# FUMIGATION AS A POSTHARVEST TOOL FOR SWD CONTROL: CURRENT PROGRESS AND INSIGHTS

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# BACKGROUND

Export and Phytosanitary Concerns

- Many international trading partners maintain restricted SWD distributions.
- Export markets may require validated postharvest mitigation treatments.
- Air freight fruit is particularly vulnerable because cold exposure periods may be too short for effective SWD control.

Need for Alternative Treatments

- Extended cold treatment during sea freight may provide adequate control.
- Additional postharvest fumigation options are needed for air-freighted blueberries.
- Alternatives to methyl bromide are increasingly important for sustainability and regulatory compliance.

# BACKGROUND

Sea Freight – Cold Sterilization

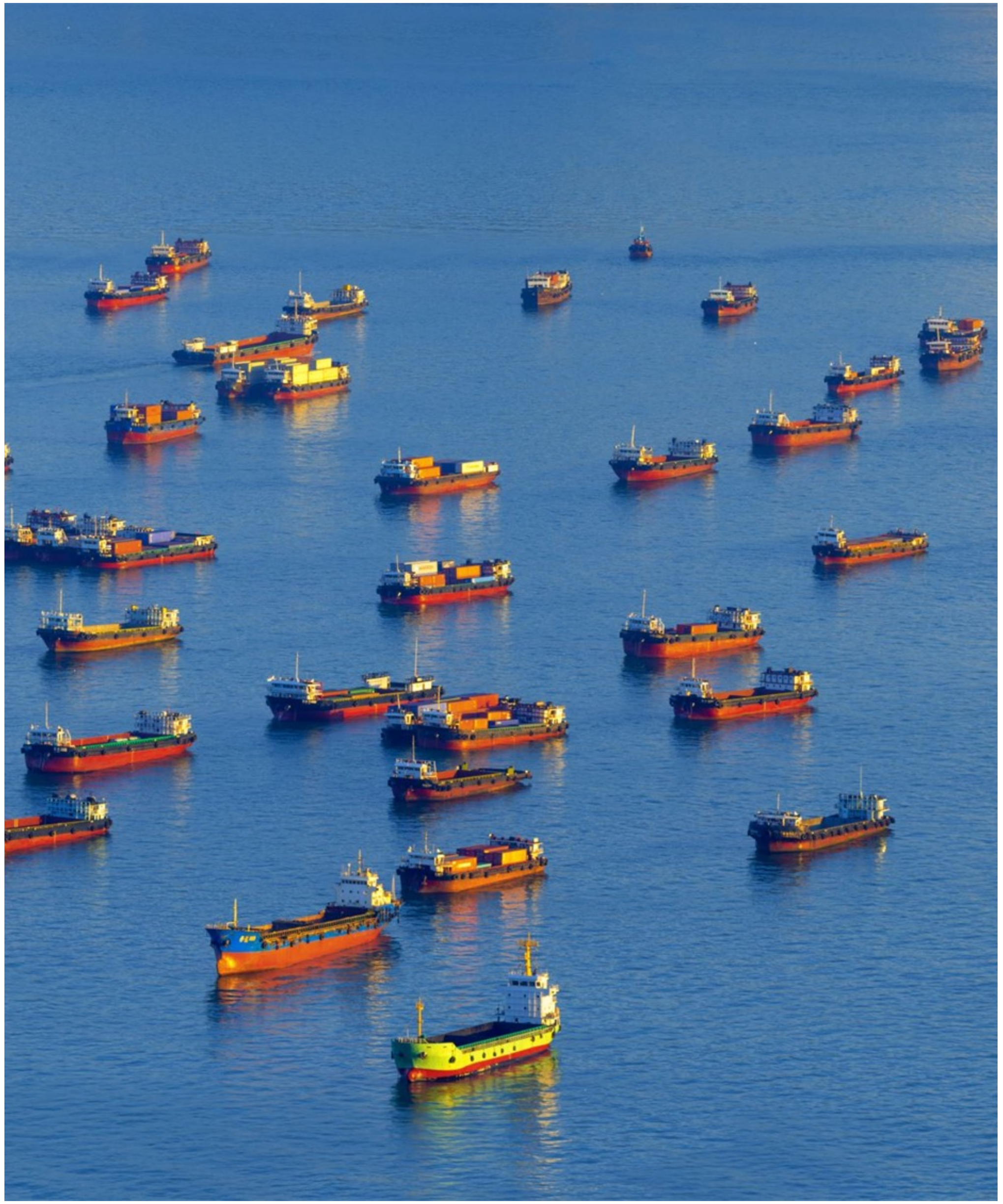
- 1.11°C (pulp temp) below for 15+ days
- 1.67°C (pulp temp) or below for 17+ days
- 2.22°C (pulp temp) or below for 21+ days

