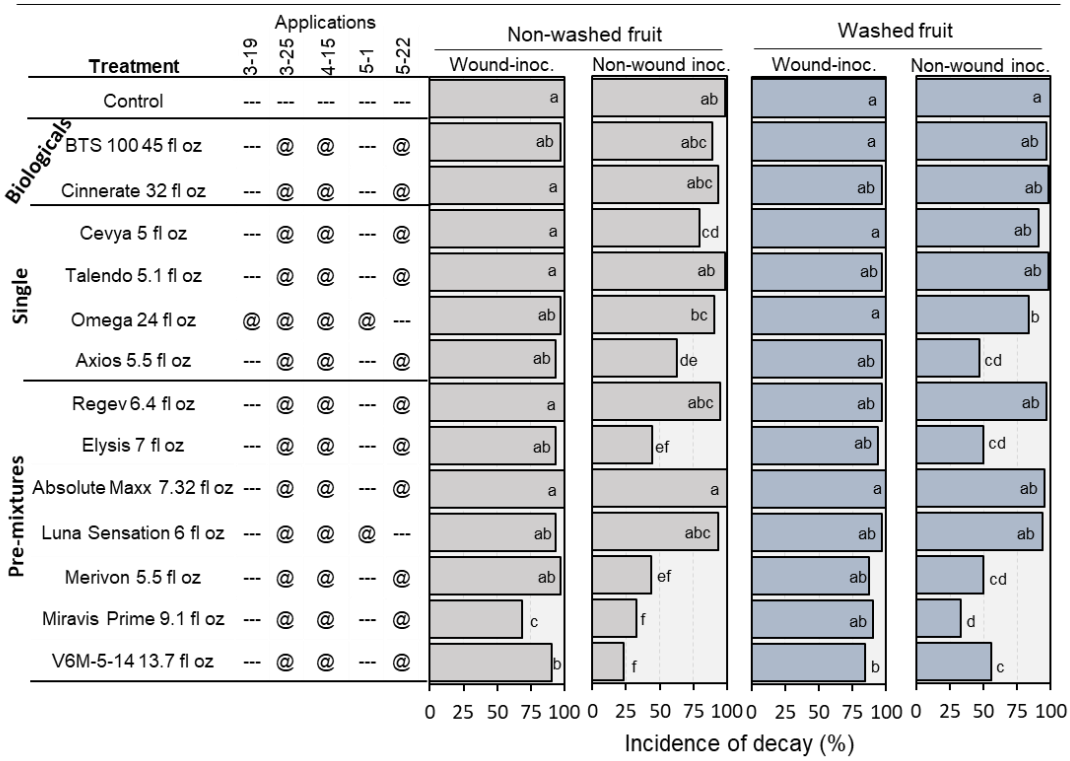
b

Treatments were applied starting at 20% bloom (fluazinam only) using an air-blast sprayer at a rate of 100 gal/A, and all except Cinnerate, Regev, and Miravis Prime were done in combination with DynAmic at 8 fl oz/A. Early-season treatments were part of a powdery mildew program, whereas the last timing was specifically targeted towards fruit decay. Fruit were harvested on 5-28-25. Washing was done by gently agitating in water for 2 min. Fruit were wound-inoculated or non-wound spray-inoculated with *M. fructicola* (40,000 spores/ml). Fruit were then incubated for 5-10 days at 24C.

moderately effective on non-washed fruit were, but not effective on washed fruit. Several treatments with low efficacy on wounded fruit were more effective after non-wound inoculation, and these included Absolute Maxx, Luna Sensation, and V6M-5-14 (**Fig. 5**).

Gray mold again was more difficult to manage, and none of the treatments was highly effective after wound-inoculation of fruit. Miravis Prime had the best efficacy with 68.8% decay incidence as compared to 100% in the control (**Fig. 6**). After non-wound inoculation of non-washed fruit, treatments were more effective, and Miravis Prime and V6M-5-14 reduced decay incidence from 98.5% in the control to 32.9% or 23.5%, respectively (**Fig. 6**). Axios, Elysis, and Merivon were also effective, and these five treatments also significantly reduced decay of washed fruit.

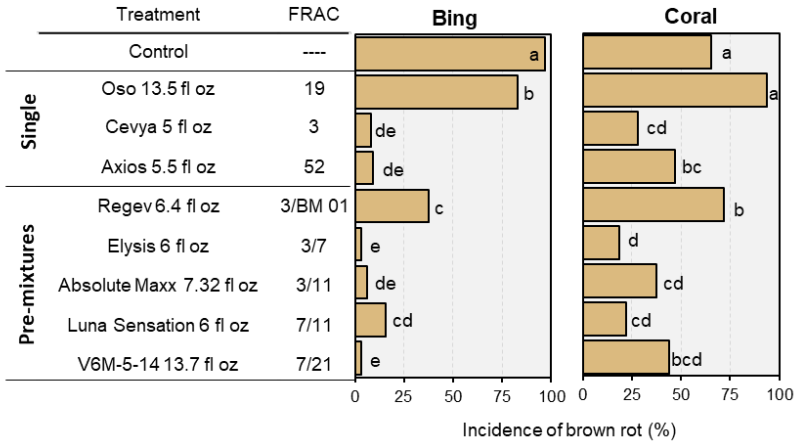
Fig. 6. Efficacy of preharvest fungicide treatments for management of postharvest gray mold of Bing cherries - San Joaquin Co. 2025



Treatments were applied starting at 20% bloom (fluazinam only) using an air-blast sprayer at a rate of 100 gal/A, and all except Cinnerate, Regev, and Miravis Prime were done in combination with DynAmic at 8 fl oz/A. Early-season treatments were part of a powdery mildew program, whereas the last timing was specifically targeted towards fruit decay. . Fruit were harvested on 5-28-25. Washing was done by gently agitating in water for 2 min. Fruit were wound-inoculated (30,000 spores/ml) or non-wound drop-inoculated (300,000 spores/ml) with *B. cinerea*. Fruit were then incubated for 5-10 days at 24C.)

Preharvest-treated Bing and Coral fruit from the UC Davis trial were evaluated against brown rot. All treatments were more effective on the Bing fruit (**Fig. 7**). Cevya, Elysis, Axios, Absolute Maxx, Luna Sensation, and V6M-5-14 were highly effective in reducing decay after non-wound inoculation, whereas Regev was less effective and Oso only slightly reduced the incidence of decay. The most effective treatments on Coral fruit were Cevya, Elysis, and Luna Sensation.

Fig. 7. Efficacy of 7-day PHI fungicide treatments for management of postharvest brown rot of Bing and Coral cherry – UC Davis 2025

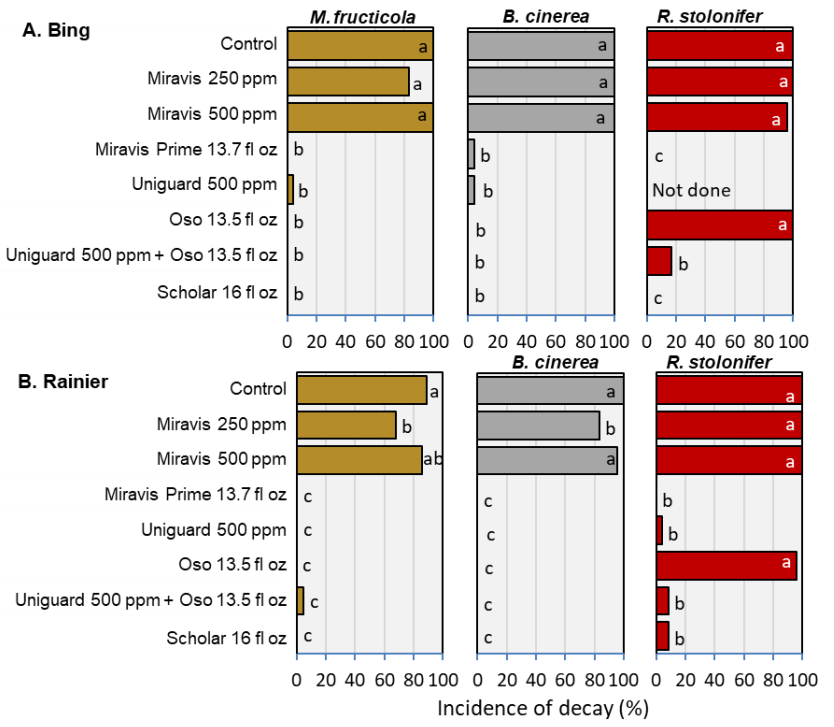


Treatments were applied using an air-blast sprayer at a rate of 100 gal/A on 5-21-25 (Bing) or 5-22 (Coral). Fruit were non-wound-inoculated with (300,000 spores/ml in 25% cherry juice) and incubated for 7 days at 20C.

