EFFICACY AND MARKET POTENTIAL OF BIOPESTICIDES DEVELOPED FROM SAPONINS AND ESSENTIAL OILS

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Introduction

The global market for biopesticides is predicted to be 20 % of total pesticide use in 2025. For those biopesticides based on plant chemicals, the chemical active ingredient generally falls within the category of vegetable oils and fatty acids, or small molecules also known as secondary plant metabolites.

The objective of our research was to evaluate the use of saponins and essential oils as active ingredients in innovative biopesticide formulations.

Methods

Insect bioassays:
- Hop or geranium essential oil was added to 60% ethanol and diluted to solutions of varying concentrations
- A paper disc treated with 400 µL of essential oil solution was put in a 1 L glass beaker (i.e. fumigation chamber)
- Five apterous adult (24 h old) aphids (*Aphis gossypii)* were placed on the first leaf of a cucumber seedling
- Behavior and mortality was recorded

Fungal in vitro and in planta bioassays:
- A paper disc treated with 20 µL of hop oil was added to the surface of PDA or, for determining volatile bioactivity, the lid of a Petri dish
- Fungal growth was calculated as colony diameter based on percent of control after a few days of growth
- For fungal in planta bioassays, tomato seedlings were transplanted into potting mix and *Fusarium oxysporum* was added at a concentration of 10^6 spores per gram of potting mix
- Hop oil was mixed with quillaja saponins and soybean saponins and applied at rates of 2.5% and 5% (v/v) of potting mix

Market potential:
- The amount of biopesticides with secondary metabolites as the main active ingredients, applied to California crops from 2010 to 2018 were calculated from the California Department of Pesticide Regulation's databases
- Retail biopesticide prices were determined by surveying suppliers.

Results: Insecticidal Activity

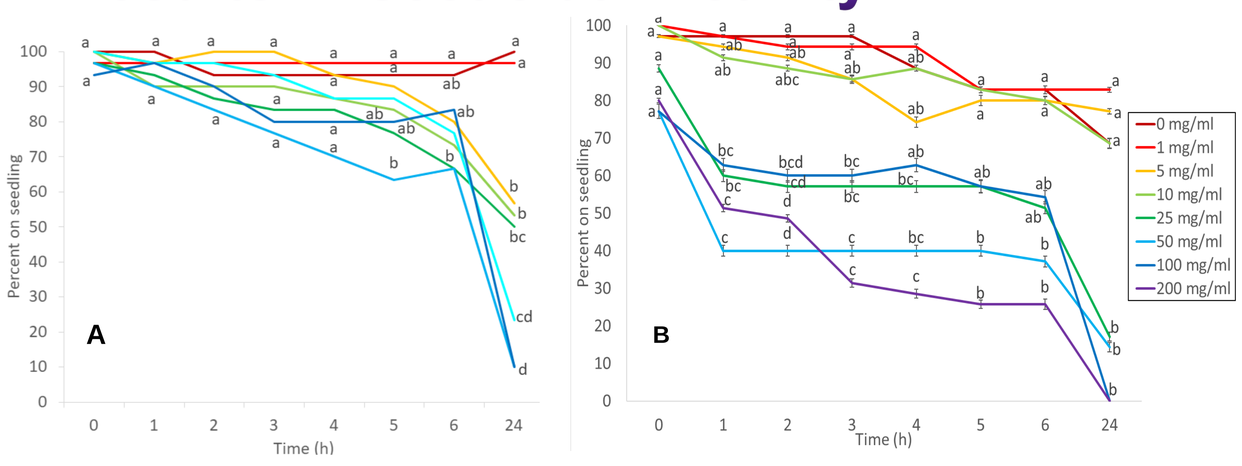

Figure 1. *The effect of* ***geranium essential oil (A)*** *or* ***hop essential oil (B)*** on the behaviour of *A. gossypii*. *The percent of A. gossypii on cucumber seedlings at each time point marked by the same letter are not significantly different.*

- A lower number of aphids were found over time on seedlings exposed to volatile essential oils (**Figure 1A and B**).
- This behaviour generally followed a dose response as higher amounts of geranium or hop oil led to lower aphid numbers
- Aphids were also observed to fall off seedlings and spend less time on seedlings that had been fumigated with geranium essential oils or hop essential oils.

