Integrated Pest Management of Arthropods on Hops: 2017 Report

Presented to Hop Research Council 1/24/18

Sally O'Neal • soneal@wsu.edu

for Doug Walsh • dwalsh@wsu.edu

WASHINGTON STATE UNIVERSITY EXTENSION

PROJECT LEADERS

Doug Walsh, State IPM Coordinator

Sally O'Neal, Senior Outreach Specialist

FIELD AND LABORATORY COORDINATORS

Dan Groenendale,
Field Research Director

Deborah Brooks,
Lead Arthropod Quantifier

COLLABORATORS

Adekunle Adesanya, WSU Entomology
Jim Barbour, U of I Entomology
David Gent, USDA-ARS/OSU
Gary Grove, WSU Plant Pathology
Laura Lavine, WSU Entomology
Tom Marsh, WSU Economic Science
Troy Peters, WSU Bio Systems Engineering
Tom Shellhammer, Oregon State University
Jennifer Sherman, WSU Sociology
Meixiang Wu, Fujian Ag & Forestry Univ.
Fang Zhu, WSU Entomology

Overall Project Objective

Provide pest management recommendations for the ever-changing hop arthropod IPM program

WASHINGTON STATE UNIVERSITY EXTENSION

Sixteen objectives were planned and addressed in 2017

These objectives combined:

RESEARCH

SERVICE

EXTENSION

Objective (a)

Field test candidate compounds:

miticides for their efficacy against spider mites and

insecticides for their efficacy against aphids

WASHINGTON STATE UNIVERSITY EXTENSION

As aphid populations failed to develop in the research hopyards,

No aphid trials conducted in 2017

WASHINGTON STATE UNIVERSITY EXTENSION

Miticide Trials 2017

	Product	Active Ingredient	Rate/Acre	
1	Control (Untreated)	None	none	none
2	GWN-10409	?	6	fl oz/acre
3	GWN-10409	?	8	fl oz/acre
4	GWN-10409	?	12	fl oz/acre
5	Vilgilant 4SC**+	Bifenazate	24	fl oz/acre
6	GWN-10194(onager Opteck)	Hexythiazox	24	fl oz/acre
7	Onager 1E	Hexythiazox	24	fl oz/acre
8	Zeal	Etoxazole	4	oz/acre
9	Fujimite 5SC***	Fenpyroximate	32	fl oz/acre
10	Fujimite 20SC***	Fenpyroximate	8	fl oz/acre
11	Fujimite 5SC+NAI-2900***	Fenpyroximate	16	fl oz/acre
12	Fujimite 5SC+NAI-2900***	Fenpyroximate	32	fl oz/acre
13	Nealta 100gpa	Cyflumetofen	13.7	fl oz/acre
14	Nealta 200gpa	Cyflumetofen	13.7	fl oz/acre
15	Nealta*** NIS Induce 100gpa	Cyflumetofen	13.7	fl oz/acre
16	Nealta *** NIS Induce 200gpa	Cyflumetofen	13.7	fl oz/acre
17	Nealta* 100gpa +oil	Cyflumetofen	13.7	fl oz/acre
18	Nealta*200gpa +oil	Cyflumetofen	13.7	fl oz/acre
19	Nealta 100gpa	Cyflumetofen	24.7	fl oz/acre
20	Nealta*** NIS Induce100gpa	Cyflumetofen	24.7	fl oz/acre
21	Nealta*100gpa+oil	Cyflumetofen	24.7	fl oz/acre

Treatment Variation Key

* Add 1% v/v oil + water conditioner label rate

** Plus buffer at 5.5-6.5 and crop oil at 1% v/v

*** Non-ionic surfactant 0.25% v/v or 0.125% v/v depending on protocol, NAI-2900 @6.25 ml/gal

No significant differences among the various Nealta treatments

Miticide Trials 2017

Two-spot motiles					
Trt		Pretreat	4DAT	10DAT	17DAT
MS df=20		30.63	14.3	481.95	473.18
error df=63		70.18	37.45	552.93	549.72
1	Fujimite 5SC+NAI-2900*** 16 oz	9.55	7.5	22.3	20.5
2	GWN-10194(onager Opteck) 24 oz	6.15	5.8	29.5	31.2
3	Nealta *** NIS Induce 200gpa 13.7 oz	13	5.15	21.15	22.1
4	Fujimite 5SC+NAI-2900*** 32 oz	8.1	6.9	49.8	43.6
5	Nealta 100gpa 13.7 oz	14.05	6.6	19.85	20.45
6	Nealta 100gpa 24.7 oz	8.75	3.8	20.5	16.15
7	Control (Untreated)	6.65	25.35	51.9	42.85
8	Nealta 200gpa 13.7 oz	4.9	7.45	16.5	17.75
9	Nealta*** NIS Induce 100gpa 13.7 oz	10.1	2.75	18.2	17.5
10	Nealta*** NIS Induce 100gpa 24.7 oz	7.65	2.55	28	28.9
11	Fujimite 20SC*** 8 oz	7.75	6.85	28.5	31.7
12	Fujimite 5SC*** 32 oz	12.25	7.65	39	38.65
13	gNealta*100gpa+oil 13.7 oz	5.2	4.3	35.5	35.4
14	GWN-10409 12 oz	10.8	5.5	25.75	23.45
15	GWN-10409 6 oz	9.6	9	20.1	19.85
16	GWN-10409 8 oz	4.7	3.4	58.45	58.7
17	Nealta*100gpa+oil 24.7 oz	4.2	5.2	27.8	29.1
18	Nealta*200gpa+oil 13.7 oz	6.3	4.25	32	33.6
19	Onager 1E 24 oz	7.9	4.2	34.6	31.95
20	Vilgilant 4SC**+ 24 oz	7.05	5.3	16.6	16.95
21	Zeal 4 oz	6	9.2	25.6	26.45

- All treatments reduced mite abundance
- Results most significant 4 days after treatment
- Abundance reduced until 17 days post-treatment

Nealta (cyflumetofen) advanced at the IR-4 Food Use Workshop into the 2018 residue trial work plan.

WASHINGTON STATE UNIVERSITY
EXTENSION



Objective (b)

Field test efficacy of candidate insecticides applied post-harvest for weevil control. Target species include black vine and strawberry root weevil.

- Chemigated via extant systems
- Candidate Verimark (cyantraniliprole) vs. grower standard Platinum (thiamethoxam)
- This a.i. has proven effective in crops including Willamette strawberries
- Verimark has been advanced to IR-4
    - Request was for foliar application for flea beetles, but
    - Doug has added chemigation to IR-4 protocol to ensure that use

Washington State University Extension

Objective (c)

Develop and validate methods for accurately monitoring abundance of black vine weevil.

- Several methods attempted in 2016 & 2017, all had issues
    - Smooth boards
    - Grooved boards
    - Pitfall traps
- New approaches will be vetted in 2018

WASHINGTON STATE UNIVERSITY
EXTENSION

Objective (d)

Field test efficacy of insecticides on other pests if opportunities arise.

- No arthropods in 2017
- Last year's Godzilla was

WASHINGTON STATE UNIVERSITY
EXTENSION

Year of the Vole

- Significant vole damage in some Yakima Valley hopyards
- “Snowpocalypse” winter?
- Got conditional 24c Special Local Need registration for zinc phosphide
- We will complete controlled efficacy trials in fall 2018 to develop data required by WSDA for full 5-year 24c SLN

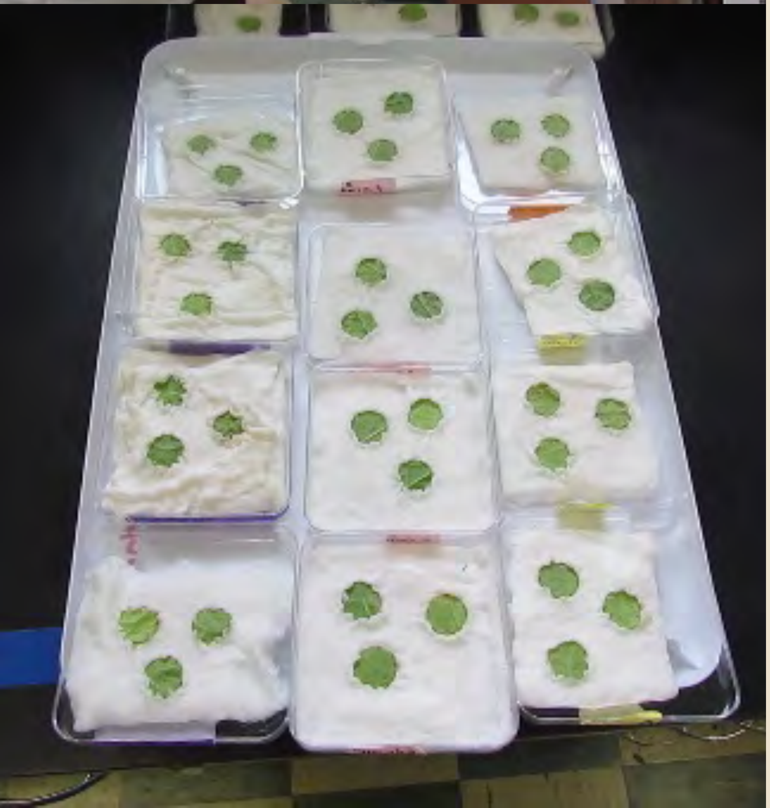
Washington State University Extension

Objective (e)

Evaluate the impact of candidate pesticides on non-target beneficial arthropods.