Our studies demonstrate that preharvest treatments with a range of conventional fungicides can effectively protect fruit from brown rot infections before and during harvest when inoculum is disseminated to the non-wounded fruit surface or when pre-existing, potentially contaminated, wounds are treated. When wounds occur after treatments and inoculum is deposited, the new Cevya and Elysis as well as Miravis Prime were found to be highly effective in preventing brown rot decay, and they apparently penetrate the fruit where they are present at high enough amounts to stop fungal development. For gray mold decay control, we identified Miravis Prime and V6M-5-14 as very promising treatments. Axios was highly effective in 2024 but was less effective in 2025. Miravis Prime (pydiflumetofen + fludioxonil) was accepted in 2021 into the IR-4 residue program. The planned registration on sweet cherry based on current communications indicate that registration is still pending. Even when preharvest treatments are properly applied, postharvest decays can still develop from injuries occurring during bulk handling of fruit if the fungicides lack local systemic action. Additionally, hydrocooling will reduce or remove residues of many fungicides. Therefore, additional postharvest treatments need to be done.

Efficacy of new postharvest treatments for managing brown rot, gray mold, Rhizopus rot, and sour rot of sweet cherry. Postharvest laboratory studies were performed where treatments were applied to fruit approximately 12 h after inoculation. Studies focused on currently registered and new fungicides. As previously established, natamycin (applied as BioSpectra or Uniguard) was very effective against brown rot and Rhizopus rot, and sometimes less effective against gray mold, whereas Oso was highly effective against brown rot and gray mold, but not effective against Rhizopus rot (**Figs. 8,9**).

Fig. 8. Evaluation of new and registered fungicides as postharvest treatments to manage major decays of Bing and Rainier cherry in laboratory studies in 2025

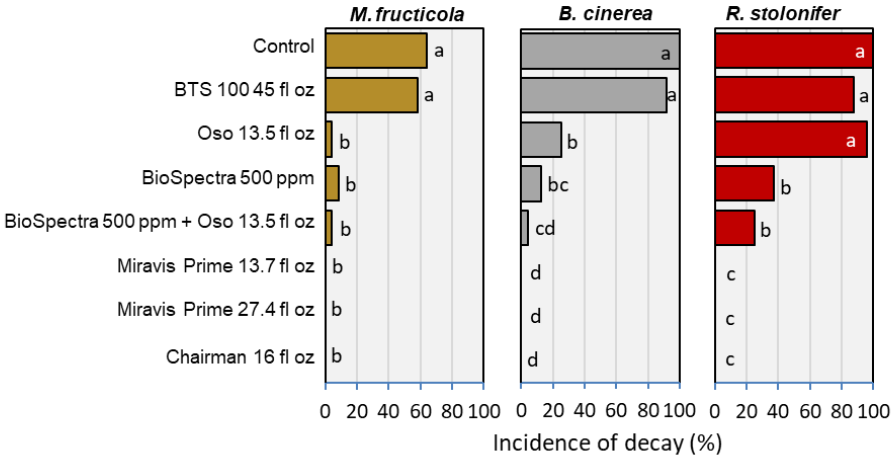


Fruit were wound-inoculated with spores of *M. fructicola*, *B. cinerea*, or *R. stolonifer* (40,000 spores/ml) and incubated for 12 h at 20C. Aqueous treatments were applied using an air-nozzle sprayer. Fruit were incubated at 20C for 4-7 days.

A mixture of natamycin with Oso reduced the three major decays to zero or very low levels, similar to Scholar or Chairman (**Figs. 8,9**). Because both treatments are registered for organic production, this mixture would provide an effective postharvest decay management strategy for the organic sector of sweet cherry marketing. Unfortunately, the registrant of Oso is not pursuing a postharvest registration (Oso is still registered for preharvest use where we found it to be of low efficacy), and a new registrant has to be identified. CODEX will still have to accept the US biopesticide classification, and MRLs need to be established worldwide. With increasing emphasis on food safety and consumer concerns on pesticide-treated food products,

natamycin and polyoxin-D with 'exempt from tolerance' status and OMRI certification could become important components of postharvest decay management in the future. As we indicated previously, natamycin is an exciting compound because resistance has never been reported in filamentous fungi. Therefore, it can have an important role in reducing the risk of selecting resistant sub-populations of the decay pathogens to other registered postharvest fungicides when mixed with these fungicides. When integrated with fruit sanitation, removal of injured and over-ripe fruit, and cold-temperature management postharvest crop losses can be minimized.

Fig. 9. Evaluation of new and registered fungicides as postharvest treatments to manage major decays of Bing cherry in laboratory studies in 2025

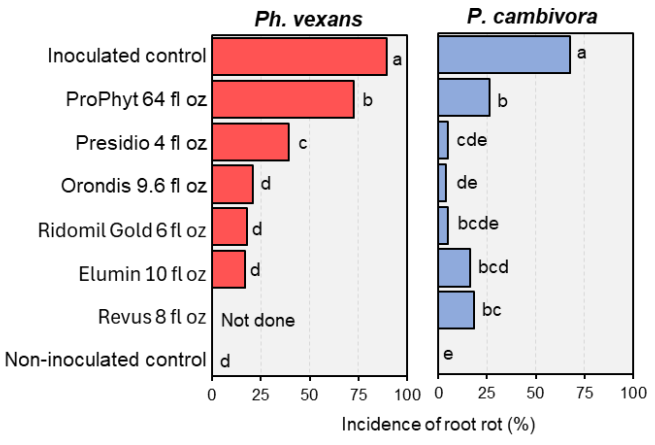


Fruit were wound-inoculated with spores of *M. fructicola*, *B. cinerea*, or *R. stolonifer* (40,000 spores/ml) and incubated for 12 h at 20C. Aqueous treatments were applied using an air-nozzle sprayer. Fruit were incubated at 20C for 4-7 days.

New postharvest treatments evaluated were Miravis and Miravis Prime. Miravis Prime was similarly effective as Scholar or Chairman against the three decays (**Figs. 8,9**), but the Miravis (pydiflumetofen) component of the Miravis Prime pre-mixture was not effective (**Fig. 8**) even when used at 1000 ppm (data not shown). This indicates that fludioxonil in the pre-mixture is responsible for its high effectiveness. Therefore, Miravis Prime will no longer be considered as a postharvest treatment.

***Evaluate new fungicides for managing root rot caused by* P. cambivora *or* Ph. vexans.** In a greenhouse study with potted Mahaleb plants, Elumin, Orondis, and Ridomil Gold were the most effective in reducing root rot caused by *Ph. vexans* (**Fig. 10**). As in previous studies, ProPhyt was the least effective, and Presidio was intermediate. Revus was not included in this evaluation, because *Phytopythium* spp. are

Fig. 10. Efficacy of soil-applied fungicide treatments for control of root rot of Mahaleb plants after soil inoculation with *Phytopythium vexans* or *Phytophthora cambivora* in greenhouse studies 2025



8- to 12-week-old Mahaleb seedlings were planted into infested soil, and the soil was treated with selected fungicides. Fungicide rates were based on field rates that were proportionally reduced based on pot surface area. After 4 weeks, roots were plated onto a selective medium, and the incidence of root rot was calculated based on the number of colonized root pieces of the total number of pieces plated. Data are the average of two experiments.

intrinsically not sensitive to this fungicide. For plants inoculated with *P. cambivora*, Orondis, Presidio, and Ridomil Gold reduced root rot incidence to the lowest levels, whereas ProPhyt, Elumin, and Revus were somewhat less effective. Considering that *Ph. vexans* is increasingly being associated with root rot of sweet cherry, these results indicate that root rot caused by both Oomycota genera can be most effectively managed using Orondis, Elumin, and Ridomil Gold, but Presidio is more effective against *P. cambivora*.