Air Freight – Fumigation

- Methyl bromide fumigation

32 g/m³ for 2 hours

At ~21.1°C or above



# MAIN OBJECTIVE

To assess the efficacy of postharvest fumigation treatments for the control of *Drosophila suzukii* in different blueberry cultivars.

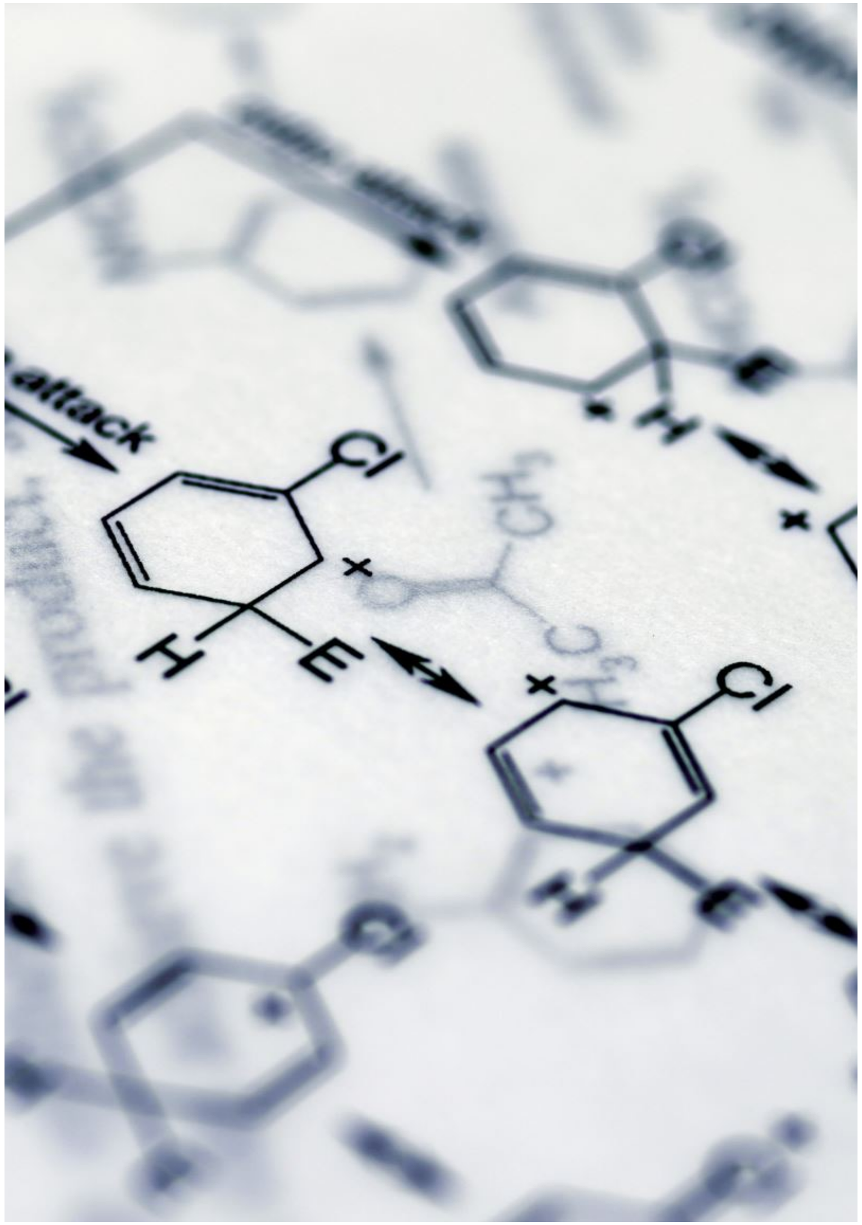
<u>Season 1</u>

<u>Fumigants Evaluated:</u>

1. Ethyl formate (EF)

- Naturally occurring volatile compound
- Food-flavoring agent with GRAS status
- Promising environmentally friendly alternative fumigant
- Rapid insecticidal activity with low residue concerns
- EF inhibits cytochrome c oxidase activity in insects

Depletes molecular oxygen in the cells → resulting in the loss of cell function and cell death.



