Protecting Bee Health and Pollination—Safety of Adjuvants When Sprayed in Combination with Pesticides

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Adjuvants-
What are they are and how are they used?

- An adjuvant is any compound intended to improve the handling or application characteristics of a pesticide application to enhance pesticidal activity, which can potentially reduce the amount of active ingredient that is necessary for pest control (Shannon et al 2023)
- Formulations include a variety of adjuvants (trade secrets)
- Others sold to be included in pesticide tank mixes
- Considered to be inert ingredients; however, some have insecticidal activities and may affect toxicities of active ingredients when added to tank mix

Classes of Spray Adjuvants

- Nonionic surfactants
  - Polyethoxylates (alcohol ethoxylates, fatty acid ethoxylates, and amine ethoxylates)
- Crop Oil Concentrates and Modified Seed Oils
  - Oils from plants or also petroleum-derived
  - Fatty acid methyl esters
- Organo-Silicone Surfactants (OSS)
  - Super spreaders
  - Different chemical modifications change properties and toxicity
- Hydrocolloid Polymers and other adjuvants

Toxicity of the not so “Inert Ingredients” in Pesticides to Adult Worker Honey Bees

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Shannon B, Tarver L, Jeon H, Johnson RM. Assessing Toxicity of Pesticide Inert Ingredients and Spray Adjuvant Principal Functioning Agents to Honey Bees (Apis mellifera). Environ Toxicol Chem. 2025 Nov 24:vgaf283. doi: 10.1093/etojnl/vgaf283.

Review of safety of spray adjuvants

- Several types of adjuvants
- Some have increased toxicity by themselves to bees and other beneficials
    - Toxicity varies, if by contact or oral consumption (pollen or nectar, or via cutting leaf pieces)
    - Non-Apis bees may be more sensitive (needs research)

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Review

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Review: the risks of spray adjuvants to honey bees

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Pesticide applications are often made as tank mixes containing multiple pesticide products and may include spray adjuvants to enhance pesticidal activities. The primary aim of adjuvant products is to increase the spreading and sticking of spray droplets and to increase the penetration of active ingredients through the cuticles of leaves or targeted pests, which can reduce the amount of active ingredient needed for effective pest control. Adjuvants are made up of compounds drawn from the “inert ingredient” list maintained by EPA but are identified as “principal functioning agents” when used in adjuvant products. These inert compounds do not undergo the same testing and risk assessment process that is required of pesticide active ingredients and generally have no mitigation measures that prevent application onto crops during bloom at times of day when bees are foraging. Honey bees (*Apis mellifera; Hymenoptera: Apidae)* are at an increased risk of exposure to adjuvant tank mixtures while providing agricultural pollination services. Colony losses attributed to pesticide applications thought to have low risk to honey bees have been reported, highlighting the need to better understand the toxicity of adjuvants included in pesticide tank mixtures. This review summarizes current literature on the risks posed to honey bees by agricultural adjuvants and tank mix combinations of adjuvants with pesticides. Based on the current state of knowledge, we make recommendations to pesticide applicators, product manufacturers, regulatory agencies, and researchers regarding adjuvant toxicity to honey bees with the goal of reducing risks that adjuvants pose to honey bees and other beneficial insects.

