



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.

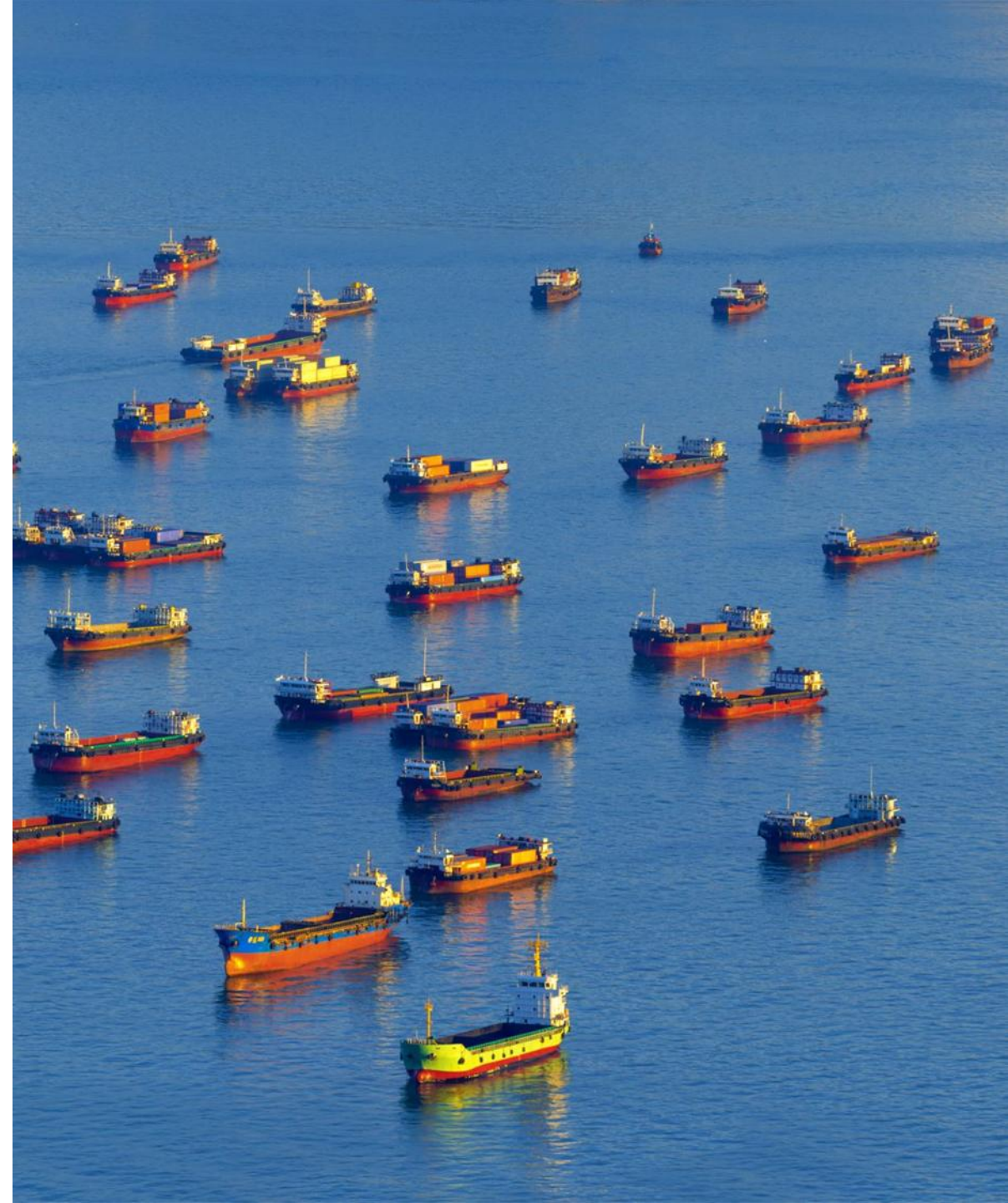
BACKGROUND

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.