# MAIN OBJECTIVE

2. Nitric oxide (NO) under low oxygen

- Previously used in medical and postharvest applications
- Reported to extend storage life and maintain fruit quality
- Demonstrated strong fumigant activity against postharvest insect pests
- Potential alternative to methyl bromide

# AIM

Season 1:

- Determine treatment efficacy against SWD
- Evaluate suitability across blueberry cultivars
- Identify sustainable alternatives to conventional fumigation treatments

Upcoming season 2: **Verification of Cold Sterilization Regimes**

**Purpose**

To verify that commercial cold storage conditions achieve complete mortality of SWD in inoculated blueberries.

**Key Considerations**

- Sea freight durations vary by export market.
- Commercial storage temperatures:
  - ❖ -0.5°C to 0°C
  - ❖ 12, 24, 30 and 40 days depending on market requirements
- 3rd instar larvae and pupae treated as the worst-case life stage.

# METHOD

## Ethyl formate fumigation

### Efficacy and phytotoxicity trials

- Desiccator – closed system
- Insect mortality
- Fruit quality evaluated
- Cultivars:

| Harvest week | Cultivar | Season |
|---|---|---|
| Wk 23 - 37 | OZ MAGICA | Early |
| Wk 23 – 37 | OZ JULIETA | Early |
| Wk 23 – 37 | SNOWCHASER | Early |
| Wk 23 – 37 | SEKOYA POP™ 'FCM14-052' | Early |
| Wk 23 - 37 | EUREKA SUNRISE | Early |
| Wk 38 - 52 | LEGACY | Mid |
| Wk 38 - 52 | EUREKA | Mid |
| Wk 38 - 52 | JEWEL | Mid |
| Wk 38 - 52 | ATLASBLUE™ 'FCM12-045 | Mid |
| Wk 1 -15 | BLUE RIBBON | Late |
| Wk 1 -15 | BRIGITTA | Late |
| Wk 1 -15 | BLUEGOLD | Late |
| Wk 1 -15 | TOP SHELF | Late |
| Wk 1 -15 | TWILIGHT | Late |

- Concentrations and duration tested: 16g/m$^3$ closed for 24h @ ambient
- Untreated control included

# METHOD

## Nitric oxide fumigation under low oxygen (0.3%)

### Efficacy and phytotoxicity trials

- Gas tight containers – closed system

- Insect mortality
- Fruit quality evaluated
- Cultivars:
- Concentration and duration tested: 3% NO (balance nitrogen) for 8h @ 2ºC
- Untreated control included

| Harvest week | Cultivar | Season |
|---|---|---|
| Wk 23 - 37 | OZ MAGICA | Early |
| Wk 23 – 37 | OZ JULIETA | Early |
| Wk 23 – 37 | SNOWCHASER | Early |
| Wk 23 – 37 | SEKOYA POP™ 'FCM14-052' | Early |
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# BOTH FUMIGATION TRIALS

**Fruit evaluation :**

- Colour (⁰ Hue Angle)
- Firmness (N) and Firmness (Durofel)
- Titratable acids (citric acid) %
- Total soluble solids (% Brix)
- External quality:
  - Phytotoxic damage
  - Shrivel
  - Decay
- Internal quality:
  - Mealiness
  - Internal browning/phytotoxic damage

# RESULTS

## Insect trials

- Fruit were exposed to adult SWD for 24 hours –after which- adults were removed
- Larval development monitored until the third instar stage