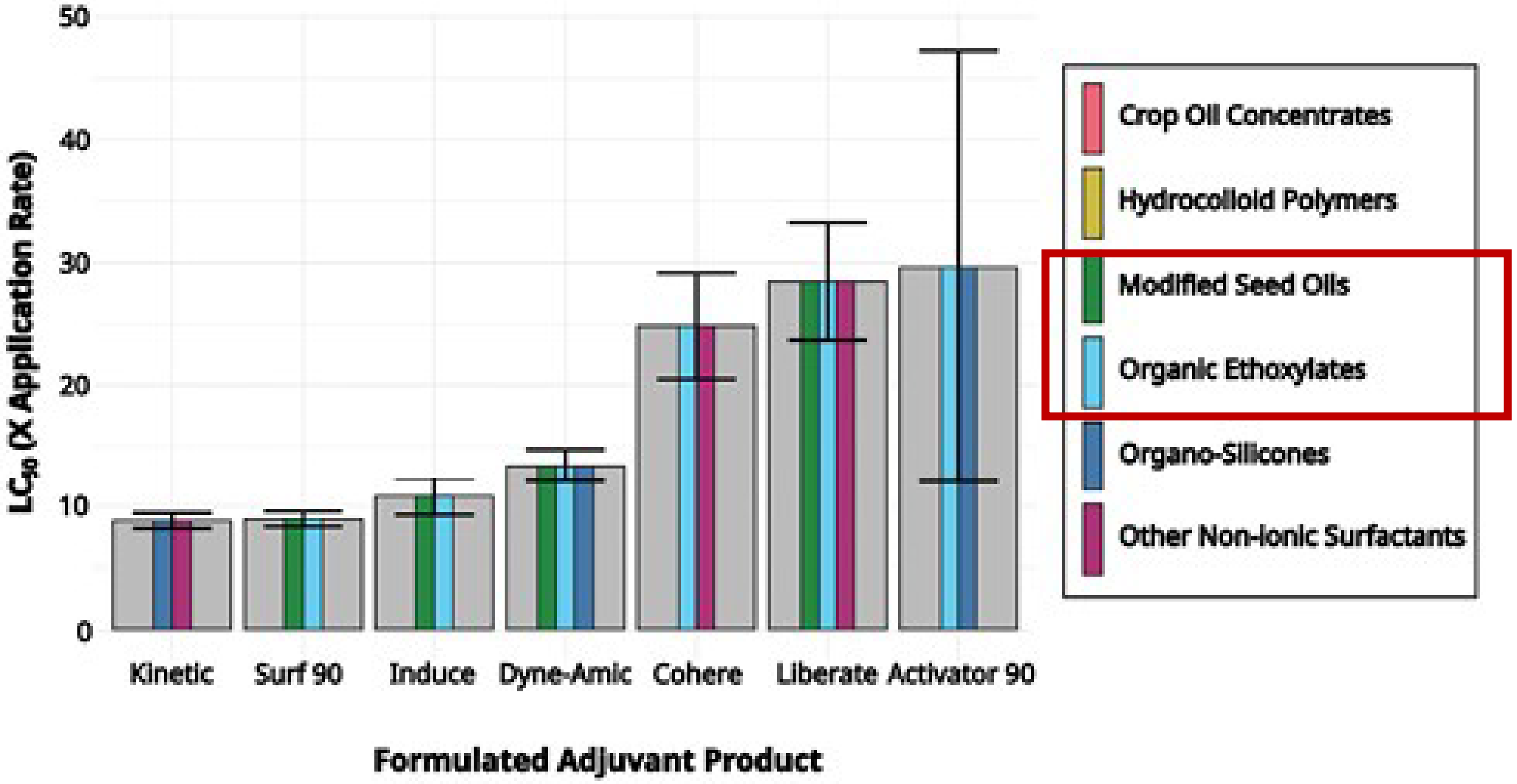
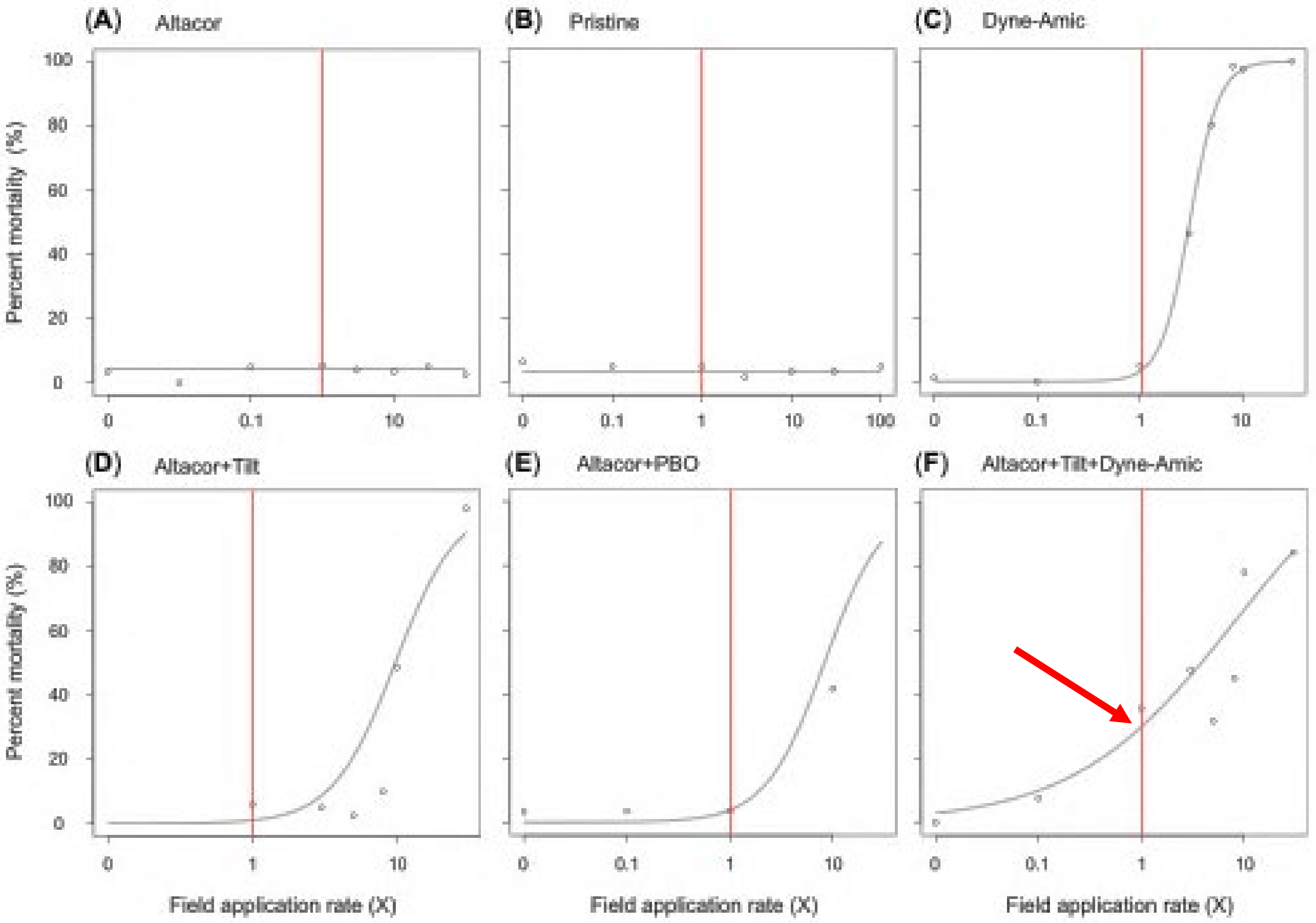


Fig. 3.
LC_{50} estimates for the 7 of the 12 adjuvants tested that demonstrated toxicity at near application rates (less than 30 times the maximum labeled application rate). LC_{50} is expressed as multiples of the maximum application rate listed on the label. The shade of vertical bars indicate the class or classes of principal functioning agent present based on information from the label. Error bars indicate 95% confidence intervals for LC_{50} estimates.