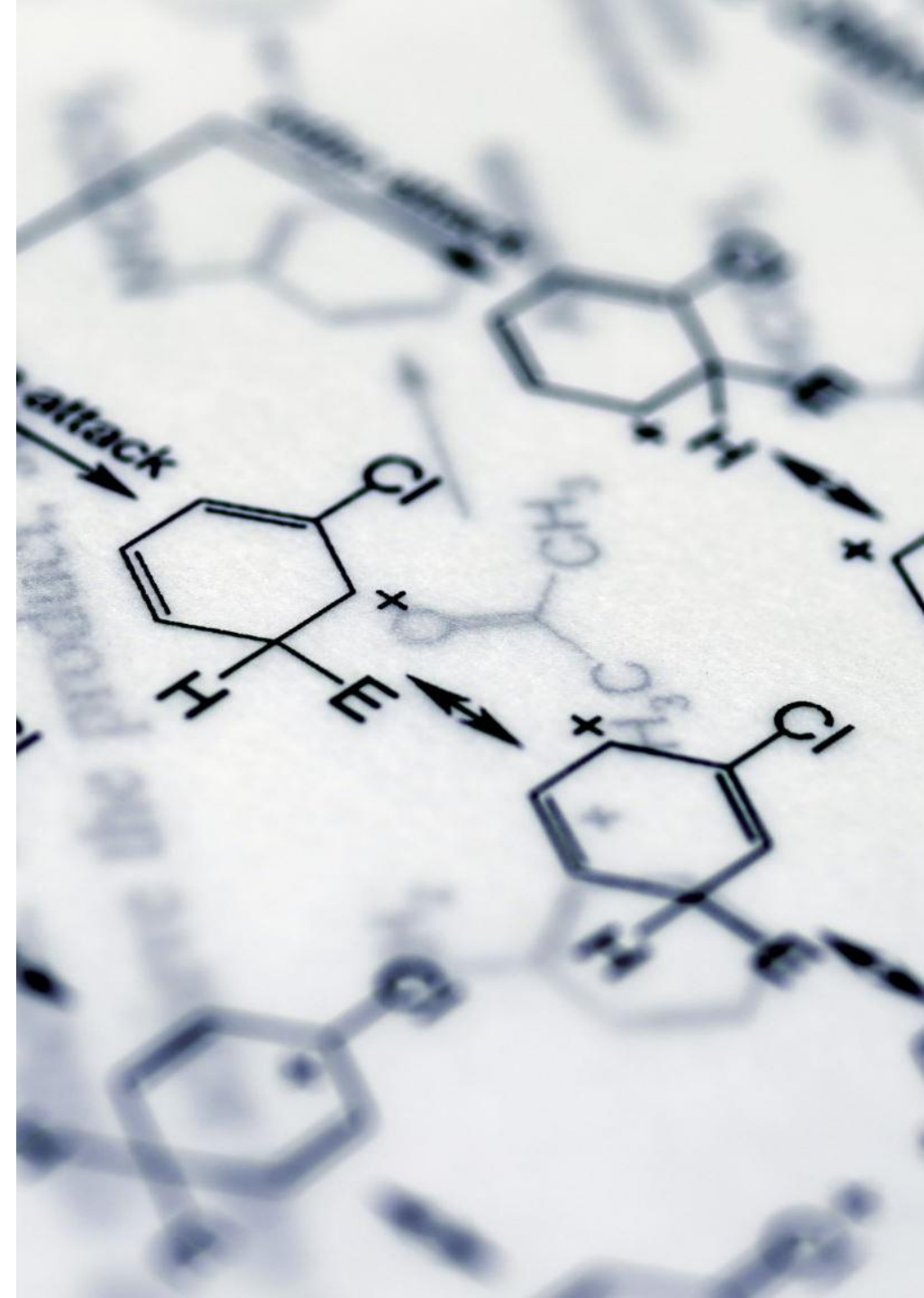
Season 1

Fumigants Evaluated:

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/m³ 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 @ 2°C
- 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
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

BOTH FUMIGATION TRIALS

Fruit evaluation :