- Exposed *G. occidentalis* to
    - Clofentezine
    - Hexythiazox
    - Etoxazole
- # of eggs laid NOT reduced
- SIGNIFICANT REDUCTION in # of eggs completing development/hatching

WASHINGTON STATE UNIVERSITY
EXTENSION



Objective (f)

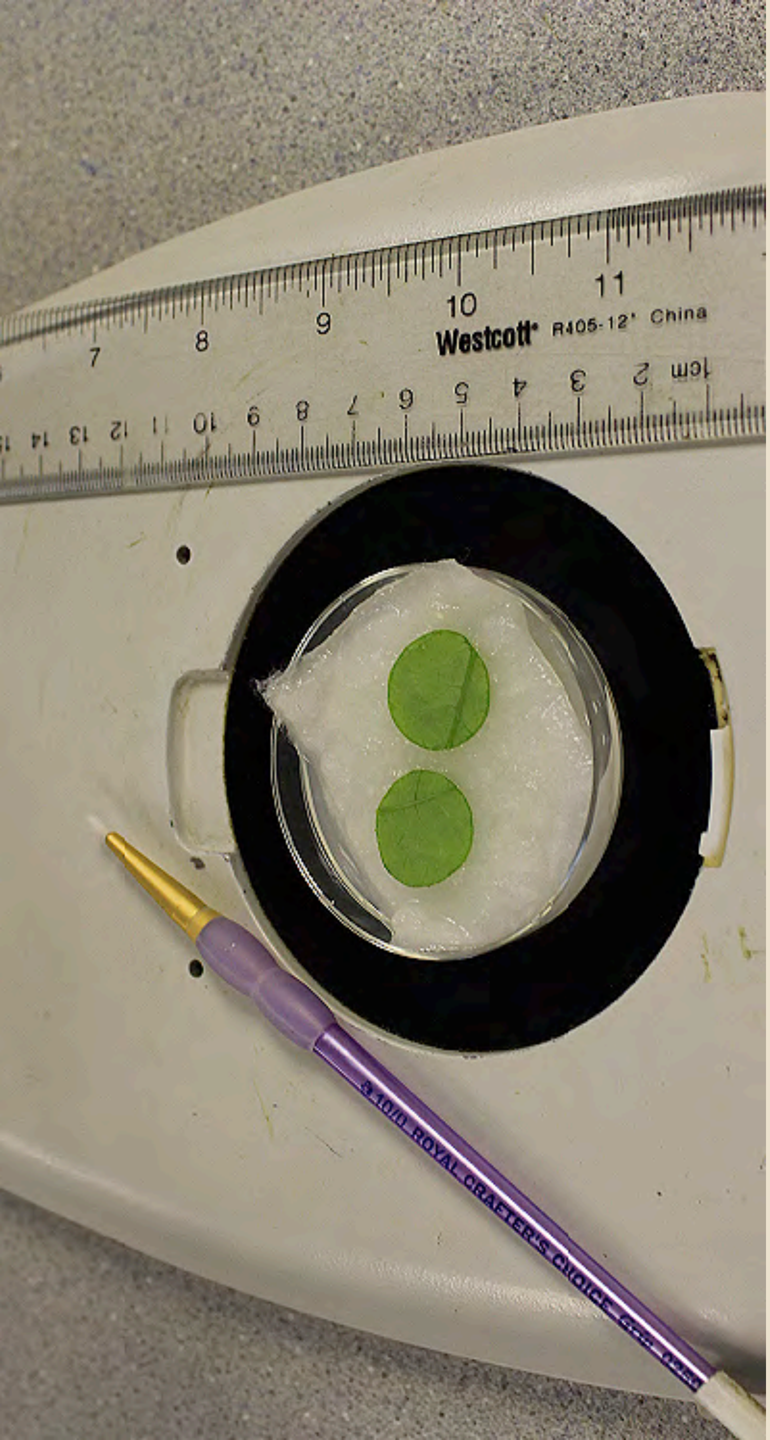
Develop a robust bioassay method for evaluating residual efficacy of miticides including spirodiclofen, fenpyroximate, and possibly spirotetramat.

- Spirodiclofen (Envidor) bioassays conducted on *T. urticae* larvae
- Fenpyroximate (Fujimite) bioassays conducted on *T. urticae* female adults
- Etoxazole (Zeal) bioassays conducted on freshly laid *T. urticae* eggs
- All bioassays using leaf discs.

WASHINGTON STATE UNIVERSITY
EXTENSION

- Mites counted, mortality scored
- Mites counted as dead if no response to gentle tap w/ fine camel-hair brush
- Dose-mortality response adjusted w/ control treatment using Abbot's formula
- Probit analysis used to estimate LC_{50} values, slopes, 95% confidence interval
- Statistical analysis performed
- PhD student Adekunle Adesanya was responsible for these experiments; see his poster in poster presentation room

Washington State University Extension



Objective (g)

Develop baseline dose response curves of spider mite populations susceptible to spiromesifen and fenpyroximate.

- Tested varying doses of both on pesticide-naïve *T. urticae* populations
- For **spiromesifen** (slope of 1.65±0.16)
  - LC_{50} = 1.9 ppm a.i.
  - LC_{90} = 17.2 ppm a.i.
- For **fenpyroximate** (slope of 0.81±0.14)
  - LC_{50} = 9.5 ppm a.i.
  - LC_{90} = 81.7 ppm a.i.

WASHINGTON STATE UNIVERSITY EXTENSION

Dose response curves of susceptible mite colony population

Acaricide	# of mites Bioassayed	% Mortality at Field Rate	LC50 (ppm a.i.)	95% Conf. Interval (ppm a.i.)	Slope ± SEM	χ^2 (*df*)	Resistance Ratio
Abamectin	241	100	0.8	0.5 - 1.3	1.4 ± 0.2	6.2 (16)	1
Bifenthrin	230	100	18	8.4 - 44.6	1.73 ± 0.1	73.6 (13)	1
Fenpyroximate	445	100	9.5	4.7 – 16.6	0.81 ± 0.1	28 (13)	1
Hexythiozox	656	100	2.2	1.0 – 4.5	0.9 ± 0.1	71.6 (13)	1
Spirodiclofen	524	100	1.9	1.5 – 2.4	1.65 ± 0.2	6.2 (22)	1

Abamectin= Agrimek; Bifenthrin=Capture; Fenpyroximate=Fujimite; Hexythiozox= Savey; Spiridoclofen=Envidor

Objective (h)

Establish mite colonies and, through constant and consistent exposure of the mite populations contained within these colonies, “breed” resistance into these mite populations.

- Previously, we bred colonies highly resistant to abamectin, bifenazate, and bifenthrin.
- In 2016 we achieved colonies that are now 200-fold more resistant to ovicidal miticides (clofentezine, hexythiazox and etoxazole) than acaricide-naïve populations.
- In 2017, emphasis was on spiromesifen and fenpyroximate.
- In 2018 we will focus on cyflumetofen.

WASHINGTON STATE UNIVERSITY
EXTENSION

Objective (i)

Develop discriminating doses of candidate miticides that can be used to rapidly identify the prevalence of tolerance or resistance in a spider mite population.

- Our 2017 studies determined:
  - 300 ppm a.i. = **spirodiclofen** discriminating dose
  - 180 ppm a.i. = **fenpyroximate** discriminating dose

Washington State University Extension

Objective (j)

Test selected field populations of spider mites from a representative sample of hopyards and compare their dose response curves to mite populations as detailed above.