Orondis was in the IR-4 program, and the final report was submitted to Syngenta in 2024 with federal registration expected in 2026. Elumin and Presidio were accepted into the IR-4 program in 2022 and 2023, respectively. Residue studies for both fungicides are ongoing. Revus is planned to be registered for nursery use by Syngenta in 2026. The goal is to have four new fungicides in addition to potassium phosphite and Ridomil Gold for use on cherry. This way, resistance management can be practiced with different MOAs applied in the nursery (potassium phosphite, Ridomil Gold, Revus – pending) and in spring and fall applications (potassium phosphite, Ridomil Gold, Orondis, Presidio, Elumin) in recently planted orchards and in orchards that have a history of Phytophthora or Phytopythium diseases.

Management and epidemiology of pre- and postharvest diseases of sweet cherry

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University of California, Riverside

Cooperating:
H. Forster, D. Thompson

Managing of pre- and postharvest diseases of sweet cherry

"One of the best ways to manage foliar and fruit diseases of tree crops is to apply effective materials that inhibit the growth of the fungal or bacterial pathogens."

"This process of screening and developing new active ingredients and working with registrants and IR-4 is the most direct way of obtaining registered materials for growers of the commodity."

Table 1: Fungicides and bactericides used in 2025 studies*

Category	FRAC Code	Trade name	Active ingredient	
Single active ingredients	M01	CS2005	Cu-sulfate pentahydrate	16
	3	Cevya	mefentrifluconazole	
	4	Ridomil Gold	mefenoxam	
	7	Miravis	pydiflumetofen	
	12	Scholar	fludioxonil	
	13	Talendo	proquinazid	
	19/BM 01	Oso	polyoxin-D	
	22	Elumin	ethaboxam	
	29	Omega	fluazinam	
	40	Revus	mandipropamid	
	43	Presidio	fluopicolide	
	48	BioSpectra, Uniguard	natamycin	
	49	Orondis	oxathiapiprolin	
	52	Axios	ipflufenoquin	
	U12	Syllit	dodine	
	P07 (33)	ProPhyt	potassium phosphite	
Antibiotics	24	Kasumin 2L, 8L	kasugamycin	2
	41	NUP	oxytetracycline	
Biologicals	BM 01	Cinnerate	cinnamon oil	8
	BM 01	Seican	cinnamaldehyde	
	BM 01	BTS	*Quillaja saponaria* extract	
	BM 01	PureCrop	soybean and corn oils	
	Food additive	Nisin	nisin	
	Food additive	EPL	ε-poly-L-lysine	
	Plant defense inducer	Vacciplant	Laminarin	
	Fertilizer	ManniPlex Zn	nitrate and urea nitrogen, zinc	
Premixtures	3 + BM 01	Regev	difenoconazole + tea tree oil	8
	3 + 7	Elysis (Mibelya)	mefentrifluconazole + fluxapyroxad	
	3 + 11	Absolute Maxx	tebuconazole + trifloxystrobin	
	3 + 12	Chairman	propiconazole + fludioxonil	
	7 + 11	Luna Sensation	fluopyram + trifloxystrobin	
	7 + 11	Merivon	fluxapyroxad + pyraclostrobin	
	7 + 12	Miravis Prime	pydiflumetofen + fludioxonil	
	7 + 21	V6M-5-14	not disclosed	

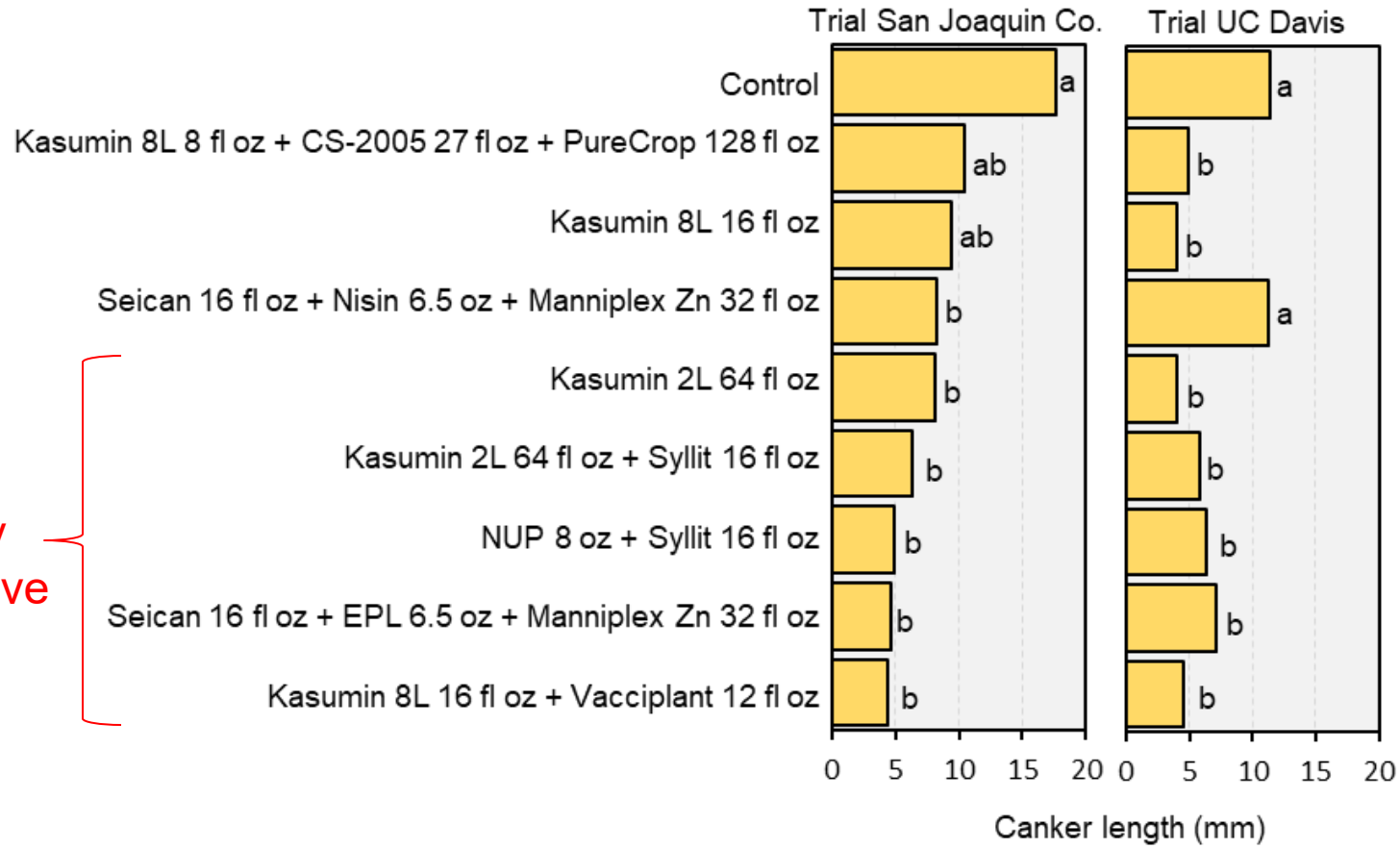
Sum= **36**

* - Chemicals are sorted by Fungicide Resistance Action Committee (FRAC) code or mode of action. Some treatments were used with adjuvants such as DyneAmic.