- Colour ($^{\circ}$ 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

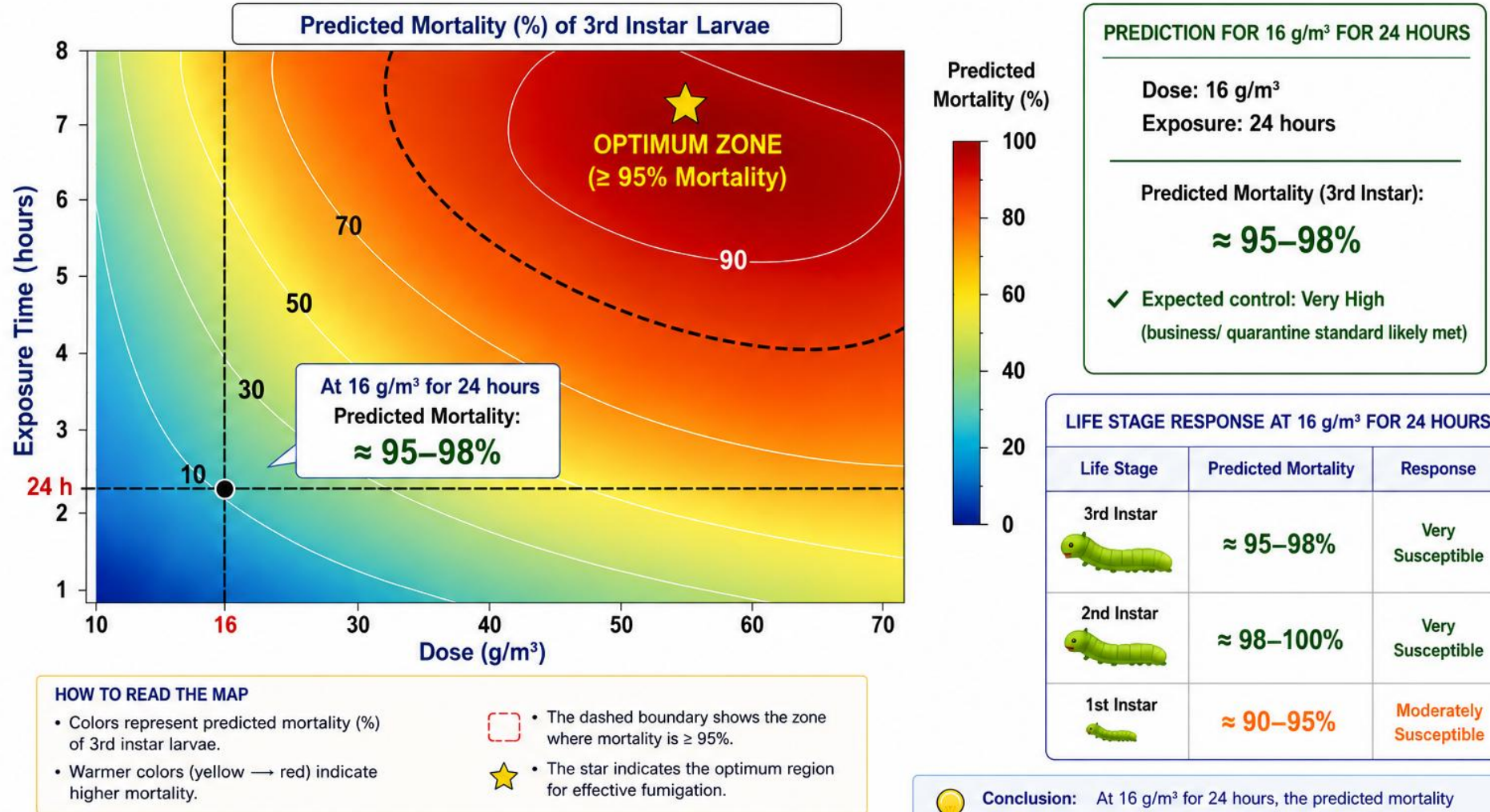
Treatment	Average larvae per fruit	Maximum larvae per fruit
Blueberries (2♀:1♂)	3	12
Blueberries (4♀:2♂)	2	15

