bpia 2026 Annual Meeting

Assessing Pesticide Tank Mix Compatibility And Combined Toxicity Effects On Monarch Butterfly Larvae

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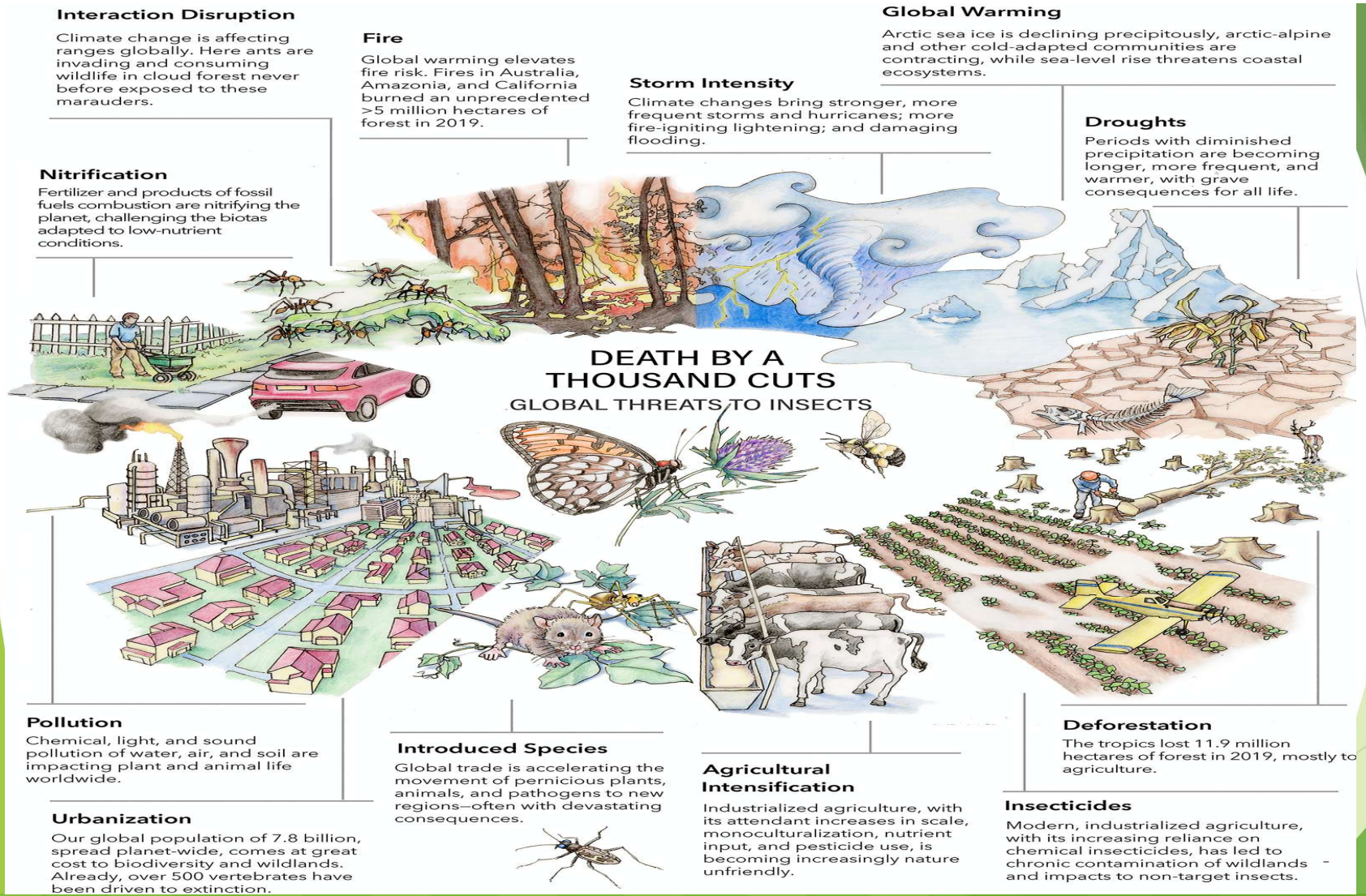
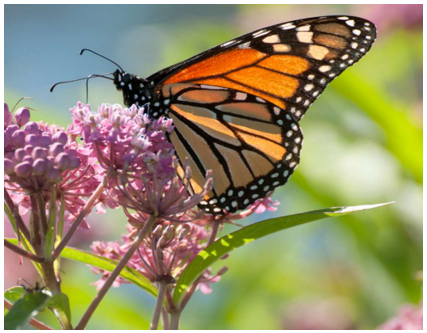
March 6, 2026