Bacterial blast and canker of sweet cherry

- Associated with any injury (cold or mechanical) or stress during cool, wet conditions
- Symptoms: Cankers with progressive dieback

Evaluation of antibacterial treatments for protection of cv. Coral branches from bacterial canker – 2025



Highly effective

On 12-17-25 (UC Davis) or 12-27-24 (San Joaquin Co.), 1- to 2-year-old branches were wounded (3 wounds/branch; 2 mm deep, 2 mm in diameter) on the tree, sprayed with selected treatments using a hand sprayer, and spray-inoculated with *Pseudomonas syringae* (4×10^7 cfu/ml) after air-drying. Disease was evaluated in May 2025, and canker length was measured after removing the bark.

Management of bacterial canker and blast

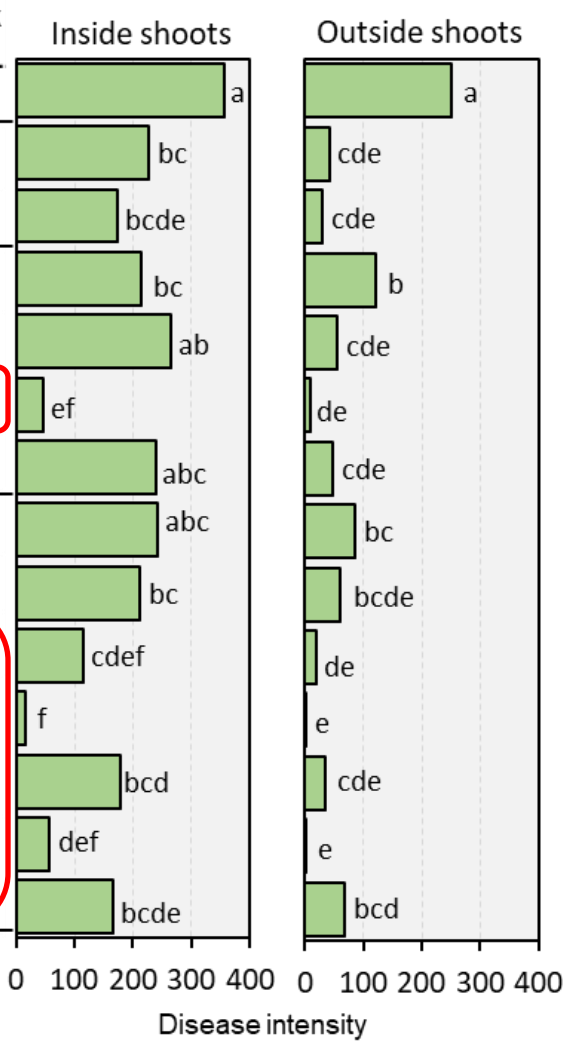
- **Copper**: inconsistently suppressive – resistance widespread
- **Kasumin:** highly and consistently effective. Registered in 2018
- **Mycoshield/FireLine:** Pending registration at EPA since 2018 (2025?)
- **Biocontrols** (Actinovate, Botector)/**PAA** (non-persistent): inconsistent.
- **New products identified** (nisin, Ɛ-poly-L-lysine, cinnamaldehyde)
- **Timing**:
  - *Canker* – Cold wet (windy) conditions favoring disease and immediately after frost injury (1-day).
  - *Blast* - A bloom treatment with Kasumin or Mycoshield (pending) in combination with fungicides for blossom blight for trees treated with rest-breaking compounds

Evaluate, under field conditions, bloom and preharvest applications of new compounds, premixtures, and biologicals

- Brown rot and Botrytis blossom blight
- Powdery mildew
- Gray mold fruit decay
- Brown rot fruit rot

Preharvest fungicide treatments for management of powdery mildew of Bing cherries 2025

	Treatment	FRAC	20% bloom	80% bloom	2wk apf	5wk apf
	Control	---	---	---	---	---
Biologicals	BTS 100 (A24881A) 45 fl oz	BM-01	---	@	@	@
	Cinnerate 32 fl oz	BM-01	---	@	@	@
Single fungicides	Cevya 5 fl oz	3	---	@	@	@
	Talendo 5.1 fl oz	13	---	@	@	@
	Fluazinam 24 fl oz	29	@	@	@	@
	Axios 5.5 fl oz	52	---	@	@	@
Pre-mixtures	Regev 6.4 fl oz	3/BM-01	---	@	@	@
	Elysis 7 fl oz	3/7	---	@	@	@
	Absolute Maxx 7.32 fl oz	3/11	---	@	@	@
	Luna Sensation 6 fl oz	7/11	@	@	@	@
	Merivon 5.5 fl oz	7/11	---	@	@	@
	Miravis Prime 9.1 fl oz	7/12	---	@	@	@
	V6M-5-14 13.7 fl oz	7/21	---	@	@	@



New and effective

New: Talendo (proquinazid) and Omega (fluazinam) are in the IR-4 program.

Applications starting at 50% bloom starting a 3-19. Evaluation on 5-21-25. Terminal shoots from inside or outside of the tree were rated for the severity of disease: 0=healthy to 4=>50% of leaf area diseased.

Efficacy of bloom fungicide treatments for management of Botrytis blossom blight rot of Bing cherries - San Joaquin Co. - 2025

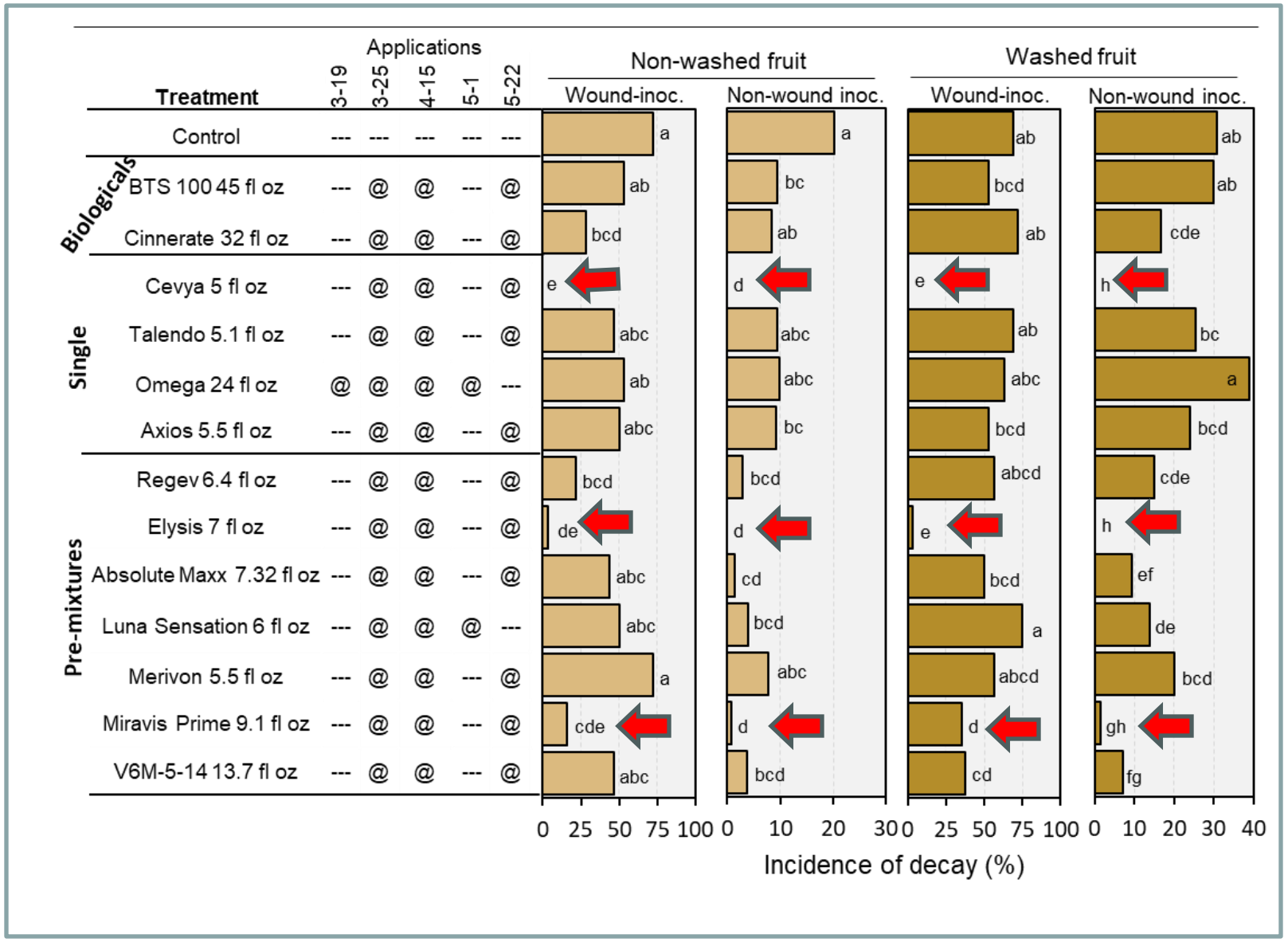
A. Trial in San Joaquin Co.