Adjuvants that are toxic at near application rates, see Organic Ethoxylates and Organo-Silicones are in commercial mixtures

Shannon B, Walker E, Johnson RM. Toxicity of spray adjuvants and tank mix combinations used in almond orchards to adult honey bees (Apis mellifera). J Econ Entomol. 2023 Oct 10;116(5):1467-1480.



Adjuvants can synergize the toxicity of active ingredients to honey bees when used in a tank mix

Walker EK, Brock GN, Arvidson RS, Johnson RM. Acute Toxicity of Fungicide-Insecticide-Adjuvant Combinations Applied to Almonds During Bloom on Adult Honey Bees. Environ Toxicol Chem. 2022 Apr;41(4):1042-1053. doi: 10.1002/etc.5297.

Brandon Shannon, Reed Johnson, 2022

Principal Functioning Agent Recommendations

Synergism with Pesticides	Toxic at near application rates	Toxic only at high concentrations (~30 X or more)	Not toxic at rates tested
• ?	• Ethoxylates	• Fatty Acid Derivatives	• Pinenes / Terpenes
	• Organic Polymers		• Lecithin
	• Organo-silicones		• Other?

Demo for some
In 2025
publication

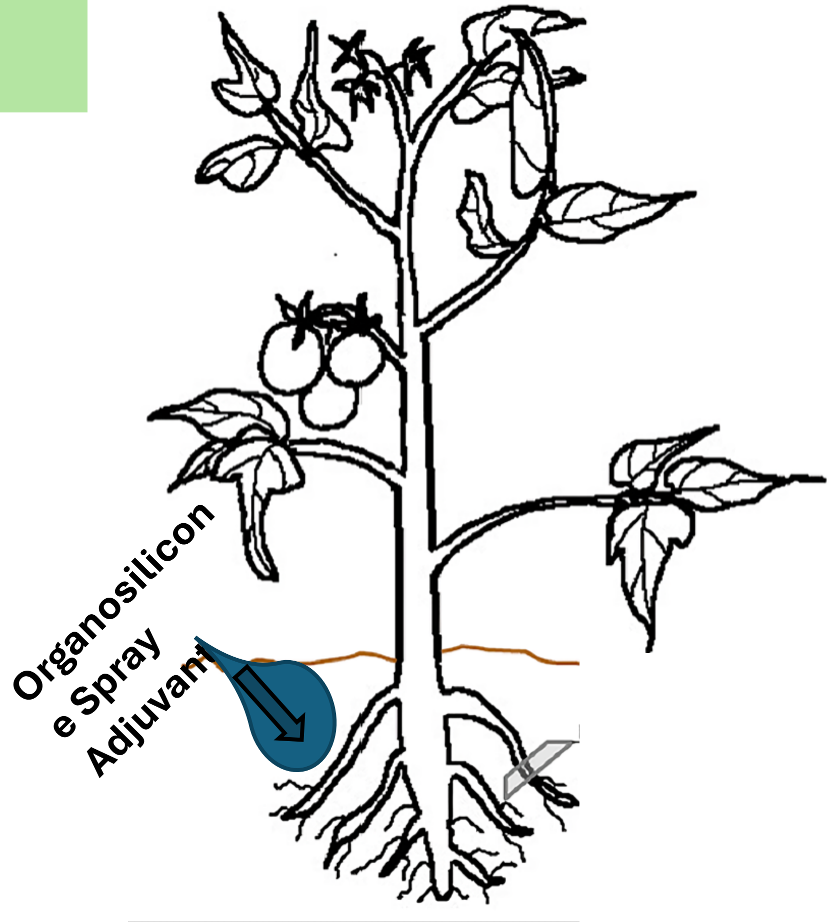
Toxic → Safe

OSS impacts on Bees

- Toxicity via oral ingestion (Chen J, Fine JD, Mullin CA. 2018. Sci Total Environ. 612:415-421.)
- Impacts on bee learning and behavior (Ciarlo TJ, Mullin CA, Frazier JL, Schmehl DR. PLoS One. 2012;7(7):e40848.)
- Interaction with viruses to cause increased toxicity in honey bee larvae (Fine JD, Cox-Foster DL, Mullin CA. Sci Rep. 2017 Jan 16;7:40499)
- Impacts on Queen health and survival of honey bee colonies
- Synergism with fungicides and insecticides for increased toxicity
- Alter gene expression in bees– changes in immune genes and detoxification genes.

Where is OSS found in plants?

- TSS-COCH3 was converted to TSS-OH and TMS in both planted and unplanted systems.
- In plants exposed to TSS-COCH3, TSS-OH was found in above ground tissues at levels higher than TSS-COCH3 with the highest concentrations found in leaves.
- In plants exposed to TMS, the highest concentrations of TMS were found in the fruit and flowers – ***potential to be in pollen and nectar (detections in HB collected pollen)***
- Previous experiments found higher uptake in stressed plants. Addition of salt had little impact on uptake, suggests not a general stress response. Needs more research.