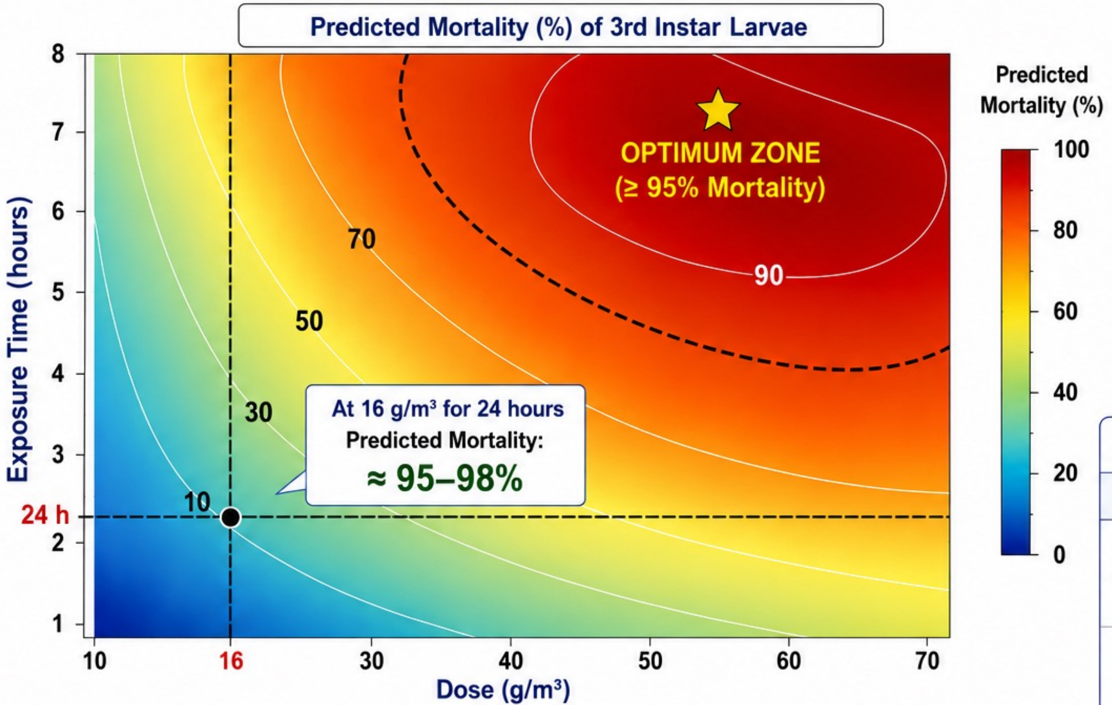
| Treatment | Average larvae per fruit | Maximum larvae per fruit |
| --- | --- | --- |
| Blueberries (2♀:1♂) | 3 | 12 |
| Blueberries (4♀:2♂) | 2 | 15 |

- Maximum larval recovery in blueberries ranged from 12–15 larvae per fruit
- SWD females successfully oviposited in intact blueberries

# RESULTS: ETHYL FORMATE

## PREDICTED INSECT MORTALITY at 16 g/m³ for 24 HOURS (3rd Instar)

***Response Surface Prediction Using CCD Model***




### PREDICTION FOR 16 g/m³ FOR 24 HOURS

Dose: 16 g/m³
Exposure: 24 hours

Predicted Mortality (3rd Instar):

**≈ 95–98%**

✓ Expected control: Very High
(business/ quarantine standard likely met)

### LIFE STAGE RESPONSE AT 16 g/m³ FOR 24 HOURS

| Life Stage | Predicted Mortality | Response |
|---|---|---|
| 3rd Instar | ≈ 95–98% | Very Susceptible |
| 2nd Instar | ≈ 98–100% | Very Susceptible |
| 1st Instar | ≈ 90–95% | Moderately Susceptible |

### HOW TO READ THE MAP

- Colors represent predicted mortality (%) of 3rd instar larvae.
- Warmer colors (yellow ⟶ red) indicate higher mortality.
- The dashed boundary shows the zone where mortality is ≥ 95%.
- The star indicates the optimum region for effective fumigation.