Wagner et al. 2021

Background

- In 2022, Environmental Protection Agency announced assessing risk of pesticides on listed species and their critical habitat.
- 99 Federally listed insect species
  - Over 40% Lepidopterans

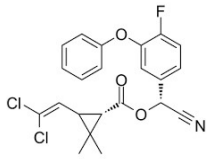


Monarch butterfly

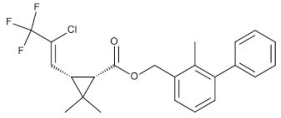
Blue butterfly

Chemical-Insecticide Toxicity Studies

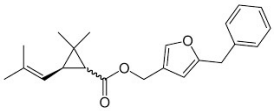
Pyrethroids



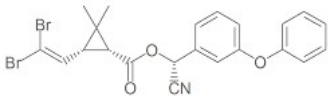
Beta-cyfluthrin



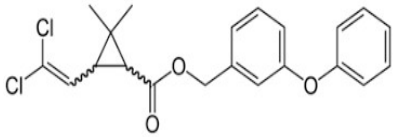
Bifenthrin



Resmethrin

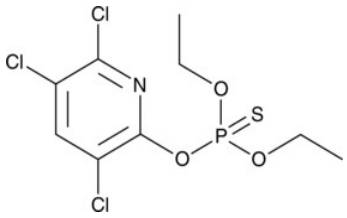


Deltamethrin



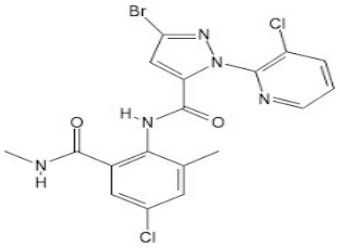
Permethrin

Organophosphates



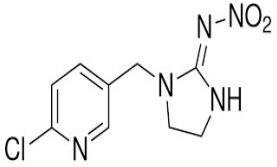
Chlorpyrifos

Diamides

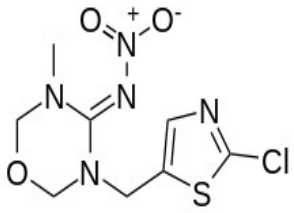


Chlorantraniliprole

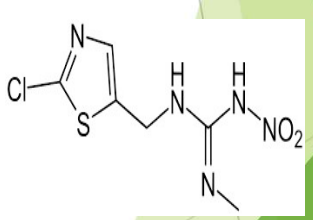
Neonicotinoids



Imidacloprid



Thiamethoxam



Clothianidin

JOURNAL ARTICLE

Monarch Butterfly Ecology, Behavior, and Vulnerabilities in North Central United States Agricultural Landscapes

Tyler J Grant, Kelsey E Fisher, Niranjana Krishnan, Alexander N Mullins, Richard L Hellmich, Thomas W Sappington, James S Adelman, Joel R Coats, Robert G Hartzler, John M Pleasants ... Show more