	Treatment	FRAC	20% bloom	80% bloom	Incidence (%)
	Control	---	---	---	ab
Biologicals	BTS 100 (A24881A) 45 fl oz	BM 01	---	@	bcd
Biologicals	Cinnerate 32 fl oz	BM 01	---	@	cd
Single fungicides	Cevya 5 fl oz	3	---	@	f
Single fungicides	Talendo 5.1 fl oz	13	---	@	cde
Single fungicides	Omega 24 fl oz	29	@	@	bcd
Single fungicides	Axios 5.5 fl oz	52	---	@	de
Pre-mixtures	Regev 6.4 fl oz	3/BM 01	---	@	ef
Pre-mixtures	Elysis 7 fl oz	3/7	---	@	f
Pre-mixtures	Absolute Maxx 7.32 fl oz	3/11	---	@	bc
Pre-mixtures	Merivon 5.5 fl oz	7/11	---	@	a
Pre-mixtures	Luna Sensation 6 fl oz	7/11	---	@	b
Pre-mixtures	Miravis Prime 9.1 fl oz	7/12	---	@	cde
Pre-mixtures	V6M-5-14 13.7 fl oz	7/21	---	@	f

0 25 50 75 100

Treatments were applied on 3-19, 3-25-25 using an air-blast sprayer at a rate of 100 gal/A. Blossoms were spray-inoculated (30,000 spores/ml with *B. cinerea*. Blossoms were then incubated for 5-7 days at 24C.

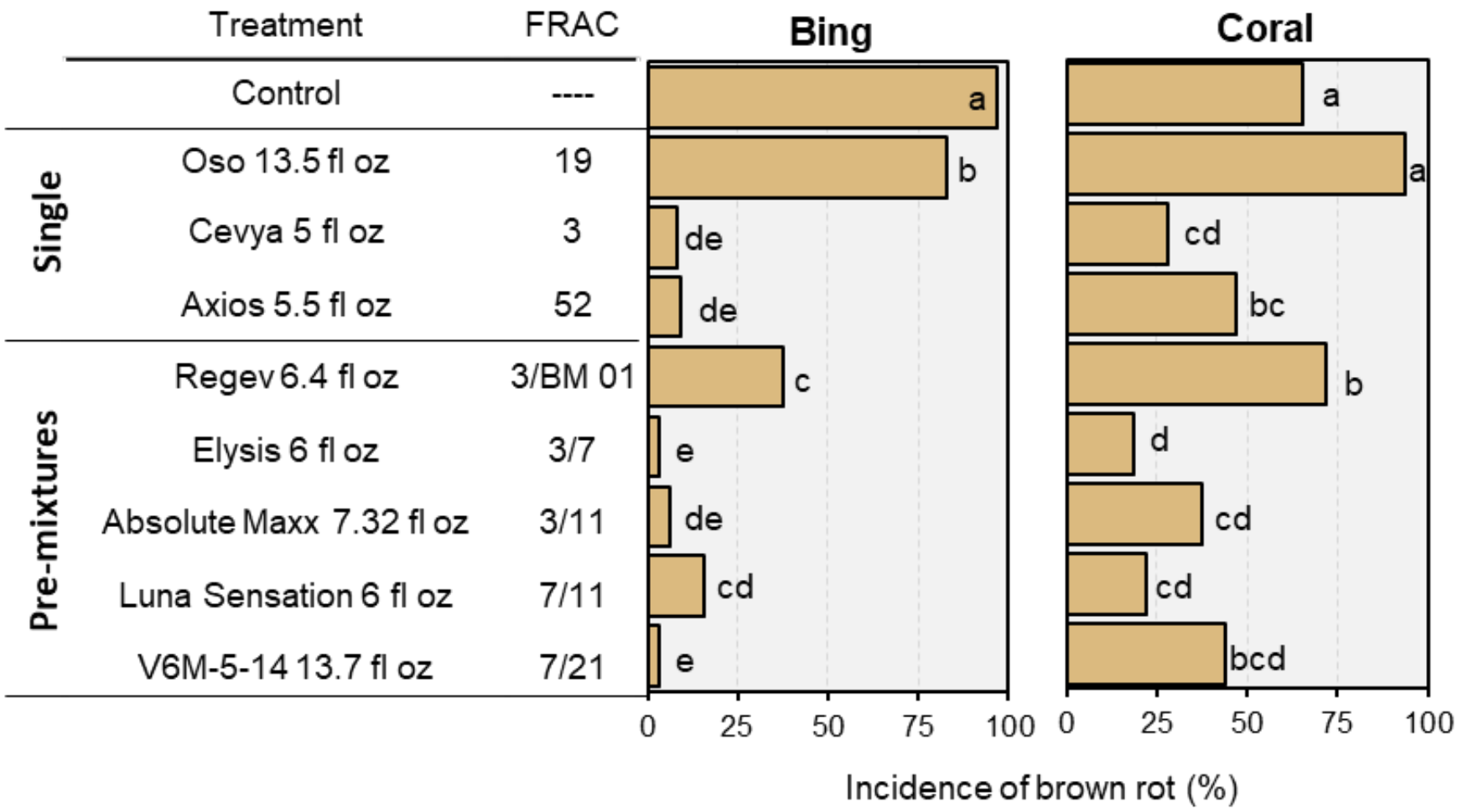
Evaluation of new fungicides for managing postharvest brown rot of Bing cherry in field studies 2025



Treatments were applied using an air-blast sprayer at a rate of 100 gal/A, and all except Regev and Miravis Prime were done in combination with DynAmic at 8 fl oz/A.

Harvested fruit (5-28) were washed by gently agitating in water for 2 min. Fruit were wound-inoculated (30,000 spores/ml) or non-wound drop-inoculated (300,000 spores/ml 25% cherry juice) with *M. fructicola*. Fruit were then incubated for 5-10 days at 24C.

Evaluation of new fungicides for managing postharvest brown rot of cvs. Bing and Coral Champagne cherry in field studies - 2025



Treatments were applied using an air-blast sprayer at a rate of 100 gal/A on 5-21-25 (Bing) or 5-22 (Coral). Fruit were non-wound-inoculated with (300,000 spores/ml in 25% cherry juice) and incubated for 7 days at 20C.