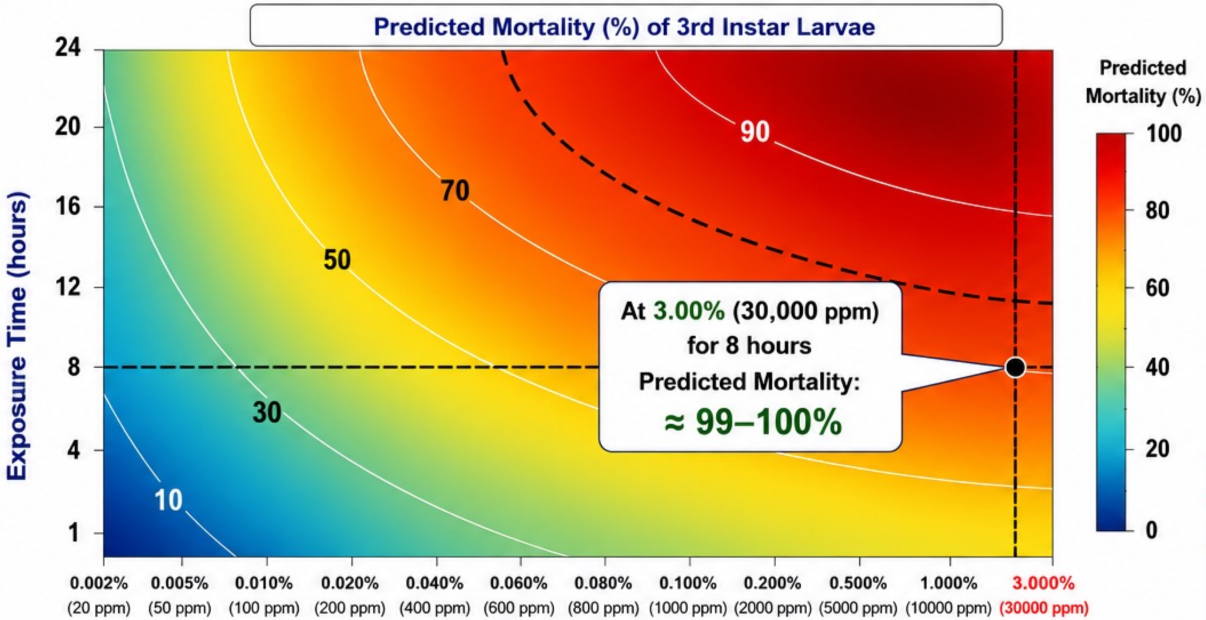
**Conclusion:** At 16 g/m³ for 24 hours, the predicted mortality of 3rd instar larvae is approximately 95–98%, which is within the ≥95% effective control threshold.

***Note:*** *Prediction based on CCD response surface model derived from experimental data. Actual results may vary with temperature, commodity condition, and system setup.*

# PREDICTED INSECT MORTALITY with NITRIC OXIDE (NO) FUMIGATION

***Response Surface Model Based on Literature Data (3rd Instar)***

***Converted from ppm to % (v/v)***




## PREDICTION AT 3.00% NO FOR 8 HOURS

**NO Concentration:** 3.00% (30,000 ppm)

**Exposure Time:** 8 hours

**Predicted Mortality of 3rd Instar Larvae:**

## ≈ 99–100%

- ☑ Very high level of control expected.
- ☑ Meets and exceeds ≥95% mortality target for quarantine and postharvest treatments.
- ☑ Supported by model extrapolation within validated range of NO response.

## LIFE STAGE RESPONSE at 3.00% (30,000 ppm) for 8 h

| Life Stage | Predicted Mortality (%) | Response |
|---|---|---|
| 3rd Instar | ≈ 99–100% | Very High |
| 2nd Instar | ≈ 99–100% | Very High |
| 1st Instar* | ≈ 98–100% | Very High |

*Pupae are generally more tolerant to NO.

### KEY LITERATURE VALUES USED FOR MODEL (Converted to % v/v)

- ☑ 0.040–0.060% (0.04–0.06% v/v) for 12–24 h → ≥ 95% mortality (*Drosophila* spp.)
- ☑ 0.060% (0.06% v/v) for 24 h widely reported for complete control in fruit fly pests
- ☑ Lower doses (0.010–0.020% / 0.01–0.02% v/v) require >24 h for similar efficacy
- ☑ Pupae consistently more tolerant than larval instars

### HOW TO READ THE MAP

- Colors show predicted mortality (%) of 3rd instar larvae.
- Dashed line encloses the zone where mortality is ≥ 95%.
- Use the map to select NO dose and exposure for desired control.

**Note:** NO is a fast-acting fumigant; efficacy increases with both concentration and exposure time.

**Conclusion: At 3.00% (30,000 ppm) NO for 8 hours,** the predicted mortality of 3rd instar larvae is approximately 99–100%, indicating a highly effective treatment that comfortably meets quarantine and postharvest phytosanitary requirements (target ≥ 95%).

**CONVERSION USED:** 1 ppm (v/v) = 0.0001% (v/v) → % (v/v) = ppm × 0.0001

Examples: 100 ppm = 0.010% | 400 ppm = 0.040% | 600 ppm = 0.060% | 1000 ppm = 0.100% | 30000 ppm = 3.000%

# PLEASE NOTE
# FRUIT QUALITY RESULTS SHOULD BE INTERPRETED WITH CAUTION

The fruit quality results presented in this presentation are based on a single season of experimental data and should therefore be interpreted with caution. Fruit response to fumigation treatments can be influenced by several factors, including pre-harvest environmental conditions, orchard management practices, storage history, and harvest maturity at the time of treatment.