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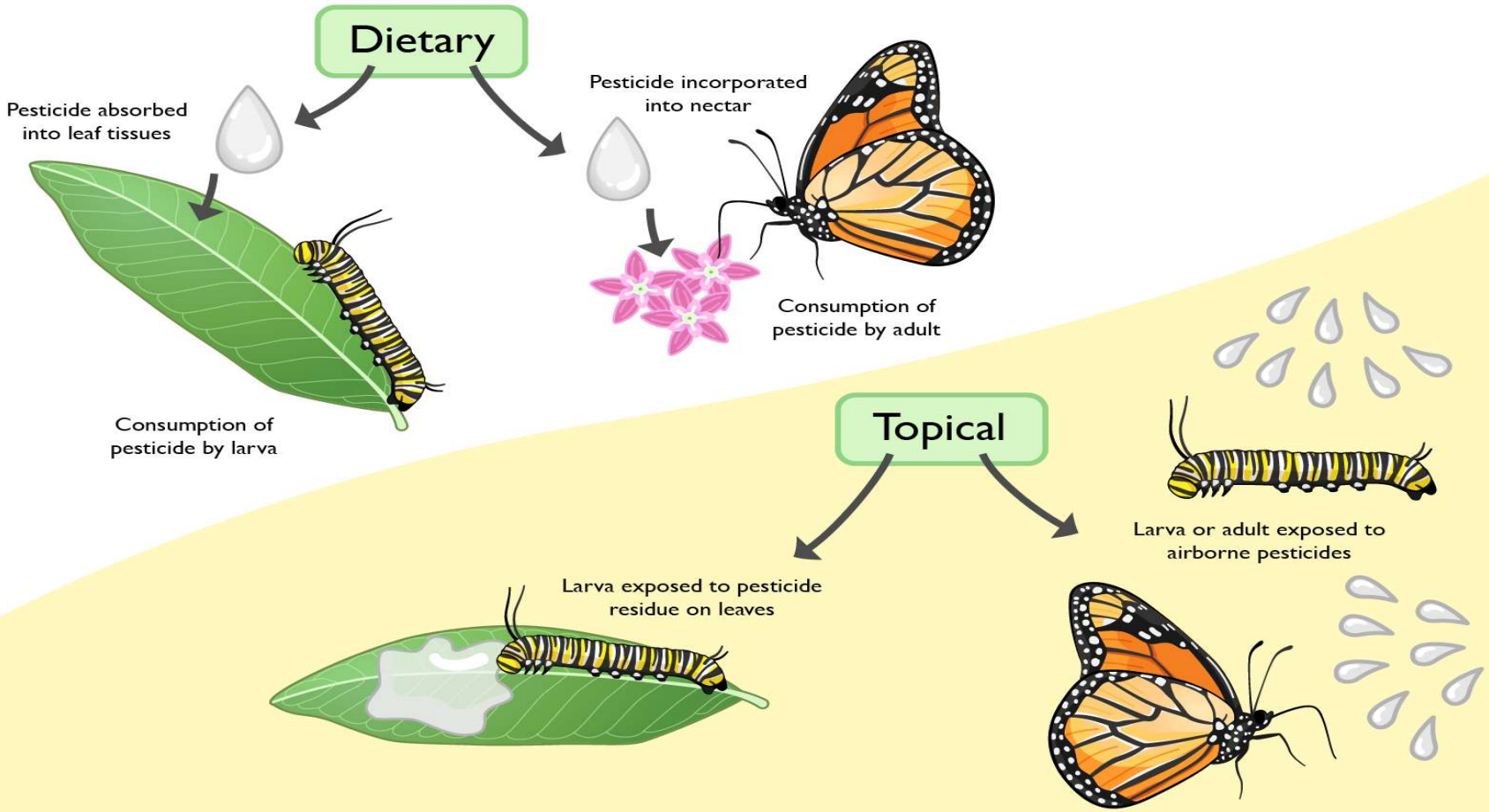
Objectives

- Evaluate the compatibility of biological fungicides and conventional fungicide in tank mixes
- Assess the individual and combined pesticide toxicity effects on monarch larvae and eastern tailed-blue larvae

Pesticide Exposure Routes



Pesticides Used

Formulated Products:

Biological Fungicides:

- Double Nickel® (*Bacillus amyloliquefaciens*)
- Howler ® (*Pseudomonas chlororaphis*)

Chemical Fungicide:

- Kocide ® (Copper-based fungicide)

Chemical Insecticide:

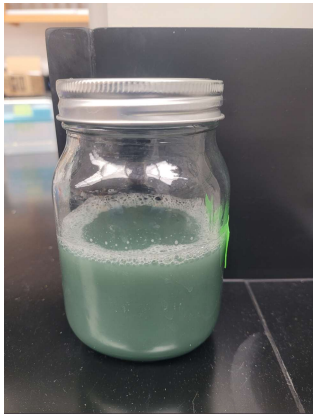
- Bifenture (Pyrethroid)