Fenpyroximate

- Mitochondrial electron transport inhibitor (METI): impacts respiration
- Dose-mortality bioassays conducted on 28 field-collected populations

Spirodiclofen

- Lipid synthesis inhibitor: impacts metabolism of fatty acids
- Dose-mortality bioassays conducted on 21 field-collected populations

WASHINGTON STATE UNIVERSITY EXTENSION

Summary of Dose-Response Comparisons

Fenpyroximate

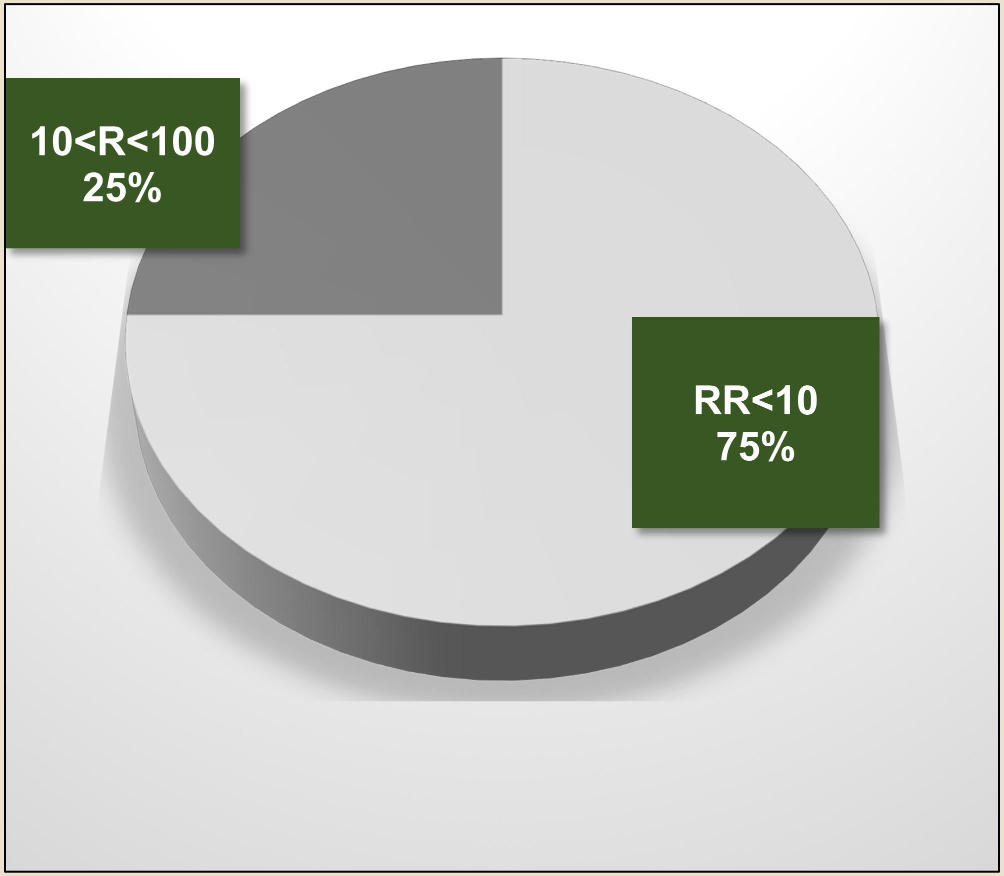
- LC_{50} of susceptible *T. urticae* population = 9.5 ppm a.i.
- LC_{50} of field-collected populations ranged from 25.0 to 228.5 ppm a.i.
- Mortality at field dose ranged from 52% to 100%

Spirodiclofen

- LC_{50} of susceptible *T. urticae* population = 1.9 ppm a.i.
- LC_{50} of field-collected populations ranged from 6.0 to 83.8* ppm a.i.
- Mortality at field dose ranged from 71% to 100%

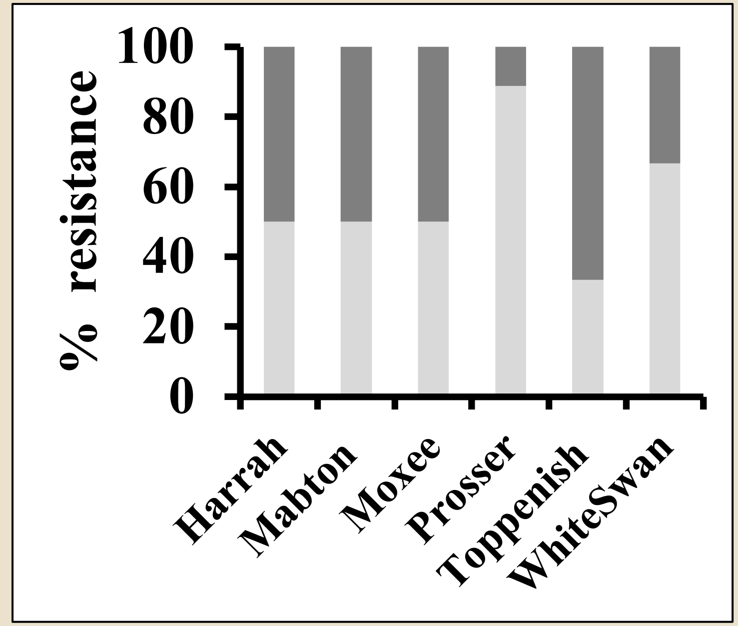
(*below the field dose of 300 ppm a.i.)