Fungicides for Sweet Cherry

- Proposed restrictions
- Proposed cancelation

Single-fungicides - Inorganics and Conventional Synthetics

Inorganics
M1: Copper, Sulfur — 1960s

Dithiocarbamates
M2: Ziram, (Maneb) — 1940s

Phthalimides
M3: Captan — 1950s

Isophthalonitriles
M4: Bravo, Echo, Equus — 1960s

Aromatic Hydrocarbons
14: Botran — 1960s

Benzimidazoles
1: Topsin-M, T-Methyl — 1970s

Dicarboximides
2: Rovral, Meteor — 1980s

Sterol inhibitors (DMIs)
3: Tebucon/Toledo, Indar, Tilt, Procure, Quash, Rally, Rubigan, Rhyme, Cevya — 1970s – 1980s

PM Fungicides

Quinolines
13: Quintec, *Proquinazid* — 2000s

Benzophenones
50: Vivando, Gatten

SDHIs
7: Endura, Luna Privilege, Kenja, Fontelis — 1960s

QoIs
11: Abound, Gem, Cabrio — 1990s

Hydroxyanilides
17: Elevate — 1990s

Polyene macrolides
48: BioSpectra, CeraFruta, Uniguard

Polyoxins
19: Ph-D, Tavano, Oso — 1960s

DHODHI
52: Axios, pending

New 2025: Cevya, Miravis Duo, Elysis, Regev, BioSpectra/Cerafruta (postharvest). *Pending*: Axios, Parade, Miravis Prime

Multi-site MOA | Single-site MOA | Reduced risk fungicides

Premixture Fungicides and Natural Alternatives for Managing Cherry Diseases

Conventional Synthetic Fungicides – Pre-mixtures

- Quadris Top, Quilt Xcel — 3+11
- Pristine, Luna Sensation, Merivon — 7+11
- Miravis Duo, Luna Experience, **Elisys** — 3+7
- **Pending** — **Miravis Prime** — 7+12
- **New** — **Regev** — 3+BM01
- **New** — Experimentals – for PM, BR and GM — X+Y

Natural Products, Biocontrols, Fermentation Extracts

- Regalia, EF400, ProBlad Verde, Timorex Act, EcoSwing, BacStop — BM 01
- Actinovate, Botector, Serenade, Howler, Theia, AVIV — BM 02
- Seican, Cinnerate, Cinnacure — BM 03
- Ph-D/Oso, BioSpectra, Uniguard, CeraFruta — Fermentation Products

3 DMIs | 7 SDHIs | 11 QoIs | BM 01 Plant Extracts | BM 02 Biological Controls | BM 03 Cinnamaldehyde

Natural products and biocontrols that already are or potentially will be OMRI approved are being continuously evaluated for organic farming of stone fruits.

Statewide IPM Program - *www.ipm.ucdavis.edu*

Bold = not registered

Crown rot with associated cankers and gumming followed by tree death are the most common symptoms of *Phytophthora* sp. infection on sweet cherry

Infected trees decline and may die.

Five species of *Phytophthora* (*P. cactorum, P. cambivora, P. cryptogea, P. syringae,* and an unidentified species) and *Phytopythium vexans* were recovered.

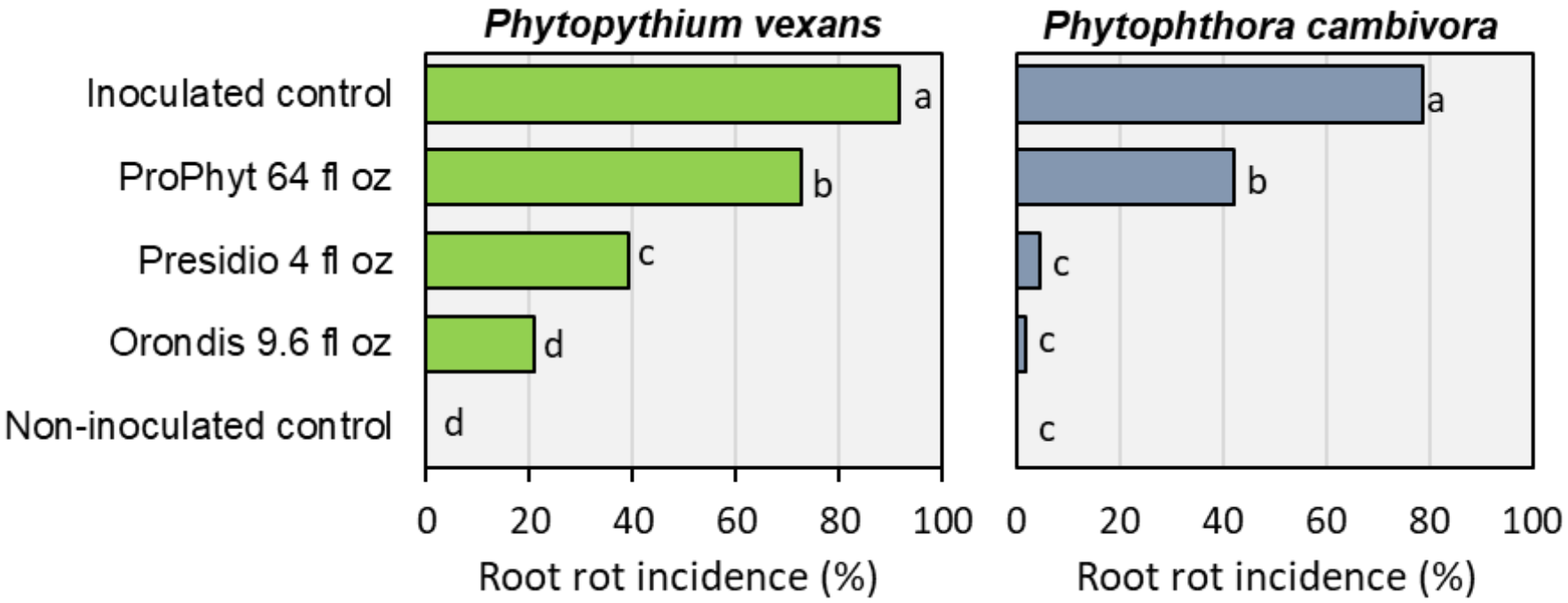
Laboratory and field studies on new Phytophthora root rot fungicides

Fungicides for managing Phytophthora root and crown rot diseases

	Common Name	Trade Name	Class	FRAC
Currently registered	metalaxyl, mefenoxam	Ridomil Gold	phenylamides	4
	fosetyl-Al, phosphorous acid	Various	phosphonates	P07 (33)
In development for cherry	mandipropamid	Revus	CAAs	40
	fluopicolide	Presidio	benzamides	43
	ethaboxam	Elumin	thiazole carboxamide	22
	oxathiapiprolin	Orondis	piperidinyl thiazole isoxazolines	49

The new fungicides were shown to have high in vitro activity against all *Phytophthora* species from cherry with EC_{50} values mostly of less than 0.1 ppm. Oxathiapiprolin was most toxic at extremely low concentrations (EC_{50} values $\leq$0.001 ppm or $\leq$1ppb).

Efficacy of soil-applied fungicide treatments for management of Phytophthora crown and trunk cankers in greenhouse studies - 2025



8- to 12-week-old Mahaleb seedlings were planted into infested soil, and the soil was treated with selected fungicides. Fungicide rates were based on field rates that were proportionally reduced based on pot surface area. After 4 weeks, roots were plated onto a selective medium, and the incidence of root rot was calculated based on the number of colonized root pieces of the total number of pieces plated. Data are the average of two experiments.

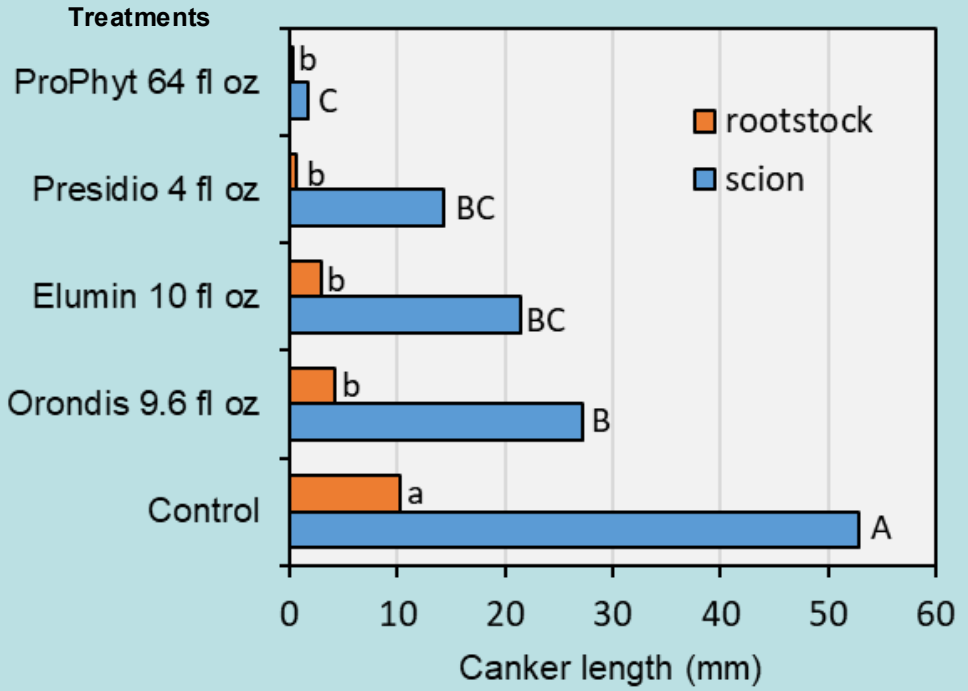
- New Oomycota fungicides significantly improved tree health.
- *P. cactorum* and *P. cambivora* were recovered from trunk cankers.
- Fluopicolide (Presidio) showed some phytotoxic in sandy soils