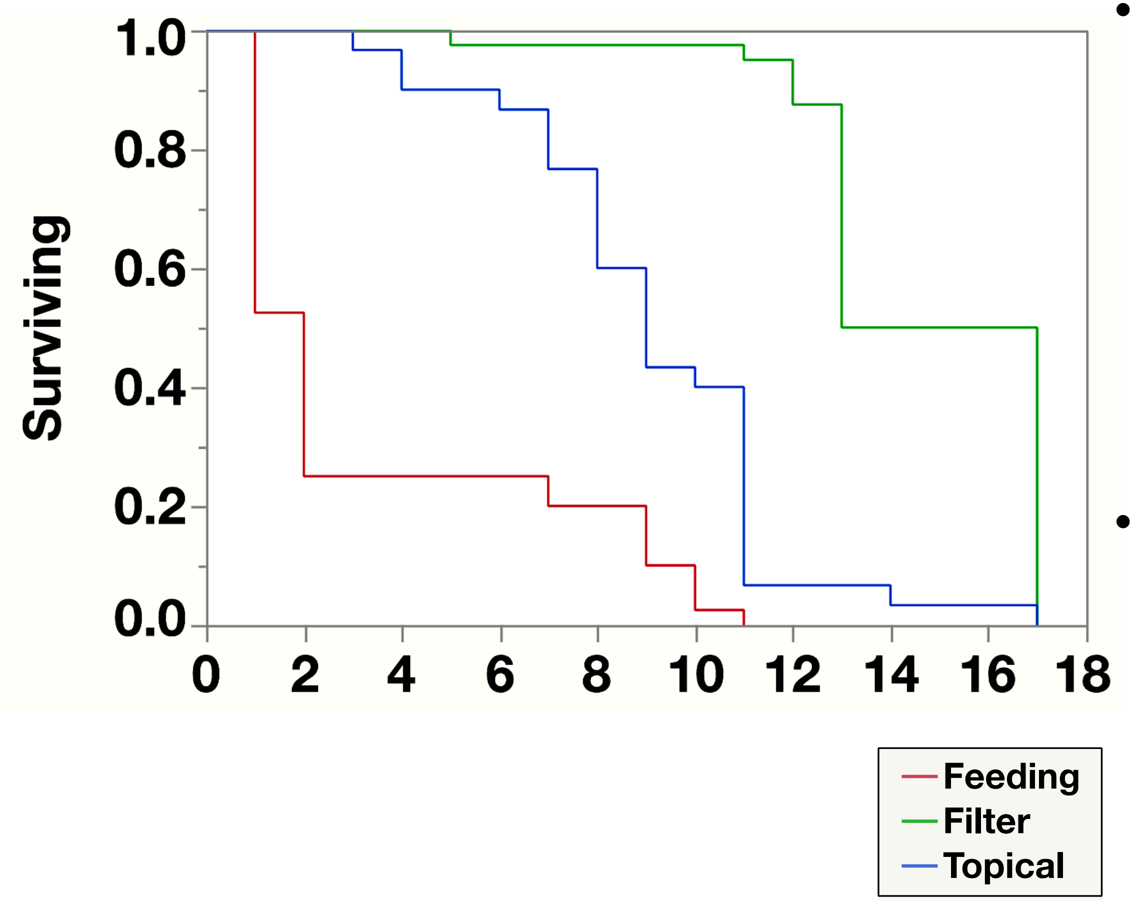
Collaborators-- Autumn Slade and Dr. Bill Doucette, Utah Water Research Laboratory, Utah State University, Logan Utah

What is the impact of OSS on Alfalfa Leaf Cutting Bees?

- See that OSS affected the ability of the ALCB to do their job
  - Lower number of nests for each bee
  - Fewer number of cells in each nest
  - Fewer eggs being laid

- ***OSS caused bees to collect much less pollen for provisioning their cells***
- ***Potential impact on seed set and yield***

Toxicity to 100 ppm OSS differ by mode of exposure- feeding, topical, or walking/chewing to ALCB



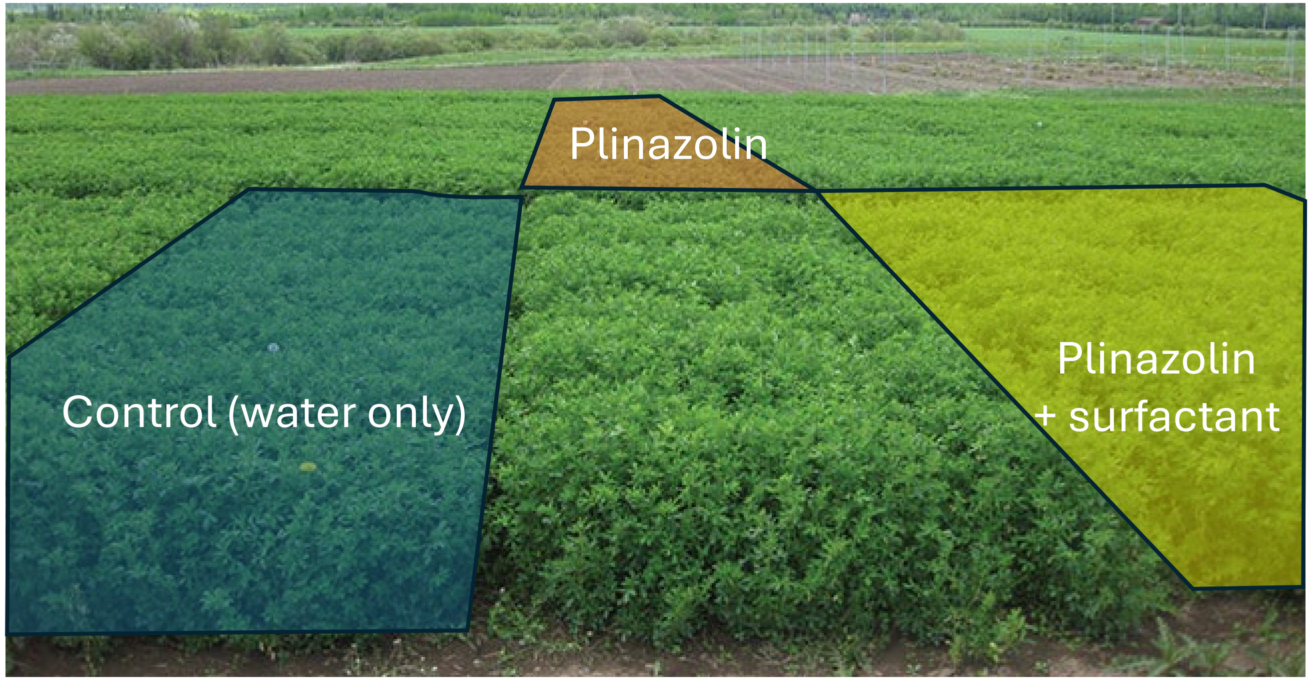
- Adult female bees were exposed to OSS via 3 ways
  - Fed in sugar water (i.e., nectar/pollen ingestion)
  - Topical application (i.e., exposure during application of pesticide tank mix)
  - Contact and chewing on filter paper with dried OSS
- Bees fed sugar water and survival monitored