Fenpyroximate Resistance Ratios

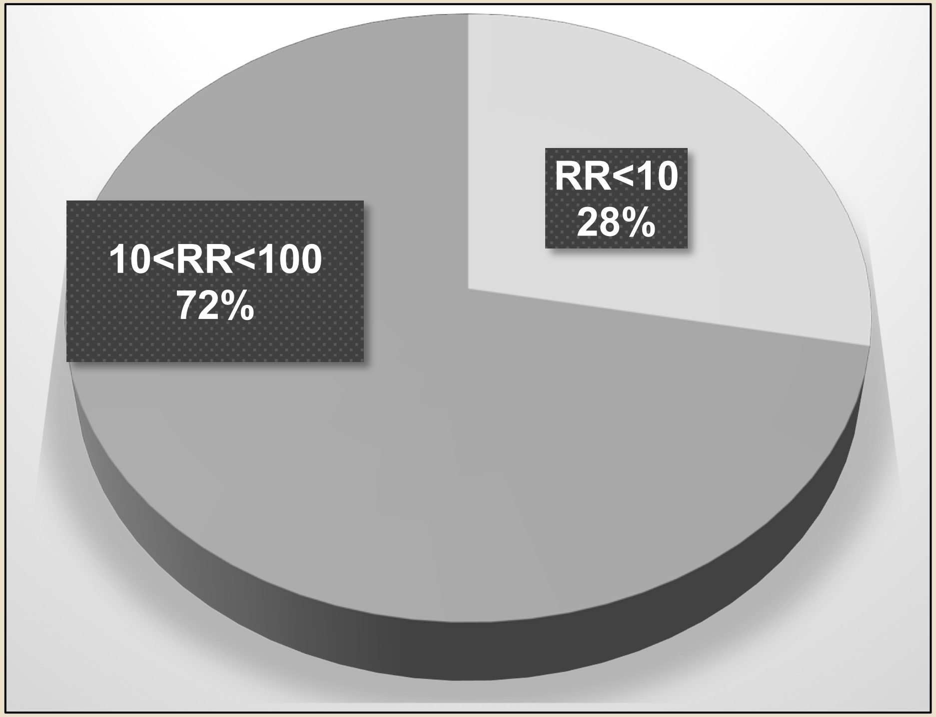


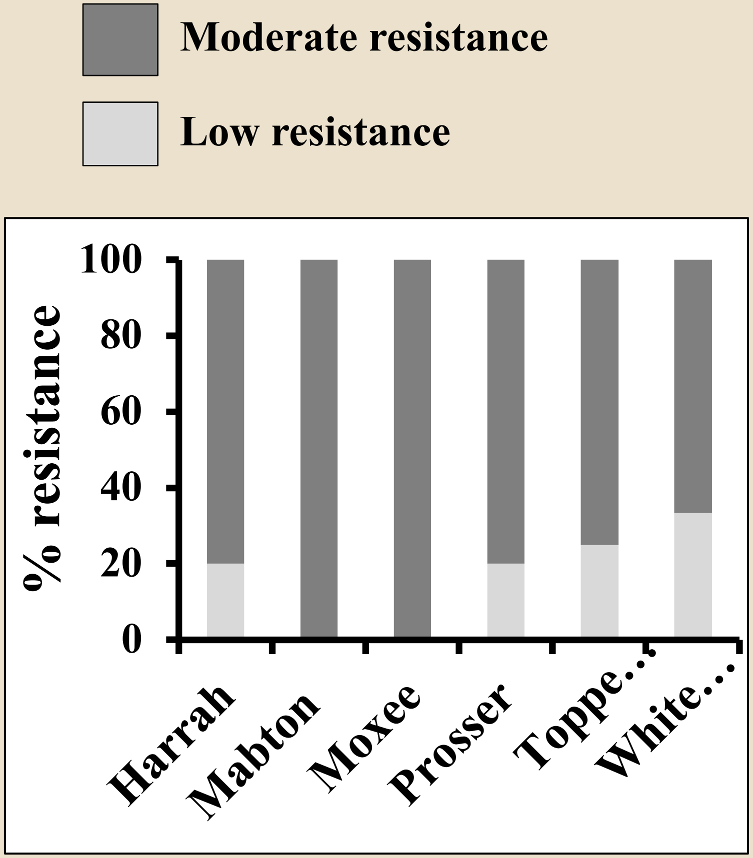
Moderate resistance

Low resistance



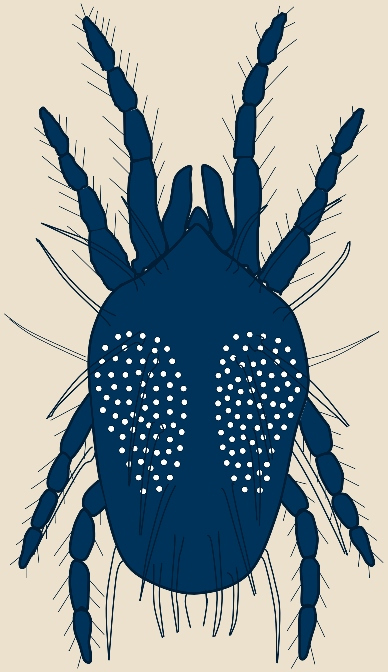
Spirodiclofen Resistance Ratios



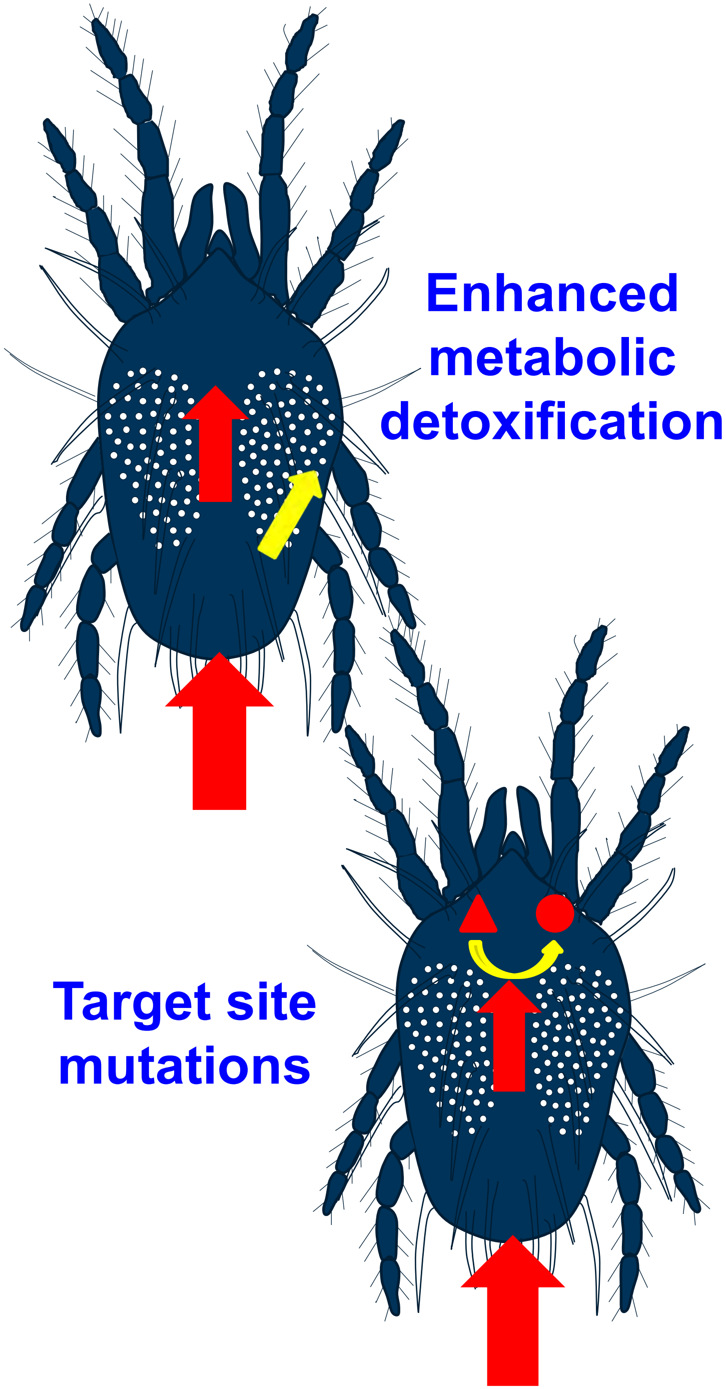


Objective (I)

Expand robust molecular diagnostics to predict (multiple) acaricide resistance in the field.



WASHINGTON STATE UNIVERSITY
EXTENSION



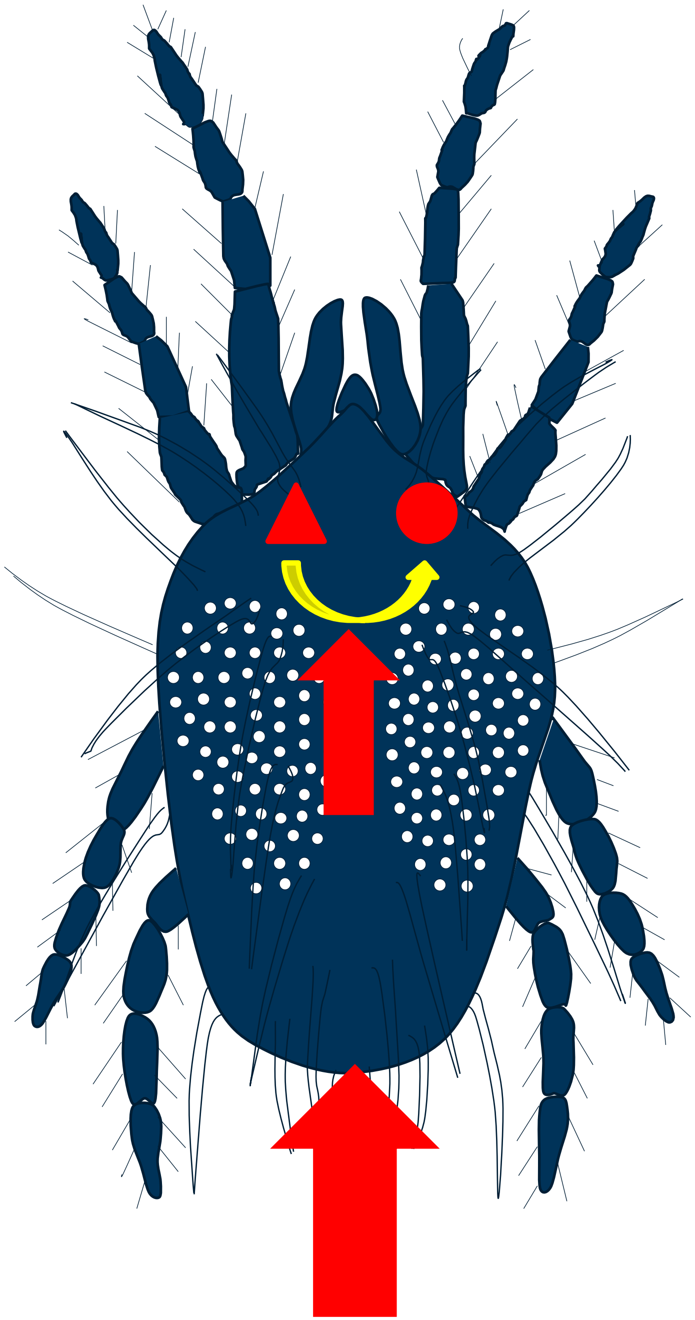
Previous years' studies suggest that miticide resistance is mediated by