Fungicide mobility after soil application in greenhouse and field studies

Control

Fluopicolide

Rootstocks (cvs. Mazzard and Mahaleb) and scions (cvs. Coral and Rainier) inoculated with *P. citricola* after soil treatment in field studies published in 2025



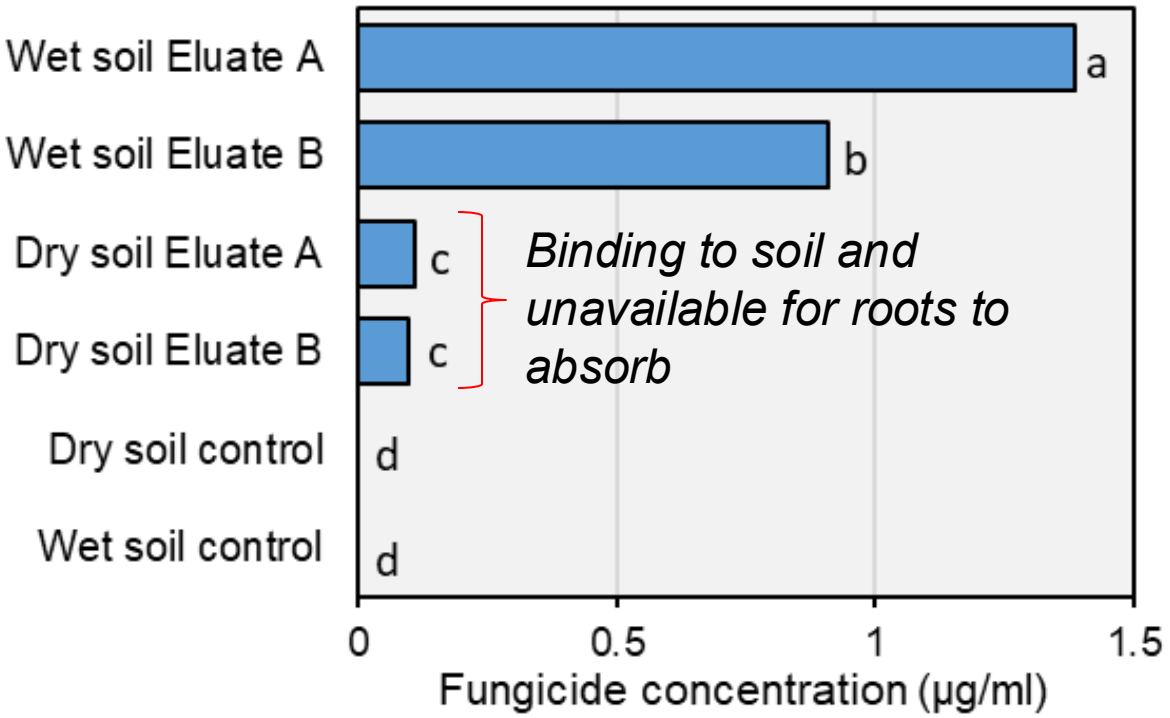
Fungicide treatments were applied in the field to first-leaf Coral on Mahaleb rootstock cherry trees. Tree trunks were inoculated with *P. citricola* after two weeks by placing agar plugs containing mycelium onto wounds 8 cm above the soil-line for the rootstock and 16 cm above the graft union for the scion. Cankers were measured 3 weeks later. Lower- and uppercase letters next to the bars indicate statistical significances for rootstocks and scions, respectively. (This is a repeat of last year's study)

Control

Fluopicolide

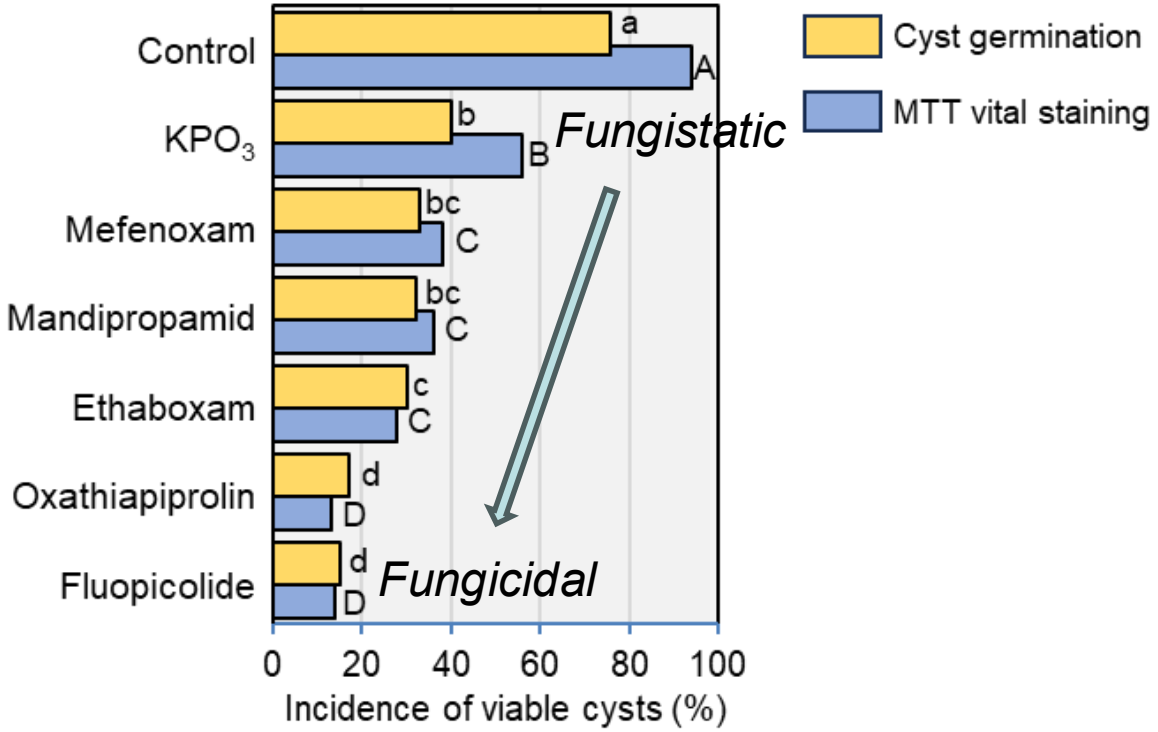
New Oomycota fungicides show systemic movement in cherry plants.

Evaluation of soil binding of Orondis in a laboratory study



Oxathiapiprolin was applied to 100 ml wet (12% water content) or dry (0.9% water content) Riverside field soil in a Buchner funnel. After 10 min, 10 ml or 25 ml of water was applied to the wet or dry soil, respectively. After 30 min, two 6-ml fractions of eluate were obtained by applying a vacuum. Eluates were applied to filter paper disks in bioassays, inhibition zones of *Phytophthora* growth were measured, and fungicide concentrations were calculated based on inhibition zones developing using fungicide standards in the bioassay.

Evaluation of the fungicidal and/or fungistatic action of Oomycota fungicides



Fungicides (1 ppm, except for KPO_3 where 100 ppm was used) were added to encysted zoospores of *P. citrophthora* on the bottom of empty petri dishes. After 2 h, cysts were washed four times with water for 30 min each. Cysts were then either treated with the MTT vital stain or allowed to germinate. Staining (viable cysts were stained blue) and germination were observed microscopically after 1 or 4 h, respectively.