Test	ChiSquare	DF	Prob>ChiSq
Log-Rank	117.0630	2	<.0001*
Wilcoxon	103.0764	2	<.0001*

Testing the impact of adding a surfactant to an insecticide treatment

Photo: Doug Walsh

- Applied three treatments in a field of alfalfa
  - Plinazolin (1.6 fl oz/acre)
  - Plinazolin + surfactant (Hi-Yield Spreader Sticker, composed of Alcohol ethoxylate and Alkylphenol ethoxylated)
  - Control (water)



Testing the impact of adding a surfactant

- Clipped alfalfa leaf material from each treatment plot at 3 time intervals and placed into small screened arenas (3 arenas per treatment)

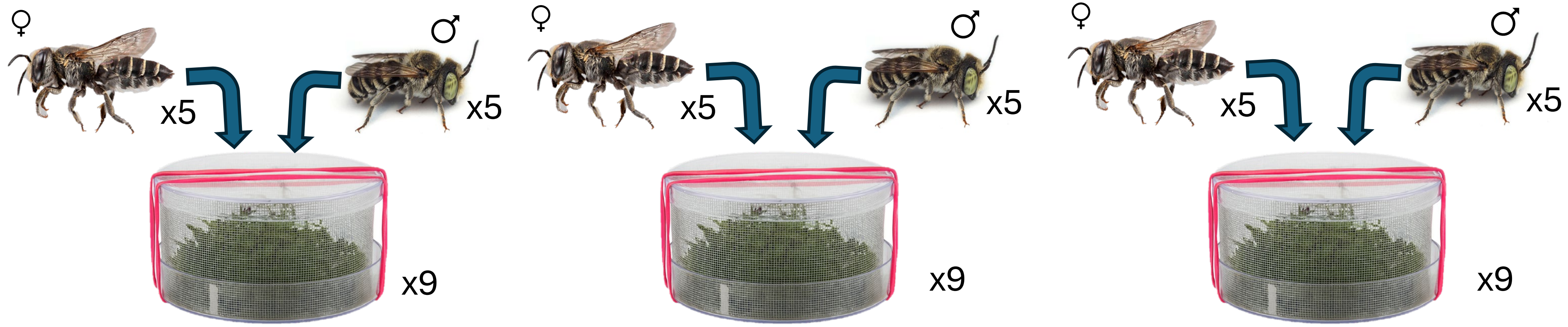
48 hours (2 days) post application

96 hours (4 days) post application

144 hours (6 days) post application

Testing the impact of adding a surfactant

- Placed 10 alfalfa leafcutting bees (*Megachile rotundata*) in each enclosure (5 females/5 males in each).
- Monitored survival and ability to fly away after 48 hours in arenas.