MULTIPLE MECHANISMS

WASHINGTON STATE UNIVERSITY EXTENSION

Experimental Approach to Determine

TARGET SITE MUTATIONS



Diagnostic PCR

↓

Extract gDNA

↓

Design primers around mutation region on gDNA

↓

Amplify mutation region

↓

Sanger sequencing of amplicon

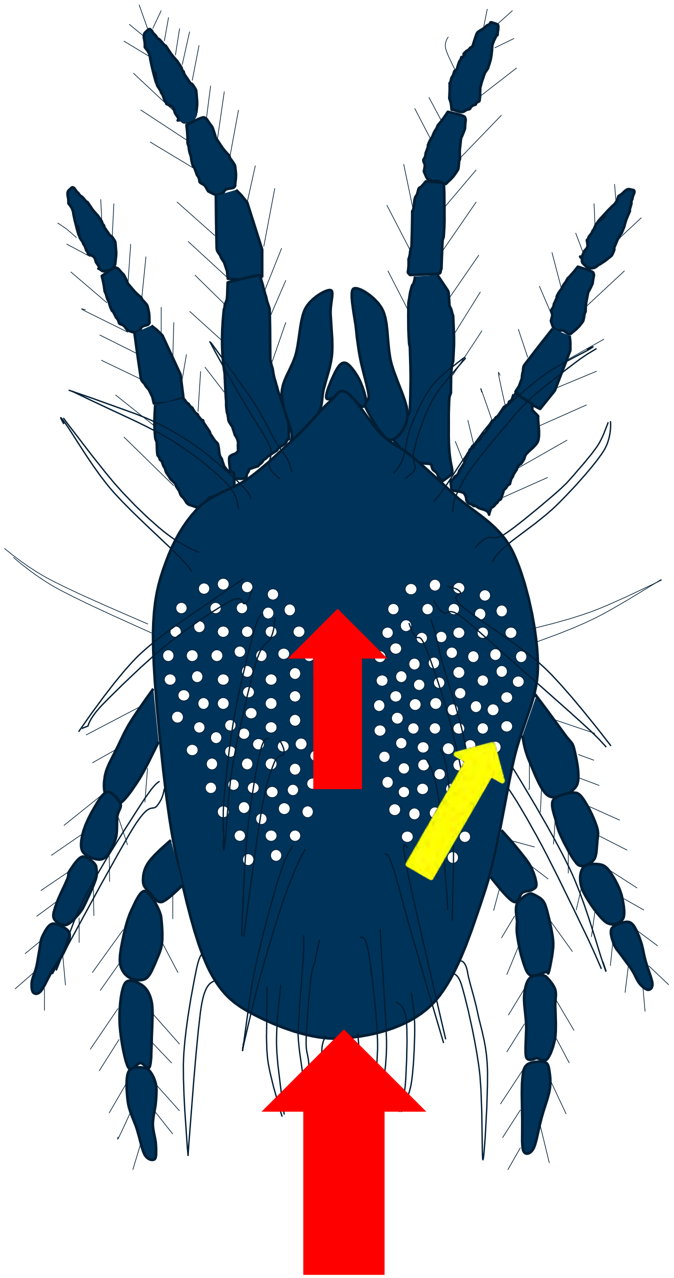
↓

Examine presence of mutation

Washington State University Extension

ABSENCE of resistance-associated mutation to fenpyroximate and spirodiclofen in *T. urticae on WA hops*

Population	ACCase K645	PSST H92R	Population	ACCase K645	PSST H92R	Population	ACCase K645	PSST H92R
Susceptible	**K**	**H**	Prosser_1	K	H	Toppensih_6*	K	H
Grandview	K	H	Prosser_2	K	H	Toppenish_7	K	H
Harrah_1	K	H	Prosser_3	K	H	Toppenish_8	K	H
Harrah_1*	K	H	Prosser_4	K	H	White_swan_1	K	H
Harrah_2	K	H	Prosser_5	K	H	White_swan_2	K	H
Harrah_3*	K	H	Prosser_6	K	H	White_swan_3	K	H
Harrah_3	K	H	Prosser_7	K	H	White_swan_4	K	H



Experimental Approach to Determine
ENHANCED METABOLIC DETOXIFICATION

qRT-PCR to measure mRNA expression

↓

Extract total RNA

↓

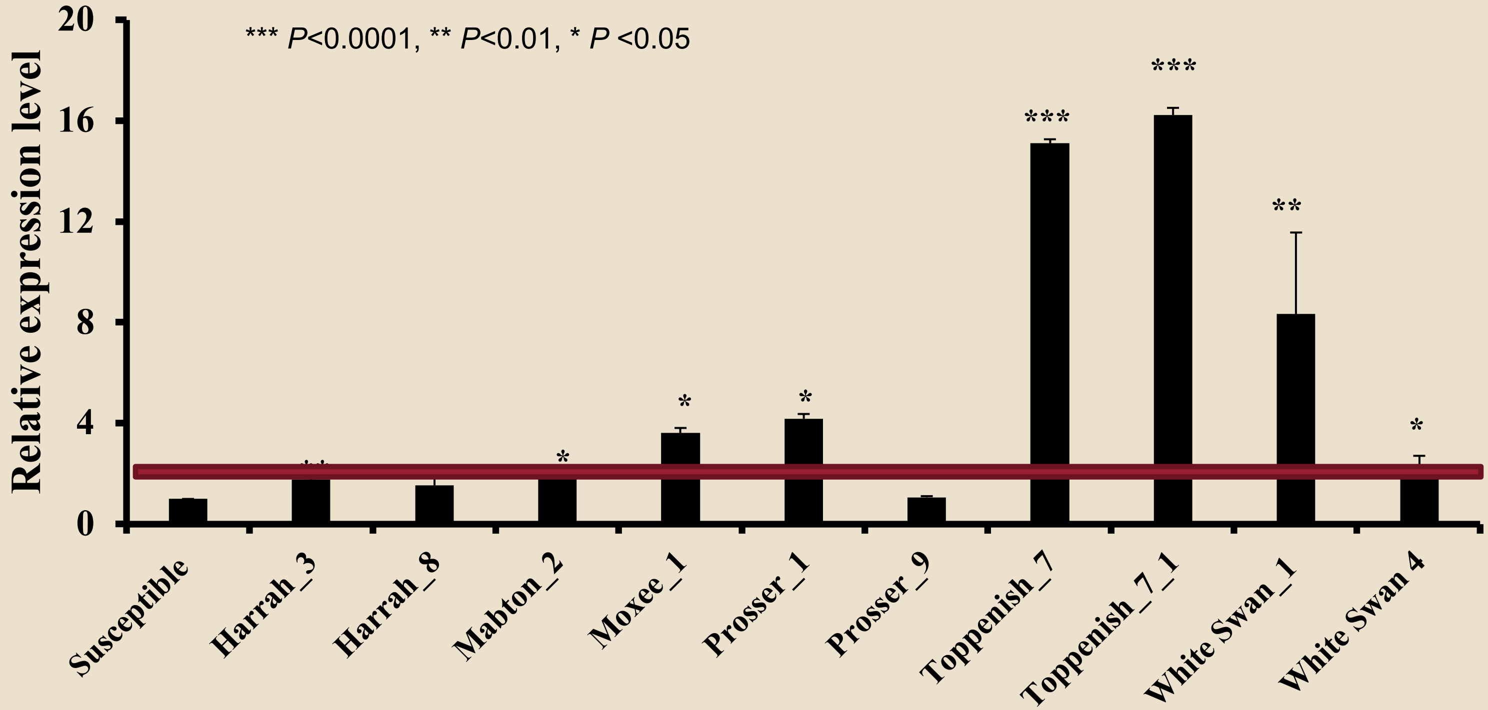
Synthesize DNA

↓

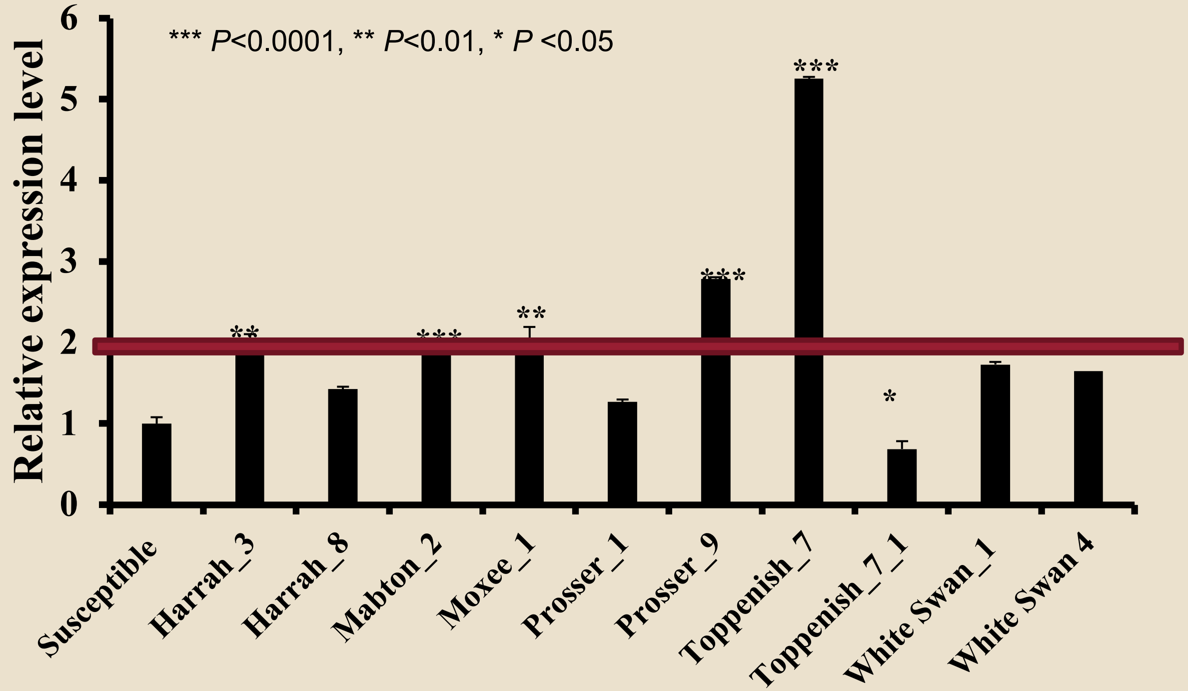
Measure mRNA expression of resistant-associated metabolic genes (i.e., cytochrome P450, glutathione S transferase, and carboxylesterases