Differences in physiological maturity may significantly affect fruit tolerance to fumigants and subsequent quality outcomes during storage and shelf-life evaluation. Consequently, the responses observed for specific cultivars in this study may not fully represent the range of responses that could occur under different harvest timings, seasons, or production conditions.

Based on the current dataset, no cultivar can be conclusively excluded from further consideration for fumigation treatments. While cultivar-specific differences in quality response were observed, these should be regarded as preliminary indications rather than definitive evidence of susceptibility or intolerance. Additional validation across multiple seasons, maturity stages, production regions, and commercial production lots is required before robust conclusions can be drawn regarding cultivar suitability, treatment tolerance, or commercial risk.

# RESULTS

## Overall Fumigant Response Relative to Control

- Both nitric oxide (NO) and ethyl formate (EF) treatments = maintained acceptable fruit quality after shelf-life when compared with untreated controls

### Nitric Oxide (NO) vs Control

- NO resulted in:
  - Equal or improved firmness retention relative to the control
  - Reduced softening during shelf-life
  - Better texture preservation in softer cultivars

- NO provided limited but sometimes beneficial suppression of postharvest decay development.
- NO did not substantially increase water loss or dehydration symptoms – shrivel
- Phytotoxicity:
  - NO was generally well tolerated across cultivars at the evaluated treatment conditions.

# RESULTS

## Overall Fumigant Response Relative to Control

### Ethyl Formate (EF) vs Control

- EF responses were more variable than NO:
  - Some cultivars maintained firmness similar to the control
  - Others showed increased softening after shelf-life
- EF demonstrated stronger antimicrobial activity relative to NO and untreated fruit.

- EF posed a slightly greater phytotoxicity risk - but remained within acceptable limits for most cultivars
  - Slight berry discoloration
  - Injury levels were generally low
  - Most fruit remained commercially acceptable

| Cultivar | NO vs Control | EF vs Control | Firmness Response | Decay Response | Shrivel Response | Phytotoxicity Response | Overall Interpretation |
|---|---|---|---|---|---|---|---|
| 'BLUE RIBBON' | Maintained firmness well | Reduced decay slightly | NO better than EF | EF lower decay than control | Minimal differences | Very low injury | **Good tolerance to both treatments** |
| 'BLUE GOLD' | Similar to control | Similar to control | Small treatment effects | Minor differences | Non-significant | Negligible | **Stable cultivar with limited treatment response** |
| 'BRIGITTA' | Better firmness retention | Slight softening observed | NO superior | Similar decay to control | Minor increase under EF | Low | **NO more favourable after shelf-life** |
| 'EUREKA' | Comparable or improved firmness | Good overall response | Both acceptable | Low decay overall | Minimal changes | Very low | **High tolerance to both fumigants** |
| 'EUREKA SUNRISE' | Good firmness retention | Slightly more variable | NO slightly superior | Similar to control | Low shrivel | Minimal injury | **Commercially acceptable response** |
| 'OzBlu JULIETA' | Improved texture retention | Some softening under EF | NO superior | Small decay reduction under EF | Minor changes | Low | **NO favoured for quality retention** |
| 'OzBlu MAGICA' | Maintained firmness | Slight firmness reduction | NO superior | EF slightly reduced decay | Minor differences | Low | **Cultivar sensitive to EF softening** |
| 'SEKOYA POP' | Similar to control | Similar to control | Stable across treatments | Low decay overall | Minimal shrivel | Negligible | **Very tolerant cultivar** |
| 'SNOWCHASER' | Better shelf-life firmness | More variable response | NO superior | EF reduced decay slightly | Moderate shrivel sensitivity | Low-moderate | **More sensitive cultivar after shelf-life** |

# SUMMARY

- **NO treatments** most consistently preserved firmness and texture after shelf-life.
- **EF treatments** often provided slightly improved decay suppression.
- Shrivel differences were generally small across all cultivars.
- Phytotoxicity remained low and commercially acceptable for both fumigants.
- Cultivar-specific responses indicate that fumigation optimization should be tailored per cultivar.