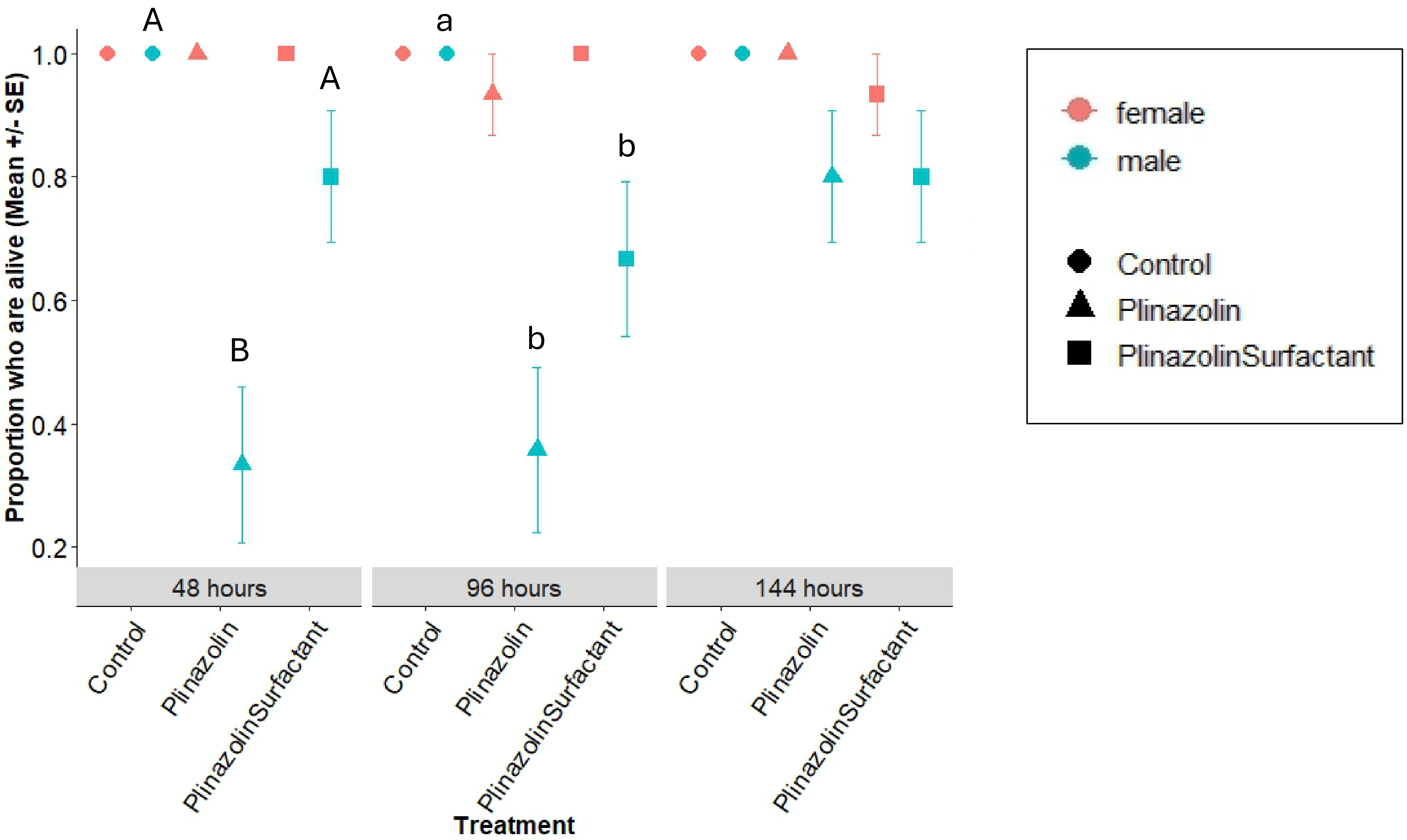


<u>Control (water)</u>
- 48 hours post application (x3 arenas)
- 96 hours post application (x3 arenas)
- 144 hours post application (x3 arenas)

<u>Plinazolin</u>
- 48 hours post application (x3 arenas)
- 96 hours post application (x3 arenas)
- 144 hours post application (x3 arenas)

<u>Plinazolin + surfactant</u>
- 48 hours post application (x3 arenas)
- 96 hours post application (x3 arenas)
- 144 hours post application (x3 arenas)

Observe significant mortality in males at 48 and 96 hrs, but not 144 hrs (6 days) post-application