WASHINGTON STATE UNIVERSITY
EXTENSION

Molecular mechanism of resistance to fenpyroximate indicated by relative expression of TuCYP392A11 in field-collected *T. urticae*

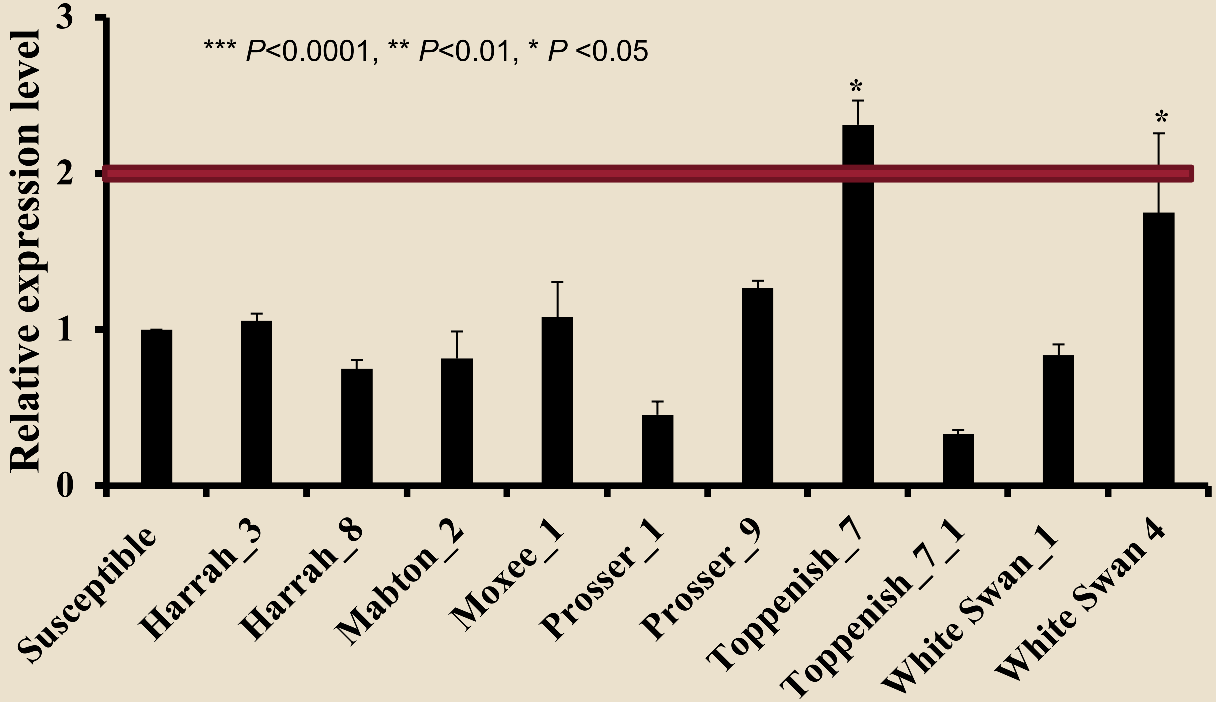


Molecular mechanism of resistance to spirodiclofen indicated by relative expression of TuCYP392E10 in field-collected *T. urticae*



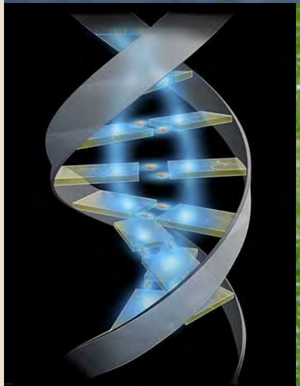
WASHINGTON STATE UNIVERSITY EXTENSION

Molecular mechanism of resistance to spirodiclofen indicated by relative expression of TCCE04 in field-collected *T. urticae*



Conclusions and Path Forward

- Target-site mutations does not appear to be an important factor in *T. urticae* resistance to fenpyroximate or spirodiclofen
- Enhanced metabolic detoxification appears to play a role in resistance to these two miticides, but other mechanisms may play a role
- Currently conducting transcriptome sequencing of resistant *T. urticae* strains to identify novel molecular biomarkers
- This genetic characterization, coupled with past work and recent advances in portable, real-time PCR equipment, should advance our goal in 2018…



Eventual goal is

RAPID, PRACTICAL

tool to diagnose resistance

IN THE FIELD

WASHINGTON STATE UNIVERSITY EXTENSION

Objective (m)

Evaluate the interactions of plant nutrition with arthropod pest abundance and disease severity.

- Multi-factor, multi-year (2013-2018) study in our research Cascade block
- Manipulated factors including:
  - fertilizer amount
  - fertilizer application method (dry vs. chemigated) and mix thereof
  - fertilizer timing and cutoff date
  - treated/not treated with pesticides
- Analyzed outcomes including:
  - yield
  - α and β acids
  - pest abundance
  - nutrient levels in harvested cones

WASHINGTON STATE UNIVERSITY EXTENSION

Fertilizer Treatments and Cutoff Dates for Chemigation in 2016

Dry[1]	N applied by chemigation	Cut off date	Total lb N/acre	Pesticides applied
120	**120 (10#/ wk from 5/3-7/19)**	**7/19/16**	**240**	**Yes**
120	120 (15#/ wk from 5/3-6/21)	6/21/16	240	Yes
90	90 (11.25#/ wk from 5/3-6/21)	6/21/16	180	Yes
90	90 (7.5#/ wk from 5/3-7/19)	7/19/16	180	Yes
120	156 (7.5#/ wk from 5/3-harvest)	8/26/16	276	Yes
120	120 (10#/ wk from 5/3-7/19)	7/19/16	240	No
120	120 (15#/ wk from 5/3-6/21)	6/21/16	240	No
90	90 (11.25#/ wk from 5/3-6/21)	6/21/16	180	No
90	90 (7.5#/ wk from 5/3-7/19)	7/19/16	180	No
120	156 (7.5#/ wk from 5/3-harvest)	8/26/16	276	No

Bold denotes grower standard

1/ Urea applied in soil band prior to stringing of the yard

Fertilizer Treatments and Cutoff Dates for Chemigation in 2017

Dry[1]	N applied by chemigation	Cutoff date	Total lb N/acre	Pesticides applied
90	**150 (10#/wk 5/3 to 7/19)**	**7/19/17**	**240**	**Yes**
90	150 (15#/wk 5/3 to 6/21)	6/21/17	240	Yes
90	90 (11.25#/wk 5/3 to 6/21)	6/21/17	180	Yes
90	90 (7.5#/wk 5/3 to 7/19)	7/19/17	180	Yes
90	186 (7.5#/wk 5/3 to harvest)	8/26/17	276	Yes
90	150 (15#/wk 5/3 to 6/21)	6/21/17	240	No
90	90 (11.25#/wk 5/3 to 6/21)	6/21/17	180	No
90	150 (10#/wk 5/3 to 7/19)	7/19/17	240	No
90	90 (7.5#/wk 5/3 to 7/19)	7/19/17	180	No
90	186 (7.5#/wk 5/3 to harvest)	8/26/17	276	No

Bold denotes grower standard

1/ Urea applied in soil band prior to stringing of the yard

Pesticide Regimen

- 2 pre-emergent herbicides (2 apps total)
- 3 defoliant herbicides (5 apps total)
- 7 fungicides (15 apps total)
- 4 insecticides (4 apps total)
- Rates, targets, cost/acre, application dates, and other pertinent information in written report