# SUMMARY

| Rank | Cultivar | Overall Response | Main Strength | Main Limitation |
|---|---|---|---|---|
| 1 | 'SEKOYA POP' | Excellent | Very stable across treatments | Limited measurable treatment benefit |
| 2 | 'EUREKA' | Excellent | Strong tolerance to both EF and NO | Minor variability in firmness |
| 3 | 'BLUE RIBBON' | Very Good | Good decay suppression and firmness | Slight EF sensitivity |
| 4 | 'EUREKA SUNRISE' | Very Good | Strong overall quality retention | Slightly variable response late shelf-life |
| 5 | 'OzBlu JULIETA' | Good | NO maintained texture well | EF-related softening tendency |
| 6 | 'OzBlu MAGICA' | Good | Strong NO response | More sensitive to EF |
| 7 | 'BRIGITTA' | Moderate-Good | NO firmness retention | Shelf-life sensitivity under EF |
| 8 | 'BLUE GOLD' | Moderate | Stable but limited treatment response | Lower overall differentiation |
| 9 | 'SNOWCHASER' | Moderate-Sensitive | Some decay reduction under EF | More shelf-life deterioration overall |

# SUMMARY

Blueberry fumigation response = highly cultivar dependent

Seasonal harvest timing = fumigation tolerance

NO is generally superior for preserving shelf-life quality.

EF may provide stronger decay suppression but requires cultivar optimization.

Future commercial protocols should take into account:

- cultivar,
- harvest window,
- maturity stage,
- and storage duration.

# ETHYL FORMATE FUMIGATION

## INSECT MORTALITY VS FRUIT QUALITY

| Ethyl Formate Dose (g/m³) | 4 h Exposure | 6 h Exposure | 8 h Exposure | Fruit quality risk |
|---|---|---|---|---|
| 10 g/m³ | Low | Low | Moderate | Minimal |
| 20 g/m³ | Moderate | High | High | Very low |
| 30 g/m³ | High | Very high | Complete | Low |
| 40 g/m³ | Very high | Complete | Complete | Low–moderate |
| 70 g/m³ | Complete | Complete | Complete | Moderate–high |

| Insect mortality | Predicted mortality |
|---|---|
| Low | <50% |
| Moderate | 50–80% |
| High | 80–95% |
| Very high | 95–99% |
| Complete | 99–100% |

| Cultivar | NO Quality Response | EF Quality Response | SWD Treatment Compatibility | Commercial Risk Assessment |
|---|---|---|---|---|
| 'SEKOYA POP' | Excellent firmness retention and low injury | Very stable | Highly compatible with both NO and EF efficacy ranges | Very low risk |
| 'EUREKA' | Strong tolerance to both treatments | Low phytotoxicity | Good compatibility with higher SWD treatment exposure | Low risk |
| 'BLUE RIBBON' | Good NO response | EF reduced decay effectively | Strong candidate for EF-driven SWD protocols | Low–moderate risk |
| 'EUREKA SUNRISE' | Stable under NO | Mild variability under EF | Suitable for both fumigants with moderate optimization | Low risk |
| 'OzBlu JULIETA' | NO preserved texture well | Some EF softening | Better suited to NO-based SWD disinfestation | Moderate EF risk |
| 'OzBlu MAGICA' | Good NO tolerance | Slight EF sensitivity | NO preferred at higher efficacy exposures | Moderate EF risk |
| 'BRIGITTA' | Good NO firmness retention | More sensitive to EF | Better compatibility with NO protocols | Moderate risk |
| 'BLUE GOLD' | Stable but limited treatment response | Minimal EF benefit | Compatible but limited fumigation benefit observed | Moderate risk |
| 'SNOWCHASER' | Sensitive during shelf-life | EF reduced decay but more quality loss | Requires conservative EF dosing | Higher commercial risk |

| Parameter | Nitric Oxide (NO) | Ethyl Formate (EF) |
|---|---|---|
| SWD mortality potential | High at ~2–3% NO under ULO | High at ~16–38 g/m³ |
| Primary strength | Shelf-life and firmness retention | Rapid insecticidal and antimicrobial activity |
| Firmness after shelf-life | Generally superior | More cultivar dependent |
| Decay suppression | Moderate | Strong |
| Shrivel risk | Low | Low–moderate |
| Phytotoxicity risk | Very low | Slightly higher in sensitive cultivars |
| Cultivar sensitivity | Lower overall | Higher overall |
| Commercial robustness | High | Moderate–high |
| Export suitability | Excellent for long storage | Strong for rapid market access |
| Operational complexity | Requires ULO management | Easier fumigation implementation |

# THANK YOU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