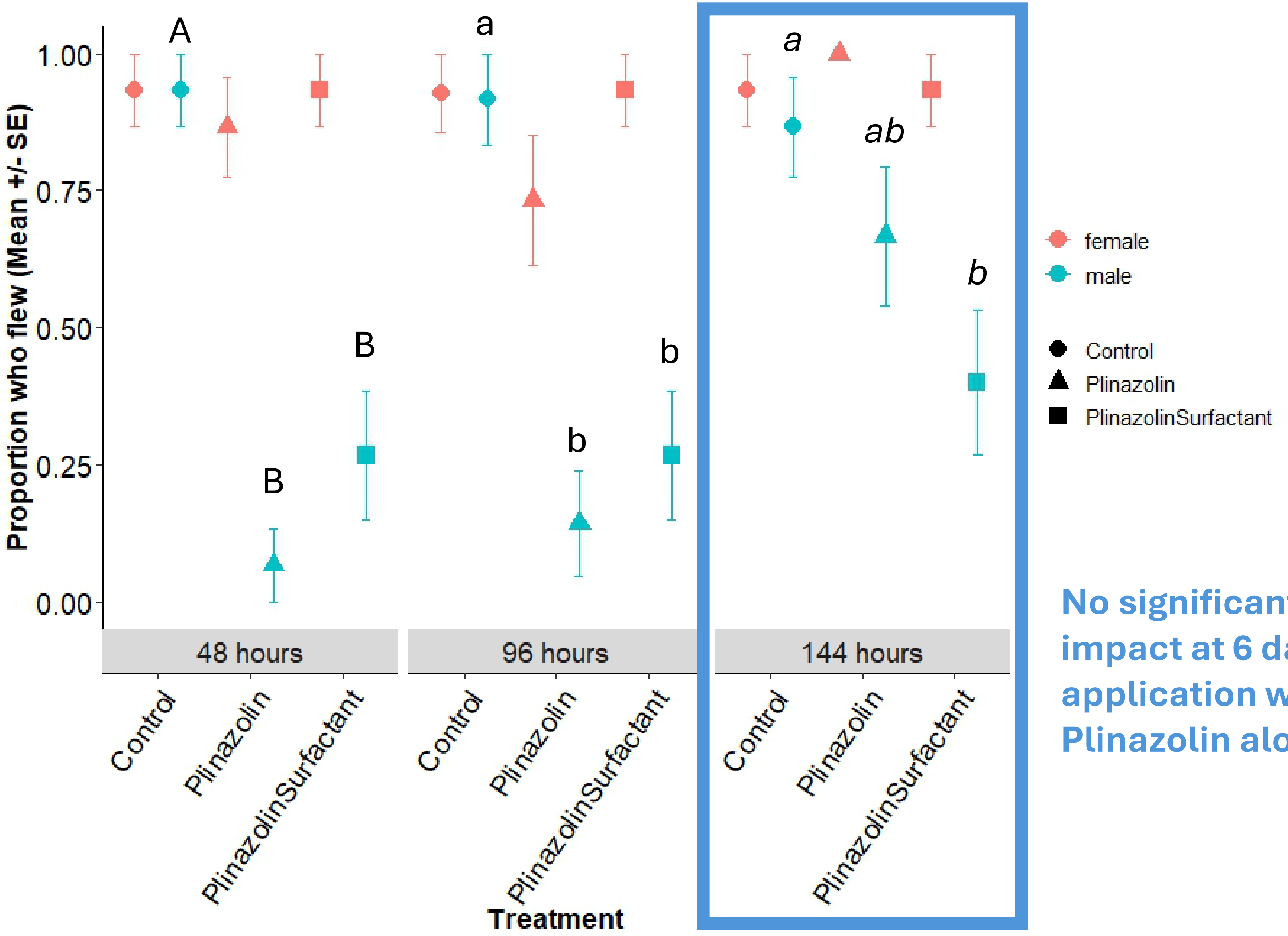


2-way ANOVA

Tukey's multiple comparisons tests comparing within time and sex

Different letters indicate a significant difference ($p < 0.05$)

Significant reduction in males who could fly in the Plinazolin+surfactant treatment compared to controls at 144 hours (6 days)



2-way ANOVA

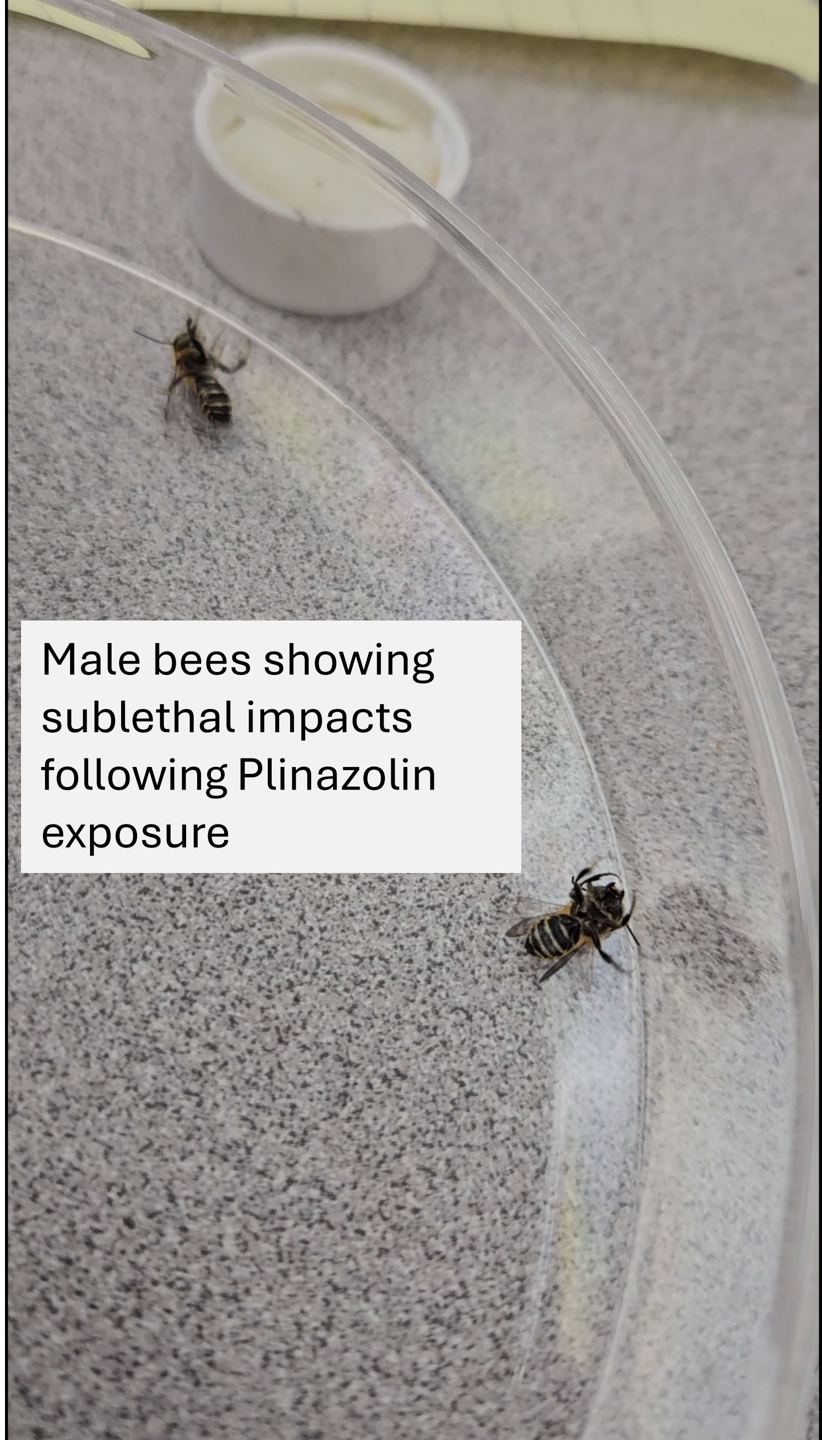
Tukey's multiple comparisons tests comparing within time and sex