Trade Name	Chemical name	Target	Application #	rate/acre	$/acre	Application Dates	Final PHI
Triflurex HFP	Trifuralin	Pre-emergent	1	24 fl oz	$ 7.13	3/16/2017	173
Solicam DF	Norflurazon	Pre-emergent	1	5 lbs	$ 174.04	3/17/2017	172
Chateau	Flumioxazin	Defoliant	1	6 oz	$ 47.83	3/17/2017	172
Gramoxone inteon	Paraquat	Defoliant	1	32 fl oz	$ 12.16	4/11/2017	147
PHT Ad Max 90	NIS	Adjuvant	1	8 fl oz	$ 0.23	4/11/2017	147
Pristine	Boscalid & Pyraclostrobin	Fungicide	1	14 oz	$ 55.55	5/26/2017	102
Rally 40 wsp	Myclobutanil	Powdery	1	10 oz	$ 44.81	6/2/2017	95
Ultra Florish	Mefenoxam	Fungicide	1	0.5 pt	$ 26.98	6/9/2017	88
CuprofixUltra	Copper hydroxide	Fungicide	1	1.25 lbs	$ 6.96	6/9/2017	88
Pristine	Boscalid & Pyraclostrobin	Fungicide	2	14 oz	$ 55.55	6/16/2017	81
Nuprid	Imidicloprid	Aphids	1	6.4 fl oz	$ 3.85	6/19/2017	78
Rally 40 wsp	Myclobutanil	Powdery	2	2 oz	$ 44.81	6/23/2017	74
Quintec	Quinoxyfen	Powdery	1	8.2 fl oz	$ 35.62	6/30/2017	67
Dipel	Bacillus T.	Looper	1	2 lbs	$ 32.65	6/30/2017	67
Trionic 4SC	Triflumizole	Powdery	1	12 floz	$ 52.45	7/6/2017	61
Rally 40 wsp	Myclobutanil	Powdery	3	10 oz	$ 44.81	7/14/2017	53
Venerate	Burkholderia	Looper	1	8 qts	$ 166.14	7/14/2017	53
Grandevo	Chromobacterium	Looper	1	3 lbs	$ 68.42	7/14/2017	53
Aim EC	Carfentrazone-Ethyl	Defoliant	1	2 fl oz	$ 12.82	7/20/2017	47
Parazone 3L	Paraquat	Defoliant	2	21 fl oz	$ 6.13	7/20/2017	47
Persist Ultra	MSO	Adjuvant	1	2 qts	$ 20.95	7/20/2017	47
Flint	Trioxystrobin	Powdery	1	4 oz	$ 66.20	7/21/2017	46
Quintec	Quinoxyfen	Powdery	2	8.2 fl oz	$ 35.62	7/28/2017	39
Aim EC	Carfentrazone-Ethyl	Defoliant	2	2 Fl oz	$ 12.82	8/3/2017	33
Persist Ultra	MSO	Adjuvant	1	2 qts	$ 20.95	8/3/2017	33
Trionic 4SC	Triflumizole	Fungicide	2	12 floz	$ 52.45	8/4/2017	32
Quintec	Quinoxyfen	Powdery	3	8.2 fl oz	$ 35.62	8/11/2017	25
Flint	Trioxystrobin	Powdery	2	4 oz	$ 66.20	8/18/2017	18
Quintec	Quinoxyfen	Powdery	4	8.2 fl oz	$ 35.62	8/25/2017	11

Yields, Alpha & Beta Acids Content

(*cv.* 'Cascade' cones dried to 8% moisture)

Dry	Drip	Cutoff	Spray	Yield estimate dry lbs./acre ± SE[1]	% α acid	% β acid	HSI
90	**150**	**7/19/17**	**Yes**	**5,040±189 ab**	**6.05±0.27**	**5.90±0.23**	**0.229±0.004**
90	150	6/21/17	Yes	5,234±282 a	6.35±0.13	5.95±0.36	0.230±0.005
90	90	6/21/17	Yes	4,921±274 abc	5.90±0.10	5.87±0.36	0.228±0.004
90	90	7/19/17	Yes	3,793±278 d	5.87±0.38	6.07±0.17	0.229±0.003
90	186	8/26/17	Yes	4,361±212 abcd	5.95±0.38	5.50±0.28	0.234± 0.003
90	150	6/21/17	No	4,656±249 abcd	5.72±0.27	6.32±0.20	0.239±0.003
90	90	6/21/17	No	4,468±220 abcd	5.72±0.24	6.37±0.16	0.227±0.002
90	150	7/19/17	No	5,036±335 ab	6.07±0.33	6.22±0.20	0.218±0.003
90	90	7/19/17	No	3,969±174 bcd	6.62±0.43	6.25±0.37	0.216±0.003
90	186	8/26/17	No	3,852± 94 cd	5.55±0.16	6.02±0.25	0.220±0.003

1/treatment means separated by an uncommon letter are significantly are significantly different by Tukey HSD at $p<0.05$.

One-Way ANOVA for: Sprayed (Y/N), #N Applied Dry, #N Chemigated, Fertilizer Cutoff Date, Plot Age, Position in Field

(8% moisture, % α and β acids, Hop Storage Index)

Factor	df=	Yield estimate dry lbs/acre±SE[‡]	% α acid[‡]	% β acid[‡]	HSI
Mean square	1	1,497,900^{ns}	0.07^{ns}	1.44*	0.000372*
error	78	652,189	0.36	0.26	0.000074
Pesticide spray	Yes (*n*=20)	4670±756	6.02±0.15	5.86±0.12^{b}	0.234±0.0028^{b}
	No (*n*=20)	4396±855	5.94±0.12	6.24±0.10^{a}	0.224±0.0015^{a}

Factor	df=	Yield estimate dry lbs/acre±SE[‡]	% α acid[‡]	% β acid[‡]	HSI
Mean square	2	5,782,129**	0.27^{ns}	0.421^{ns}	0.000070^{ns}
error	37	529,927	0.36	0.284	0.000082
Total N	180# (*n*=16)	4287±129^{b}	6.03±0.15	6.14±0.13	0.22±0.0023
	240# (*n*=16)	4991±129^{a}	6.05±0.15	6.10±0.13	0.23±0.0023
	276# (*n*=8)	4107±182^{b}	7.05±0.11	8.76±0.19	0.23±0.0032

Factor	df=	Yield estimate dry lbs/acre±SE[‡]	% α acid[‡]	% β acid[‡]	HSI
Mean square	2	2,855,986*	0.484^{ns}	0.414^{ns}	0.000260^{ns}
error	37	605,931	0.348	0.285	0.000072
Fertilizer cutoff	6/21 (*n*=16)	4819±138^{a}	5.92±0.15	6.13±0.13	0.23±0.0021
	7/19 (*n*=16)	4459±138^{ab}	6.15±0.15	6.11±0.13	0.22±0.0021
	8/26 (*n*=8)	4106±195 ^{b}	5.75±0.20	5.76±0.19	0.23±0.0030

Arthropod Abundance

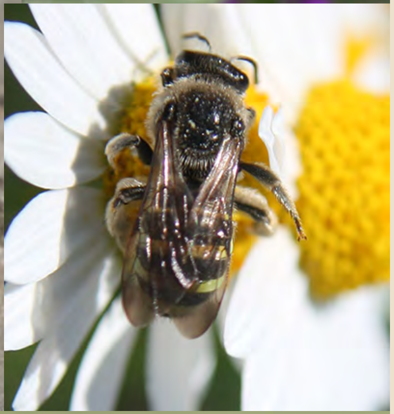
(OR LACK THEREOF)

- Measured 4x during high summer
    - July 12, 19, 26, August 1, 2017
- 15 leaves (5 high, 5 middle, 5 low) collected from each plot
- Mite-brushed by **Precision Arthropod Quantifiers** in the laboratory
- Aphids, mites, mite eggs counted
- While some differences noted, arthropod population densities were too low to impact plant performance in 2017
- **Mites and aphids were inconsequential regardless of treatment in 2017**

Nutrient Level Summary

- Cones (after harvest & dry-down) from each treatment sent to analytical lab
- **Nitrogen** % trended toward being reduced with pesticide spraying
- No significant effects on **Phosphorus** or **Magnesium** %
- No significant effects on **Zinc, Iron**, **Copper**, or **Manganese** ppm
- **Potassium** % differed significantly among treatments, with greatest concentration in the treatment with no pesticide sprays, 186# of N, and cutoff date of 8/21/17