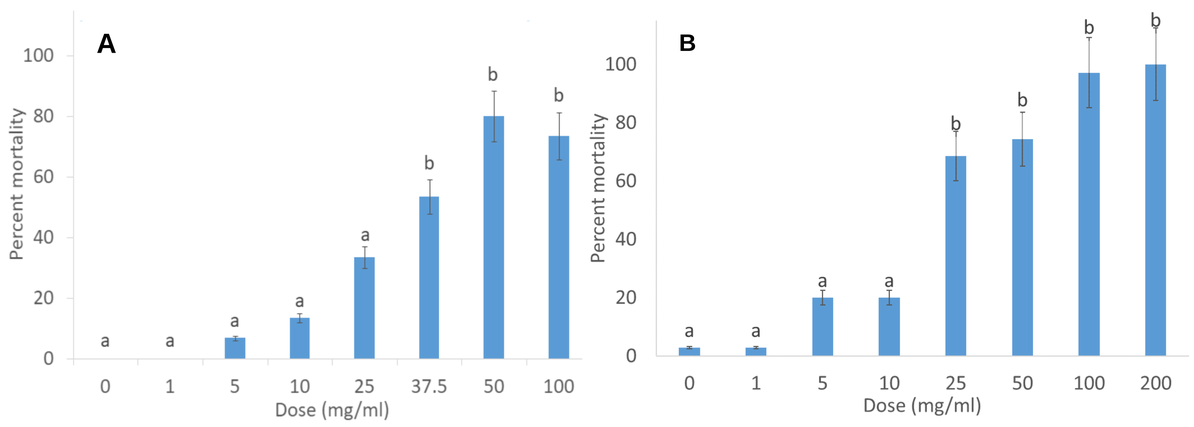

Figure 2: *Percent mortality of A. gossypii on cucumber seedlings in* ***geranium essential oil (A)*** *or* ***hop essential oil (B)*** *fumigant bioassays. Percent mortality of A. gossypii at each essential oil concentration marked by the same letter are not significantly different.*

- Essential oils delivered as a fumigant also caused mortality in aphids (**Figure 2**)
- Higher concentrations of essential oils caused higher mortality
- Hop oil caused significantly higher aphid mortality at a lower concentration, 25 mg/mL, than geranium essential oil.

Results: Fungicidal Activity

Fusarium graminearum ***Rhizoctonia solani*** ***Pythium irregulare***

Figure 3: *In vitro antifungal bioassays. Fungi received control solution (left plate) or hop oil (right plate).*

- **Hop essential oil** applied on the medium or the lid of the Petri dish (i.e. volatile) caused growth reduction in several fungal plant pathogens (**Figure 3, Table 1**).
- The growth of *Fusarium proliferatum* and *Fusarium graminearum* was reduced to a greater extent by volatile delivery while the other pathogens' growth was reduced by approximately the same amount by either delivery method.
- **Saponins** extracted from diverse plant sources also reduced pathogen growth by up to 70 % when delivered in the medium (data not shown).

Table 1: *In vitro growth of fungi treated with hop oil. Hop oil was delivered through the medium or the air.*

Fungal Pathogen	Growth Relative to Control (%)	
	Hop On Medium	Volatile Hop
Fusarium proliferatum	-5.1	-18.0
Fusarium oxysporum	-8.2	-17.8
Alternaria solani	-23.0	-24.5
Fusarium graminearum	-44.7	-44.3
Pythium irregulare	-52.5	-52.9

Figure 4: *Effect of hop oil and saponin mixtures on disease in tomato seedlings caused by F. oxysporum. There were 10 seedling in each treatment.*

- A mixture of **hop essential oil and saponins** protected tomato seedlings from disease caused by *Fusarium oxysporum* (**Figure 4**).
- Although plants were not completely disease-free, wilt symptoms were reduced when compared to the seedlings that received fungal spores but no biopesticide treatment.
- By the end of the experiment, control plants with pathogen had 70% mortality and plants treated with biopesticide had 30% mortality.

Results: Market Potential

Table 2: *Amount of the top five secondary metabolites biopesticides applied to strawberry grown in California from 2010 to 2018.*

Biopesticide	Botanical Source	Phytochemical(s)	Kg applied
Neem Extract	*Azadirachta indica*	Fatty acids plus residual limonoids and triterpenoids	193,605
Margosa Oil	*Azadirachta indica*	Fatty acids, limonoids, triterpenoids	12,212
Knotweed Extract	*Reynoutria sachalinensis*	Various	7,872
Limonene & essential oils	Citrus	Monoterpenoids	1,288
Quillaja	*Quillaja saponaria*	Saponins	33

- Biopesticides with diverse secondary metabolites as active ingredients were applied to strawberry crops grown in California (**Table 2**).
- The top five crops that received secondary metabolie biopesticides were, in descending order, strawberry, kale, broccoli, grape and onion.
- Survey of biopesticide suppliers revealed that the retail price of the active ingredients in these products is $387 per kg.
- Using this value as well as hectares of strawberries grown in Canada, the Canadian retail market value of new saponin and essential oil biopesticides for use in strawberry production was estimated to be over $3 million annually.

Conclusions and Next Steps

- ❑Essential oils had anti-insect activity when applied directly to various insect pests Aphids altered their behaviour, abandoned seedlings and had higher mortality when exposed via fumigation.
- ❑Essential oils (applied directly as well as a fumigant) and saponins caused reductions in growth of plant pathogenic fungi.
- ❑Mixtures of essential oils and saponins protected tomato seedlings from wilt caused by *Fusarium oxysporum.*
- ❑Biopesticide use had high uptake in a variety of California crops including strawberry, grape, greens, crucifers and onions. These crops are also grown in Canada. The extrapolated retail market for biopesticides in Canadian strawberry production is over $3 million annually.
- ❑Additional testing of fumigant activity in a commercial greenhouse is needed to validate results.