HOWLER fungicide

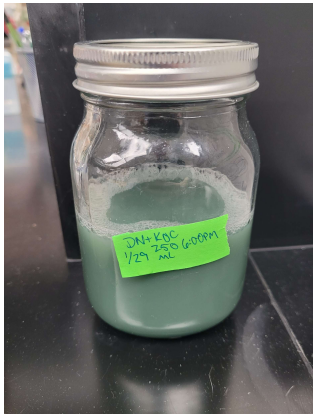
BIFENTURE LFC INSECTICIDE

Compatibility Testing

- Combinations at tank mix rate;
  - Double Nickel® + Kocide ®
  - Howler ® + Kocide ®



DN + Ko at 24 hr

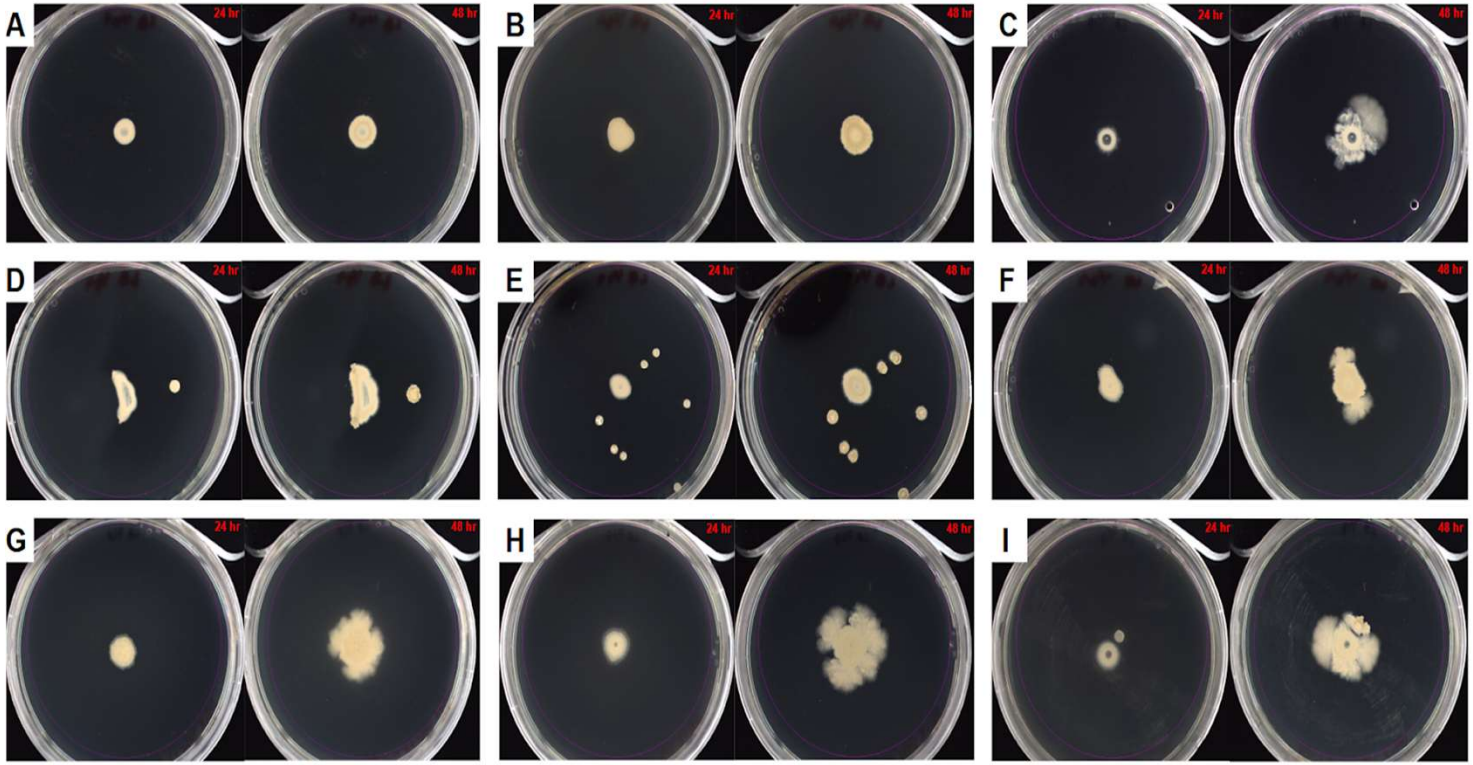


DN + Ko at 48 hr

HW + Ko at 0 hr

Sabrina

Plating



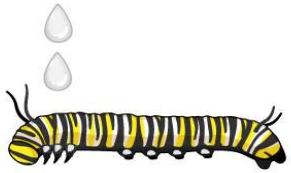
A-C = Double Nickel® only
D-F = Double Nickel® + Kocide® at 0hr
G-H = Double Nickel® + Kocide® after 24hr