WASHINGTON STATE UNIVERSITY
EXTENSION



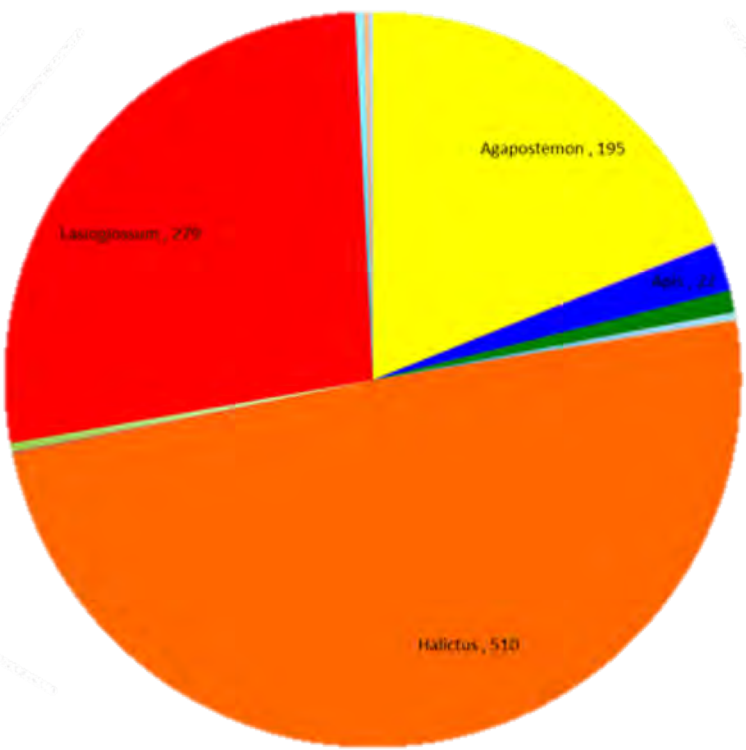
Objective (n)

Complete and publish the results from the 2014 and 2015 qualitative and quantitative survey of the honeybees, bumblebees, bees in the family Halictidae, and other pollinators present in hopyards.

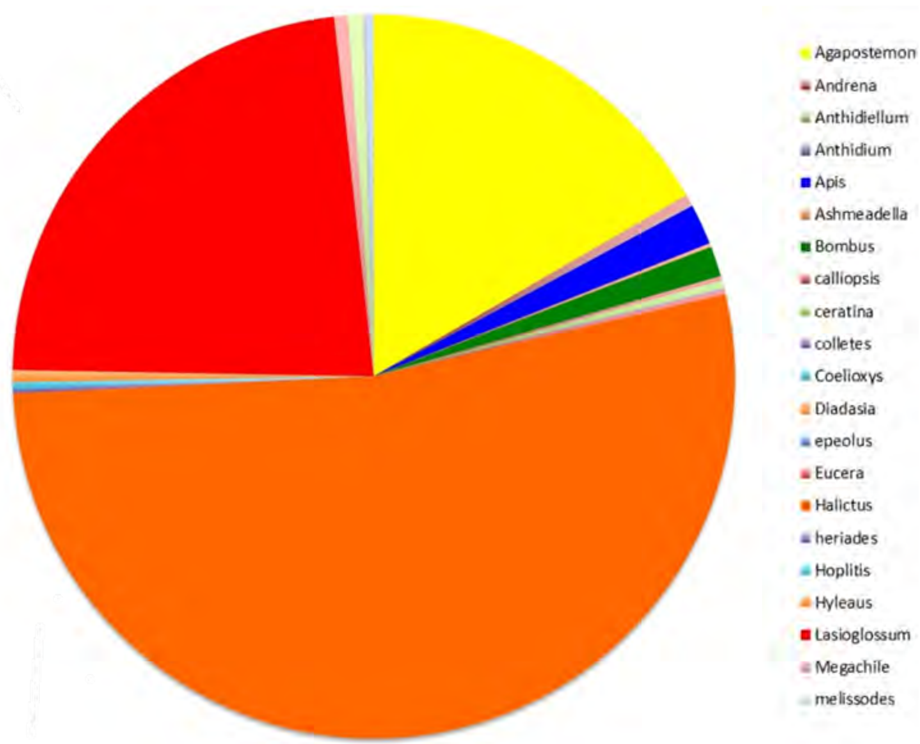
http://www.dissertations.wsu.edu/Thesis/Summer2016/C_Grula_081516.pdf

WASHINGTON STATE UNIVERSITY
EXTENSION

Bottom Line: Production Practices in Hop Have Minimal Impacts on Pollinator Abundance and Diversity



Hops



All Sites

Objective (o)

Develop and disseminate a pollinator protection plan for hops.

- Work in progress
- Walsh & O'Neal working with WSDA on Managed Pollinator Protection Plans ("MP3s")
- Full-color glossy publication showing that bees inhabit and flourish in hopyards will come out in 2018

Washington State Department of Agriculture

WASHINGTON STATE UNIVERSITY EXTENSION

Objective (p)

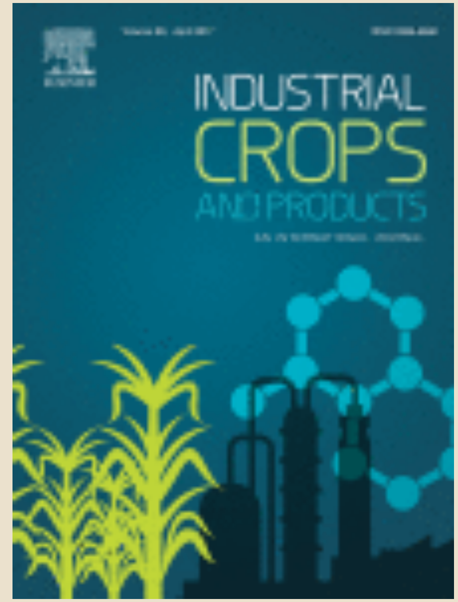
Collaborate with Jim Barbour in a California prionus mating disruption study.

- Resulting from our work, a product is now registered for use
- Commercialization is the issue
- Vendor is approaching other target markets to determine if sales will justify marketing the product for pest control

WASHINGTON STATE UNIVERSITY EXTENSION

2017 Publications

Adesanya, A.W., M.A. Morales, D.B. Walsh, L.C. Lavine, M.D. Lavine, & F. Zhu. 2017. Mechanisms of resistance to three mite growth inhibitors of *Tetranychus urticae in hops.* Bull Entomol Res doi:10.1017/S0007485317000414



Nakawuka, P., R.T. Peters, S. Kenny, and D. Walsh. 2017. Effect of deficit irrigation on yield quantity and quality, water productivity, and economic returns for four cultivars of hops in the Yakima Valley, WA. Industrial Crops and Products. 98(2017) 82-92

Objectives for 2018

Pesticide Efficacy Objectives (5 of 15)

a) Field test candidate compounds for their efficacy against spider mites and aphids.

b) Field test efficacy of candidate insecticides applied post-harvest for control of weevils. Target species include black vine and strawberry root weevil.

c) Develop and validate methods for accurately monitoring abundance of black vine weevil.

d) Field test efficacy of insecticides on other pests if opportunities arise.

e) Evaluate the impact of candidate pesticides on beneficial mites.

Objectives for 2018

Spider Mite Research Objectives (8 of 15)

f) Develop a robust bioassay method for evaluating residual efficacy of miticides including spiromesifen, fenpyroximate, spirotetramat, and cyflumetofen.

g) Develop baseline dose response curves of spider mite populations susceptible to cyflumetofen.

h) Establish mite colonies and “breed” resistance to candidate acaricides into the mite population through constant and consistent exposure (focus on cyflumetofen).

i) Develop discriminating doses of candidate miticides that can be used to rapidly identify the prevalence of tolerance or resistance in a spider mite population.

j) Test selected field populations of spider mites from a representative sample of hopyards and compare their dose response curves to mite populations as above.

continued…

Objectives for 2018

(Spider Mite Objectives, cont.)

k) Develop a damage function and dynamic action threshold for spider mites based on key risk factors.

l) Characterize the genetic structure of endemic *T. urticae* populations on PNW hops and nearby/adjacent crops. ($4,500)

m) Develop a sensitive, rapid and cost-effective method to predict multiple acaricide resistance on a portable platform.

Other Applied Research & Extension Objectives (2 of 15)

n) Evaluate the interactions of plant nutrition with arthropod pest abundance and disease severity and quantify nutrient carryover into cones and subsequent beers brewed.

o) Disseminate a pollinator protection plan for hops

Questions?

Sally O’Neal • soneal@wsu.edu
for Doug Walsh • dwalsh@wsu.edu

Washington State University
Extension