Natamycin and Polyoxin-D are Organic Materials Review Institute (OMRI) listed for organic postharvest use in the U.S.

GROUP 19 FUNGICIDE

Polyoxin D Zinc Salt 5SC Post-Harvest Fungicide

For post-harvest use on listed fruits

Polyoxin D Zinc Salt 5SC Post-Harvest Fungicide is a suspension concentrate fungicide of polyoxin D zinc salt for control of certain post-harvest diseases of fruits in storage

STONE FRUIT

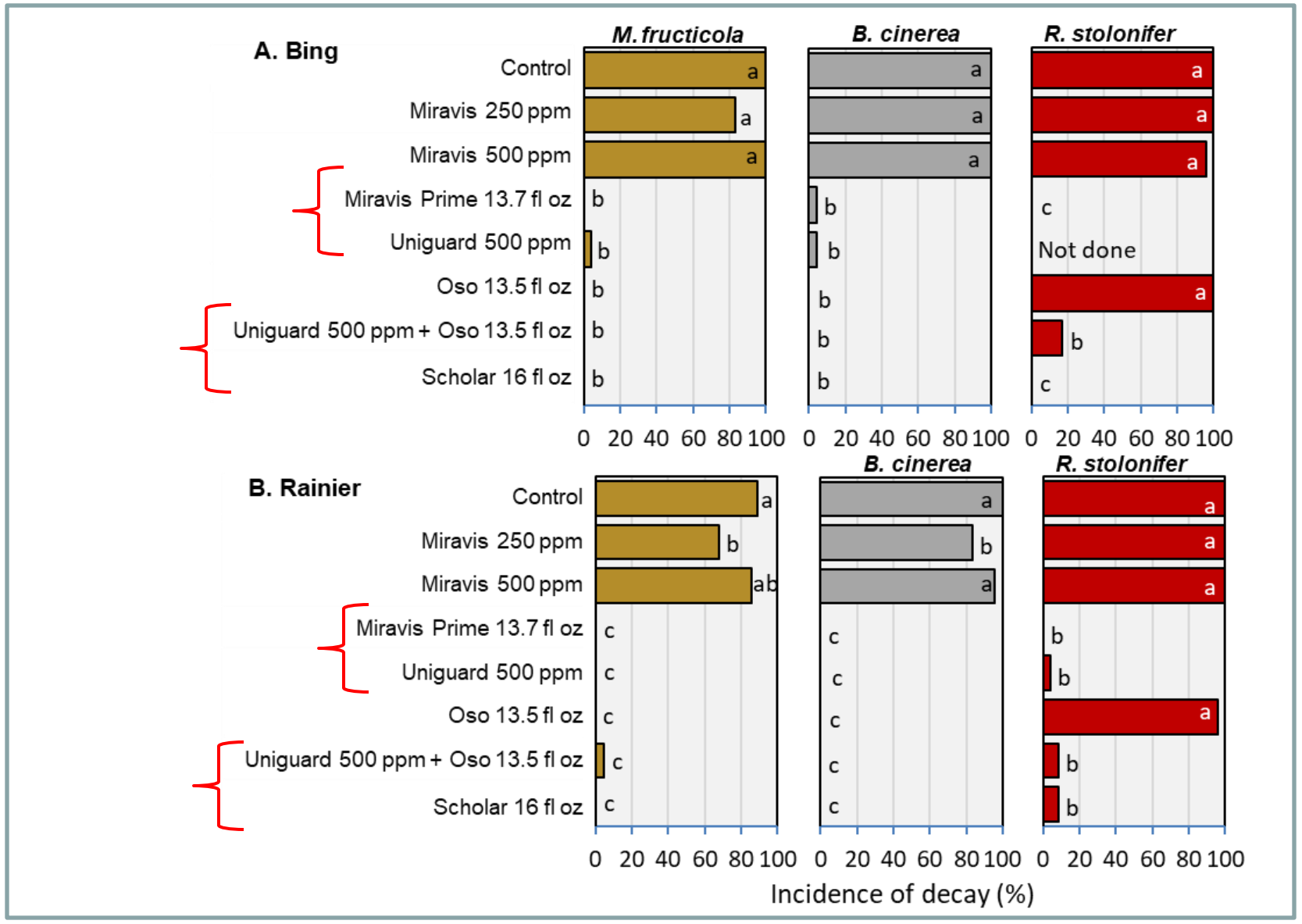
Application Method	Disease	Rate (fl. oz.)	Remarks
In-line Dip, Drench or aqueous Spray	Gray Mold (*Botrytis cinerea*) Brown Rot (*Monilinia fructicola*) Suppression of Rhizopus Rot (*Rhizopus stolonifer*) and Sour Rot (*Geotrichum candidum*)	3.5-16 fl. oz./100 gal	• Mix 3.5-16 fl. oz. of product in 100 gallons of water carrier. • Treat for approximately 15-30 seconds and allow fruit to drain. • For Rhizopus Rot and/or Sour Rot use highest rate. • Make no more than one application. • Make an application either before storage or after storage prior to shipping.

• Stone Fruit Includes - Apricot (*Prunus armeniaca*); Apricot, Japanese (*Prunus mume*); Capulin (*Prunus serotina*); Cherry, black (*Prunus serotina*); Cherry, Nanking (*Prunus tomentosa*); Cherry, sweet (*Prunus avium*); Cherry, tart (*Prunus cerasus*); Jujube, Chinese (*Ziziphus jujuba*); Nectarine (*Prunus persica*); Peach (*Prunus persica*); Plum (*Prunus domestica*); Plum, American (*Prunus americana*); Plum, beach (*Prunus maritima*); Plum, Canada (*Prunus nigra*); Plum, cherry (*Prunus cerasifera*); Plum, Chickasaw (*Prunus angustifolia*); Plum, Damson (*Prunus domestica*); Plum, Japanese (*Prunus salicina*); Plum, Klamath (*Prunus subcordata*); Plum, prune (*Prunus domestica*); Plumcot (*Prunus* hybr.); Sloe (*Prunus spinosa*); Cultivars, varieties, and/or hybrids of these.

Polyoxin D pending CA approval

Includes **sweet cherry**

Evaluation of new fungicides for managing postharvest decays of Bing cherry in laboratory studies 2025



Fruit were wound-inoculated with spores of *M. fructicola*, *B. cinerea*, or *R. stolonifer* (40,000 spores/ml) and incubated for 13-14 h at 20C. Aqueous treatments were applied using an air-nozzle sprayer. Fruit were incubated at 20C for 4-7 days.

Summary for 2025

1. New products against **bacterial blast and canker** - Biologicals/natural products, antibiotics
   - KSM, OTC, and EPL/Cinnamaldehyde mixture
2. New fungicides for control of **brown rot and Botrytis blossom blight, powdery mildew**, and **preharvest brown rot and gray mold fruit decay**: Cevya, new premixtures- Miravis Top, and biologicals like Cinnerate. *Pending* – Elysis, Axios, Parade, Talendo
3. New **postharvest treatments**: fungicides (Chairman), 'exempt from tolerance-OMRI approved biofungicides (natamycin) OMRI-approved and polyoxin-D- pending (BioSpectra+Oso)
   - Support Scholar-natamycin mixtures for food additive tolerance (FAT) in Japan
   - Support IR-4 registration of Miravis Prime for preharvest use to remove postharvest labeling in Japan
4. New fungicides for managing **Phytophthora root and crown rot**
   - Completed in vitro baseline sensitivities to oxathiapiprolin, mandipropamid, fluopicolide, and ethaboxam
   - Completed studies in experimental orchards at UC Davis and UC Riverside, demonstrating efficacy that are needed for CA registration.
   - Characterize fungicide mobility in greenhouse and field studies with selected cherry rootstocks and scions
   - Support registration of mandipropamid for use in container greenhouse trees during propagation.

Thank you!

- Questions?