- 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



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

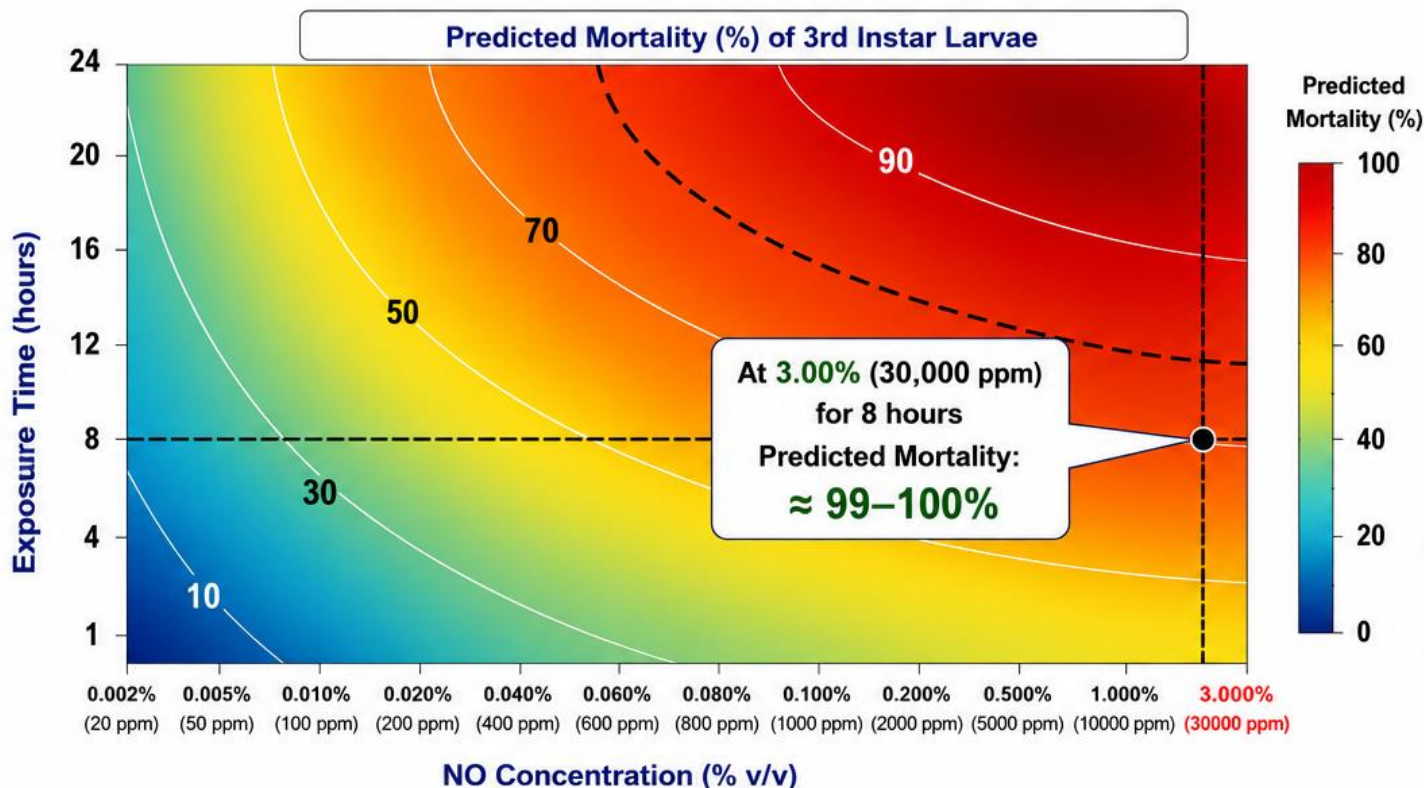


Conclusion: At 16 g/m³ for 24 hours, the predicted mortality of 3rd instar larvae is approximately 95–98%, which is within the ≥95% effective control threshold.

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

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

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.

 **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%

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
'SNOWCHASE R'	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.
- Shivel 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/m ³)	4 h Exposure	6 h Exposure	8 h Exposure	Fruit quality risk
10 g/m ³	Low	Low	Moderate	Minimal
20 g/m ³	Moderate	High	High	Very low
30 g/m ³	High	Very high	Complete	Low
40 g/m ³	Very high	Complete	Complete	Low–moderate
70 g/m ³	Complete	Complete	Complete	Moderate–high

Insect mortality

Low

Moderate

High

Very high

Complete

Predicted mortality

<50%

50–80%

80–95%

95–99%

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/m ³
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



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