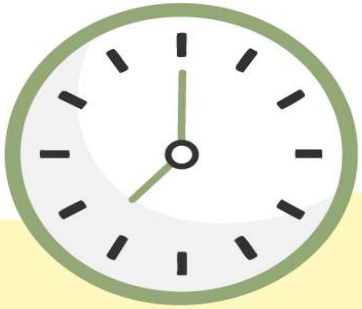
Materials and Methods: Acute Toxicity Bioassays

Topical Treatment

Pesticide and acetone solution applied to larva cuticle

3rd instar larva





Observations taken every 24hr for 4 days or until pupation

Dietary Treatment

Pesticide and silwet solution applied to leaves

Leaves fed to 3rd instar larva

Individual Toxicity

Treatment concentration was the maximum application rate

Name	Exposure	Maximum application rate concentrations	#larvae treated	% larval mortality
Double Nickel®	Cuticular	30 µL/mL	30	0
	Dietary	1.5 µL/g	30	0
Howler®	Cuticular	18 µg/uL	30	0
	Dietary	900 µg/g	30	13
Kocide®	Cuticular	3.6 µg/uL	30	0
	Dietary	180 µg/g	30	0

Bifenture caused 100% mortality in both bioassays

Combined Toxicity

No mortality at the maximum application rate

Name	Exposure	#larvae treatment	%larval mortality
Double Nickel® + Kocide®	Topical	30	0
	Dietary	30	0
Howler® + Kocide®	Topical	30	0
	Dietary	30	0

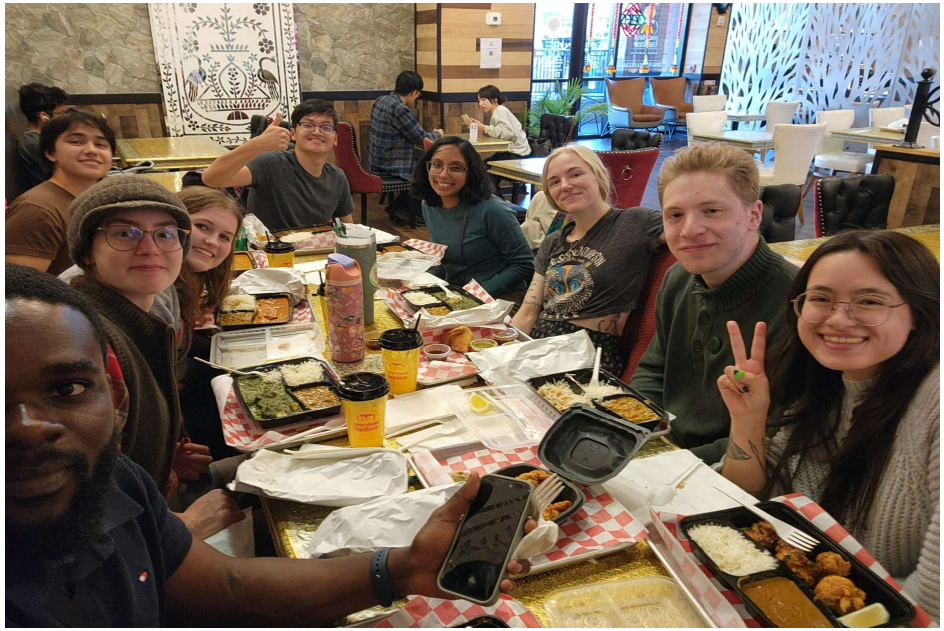
In summary

- Double Nickel®, and Howler® are physically compatible with the copper hydroxide in Kocide® at maximum application rates
- Double Nickel® is biologically compatible with Kocide® at the maximum application rates
- Double Nickel®, Howler® pose *de minimus* risk to monarchs at maximum application rate.

Future Plans

- Eastern-tailed blue (Lycaenid) toxicity studies (surrogate for listed lycaenids)

Acknowledgement



Krishnan lab members

- Ann Ryan from Monarch Watch for monarch eggs