Different letters indicate a significant difference ($p < 0.05$)

No significant sublethal impact at 6 days post-application with Plinazolin alone

Conclusions

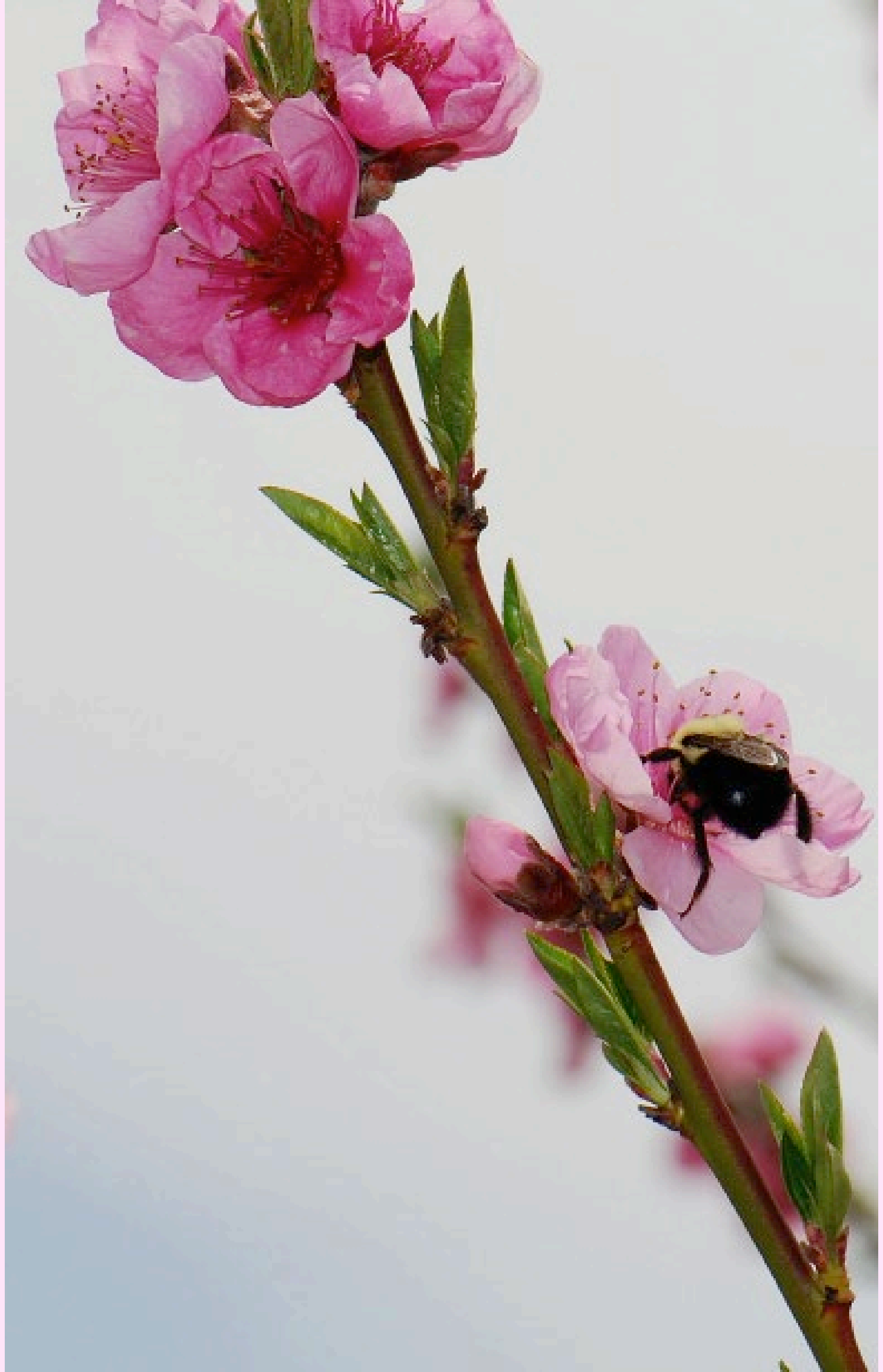
- Mixed evidence for the safety of the applied surfactant (Hi-Yield Spreader Sticker) when applied with an insecticide (Plinazolin)
    - **No increase in mortality with the addition of this type of surfactant at minimal conc.**
    - Possibly causes sublethal impacts on males (inability to fly) for longer post-application
- Questions–
    - Why are males more susceptible as compared to females?
    - How would this affect reproductive success of females?



Advice for safe use of adjuvants in tank mixes for bee pollination

Shannon B, Jeon H, Johnson RM. Review: the risks of spray adjuvants to honey bees. J Insect Sci. 2023 Nov 1;23(6):20.

- **Follow the label of the pesticide(s) being used**
- Avoid the use of adjuvant products and pesticides containing inert ingredients known to have toxicity to honey bees
- Adjuvants that are not recommended on pesticide labels can have unpredictable interactions with pesticides, such as synergistic toxicity to bees or reduce efficacy against the targeted pest
- Potential negative impacts on the crop plant itself-
    - reduced drought tolerance of crops (Räsch et al. 2018),
    - altered physiochemistry of plant surfaces (Noga et al. 1986, Rogiers et al. 2005, Schreiber 2006, Damato et al. 2017)
    - induced phytotoxic effects (Knoche et al. 1992, Jursík et al. 2013).
- If you choose to use an adjuvant-- apply at the *minimum* concentrations needed



Questions or want additional details–

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