Monitoring and Management of Mint Root Borer on Mint

Douglas B. Walsh, Ph.D.
Professor of Entomology

Mint root borer, *Fumibotys fumalis*, is a key, direct, and devastating pest in peppermint production.

- Late summer and early fall feeding by larvae on rhizomes is cryptic and severe injury is manifested as dead fields the subsequent spring.

A pheromone monitoring program for Mint Root Borer has shown promise under Willamette Valley conditions (Simmons et al. 2011).

Research Objectives 2018 & 2019

- 1. Conduct a comprehensive pheromone monitoring program in mint fields in the key growing districts near Toppenish, Paterson, and Othello, WA.
- We received a donation of mint root borer (MRB) pheromone lures from Trece™ for use in these studies. We also purchased Delta™ traps from Trece. When we established our initial study sites, the Delta traps proved problematic in early 2018 because the dusty conditions in mint fields in spring clogged the adhesive designed to trap the insects

1. Conduct a comprehensive pheromone monitoring program in mint fields in the key growing districts near Toppenish, Paterson, and Othello, WA.

- We established study sites near Paterson, Toppenish, and Othello.
- Four traps were placed in every field in early April (2018) and mid summer (2019) the traps were monitored weekly through October, with mint root borers qualified and quantified.
- Beginning in August and continuing into October, soil and rhizome samples were collected and transported to the Environmental and Agricultural Entomology Laboratory located at WSU Prosser where the samples were processed and put in a Berlese funnel for 24 to 48 hours.
- We planned to run regression analyses of the 2018 and 2019 pheromone counts against the larval abundance counts calculated from the soil and rhizome samples that were processed through the Berlese funnels.
- We hoped to determine if the trap moth counts can be used to quantify larval abundance in the soil.

Average number of male MRB captured per week at 3 mint fields near Othello in 2018.

Area	Site	Collection date	Average # moths /wk	Area	Site	Collection date	Average # moths /wk
Othello	1 (East)	31-May-18	0	Othello	2 (Baby)	31-May-18	0
Othello	1 (East)	7-Jun-18	0	Othello	2 (Baby)	7-Jun-18	0
Othello	1 (East)	13-Jun-18	0	Othello	2 (Baby)	13-Jun-18	0
Othello	1 (East)	20-Jun-18	0	Othello	2 (Baby)	20-Jun-18	0
Othello	1 (East)	27-Jun-18	0	Othello	2 (Baby)	27-Jun-18	0
Othello	1 (East)	4-Jul-18	0	Othello	2 (Baby)	4-Jul-18	0
Othello	1 (East)	11-Jul-18	0	Othello	2 (Baby)	11-Jul-18	0
Othello	1 (East)	24-Jul-18	1	Othello	2 (Baby)	24-Jul-18	0.5
Othello	1 (East)	2-Aug-18	2.75	Othello	2 (Baby)	2-Aug-18	1.5
Othello	1 (East)	8-Aug-18	0.75	Othello	2 (Baby)	8-Aug-18	0
Othello	1 (East)	14-Aug-18	0	Othello	3 (North)	14-Aug-18	0.25
Othello	1 (East)	22-Aug-18	0	Othello	3 (North)	22-Aug-18	0
Othello	1 (East)	29-Aug-18	0	Othello	3 (North)	29-Aug-18	0
Othello	3 (North)	4-Jul-18	0				
Othello	3 (North)	11-Jul-18	0				
Othello	3 (North)	24-Jul-18	6.75				
Othello	3 (North)	2-Aug-18	5.25				
Othello	3 (North)	8-Aug-18	6				
Othello	3 (North)	14-Aug-18	4.5				
Othello	3 (North)	22-Aug-18	0.5				
Othello	3 (North)	29-Aug-18	0				

Trap capture by sample date in 2019: Pheromone is the average of 4 traps per field:
Soil sample is the total number of MRB captured in eight 0.5 ft sq ft soil sample

Pheromone								
Location	**Field**	**Sample Date**	***MRB Average***	**Location**	**Field**	**Sample Date**	***MRB Average***	
Othello	4 North	9-Aug-19	0.75	Othello	6 Rill	9-Aug-19	1.75	
Othello	4 North	15-Aug-19	0.25	Othello	6 Rill	15-Aug-19	0.5	
Othello	4 North	22-Aug-19	1	Othello	6 Rill	22-Aug-19	0	
Othello	4 North	28-Aug-19	0	Othello	6 Rill	28-Aug-19	0	
Othello	4 North	5-Sep-19	0	Othello	6 Rill	5-Sep-19	0	
Othello	5 South	9-Aug-19	0	**Soil**			Total/ 8 traps	
Othello	5 South	15-Aug-19	0.25	**Location**	**Field**	**Sample Date**	***MRB***	
Othello	5 South	22-Aug-19	0	Othello	4 North	25-Sep-19	0	
Othello	5 South	28-Aug-19	0	Othello	5 South	25-Sep-19	0	
Othello	5 South	5-Sep-19	0	Othello	6 Rill	25-Sep-19	0	

Average number of male MRB captured per wk at 3 mint fields near Paterson.

		Collection date					
	Site	30-May-18	Average # moths /wk				
	1 (Sandpiper Gate)	4-Jun-18	0				
	1 (Sandpiper Gate)	12-Jun-18	0	Area	Site	Collection date	Average # moths /wk
Area	1 (Sandpiper Gate)	19-Jun-18	0	Paterson	3 (West, swam	30-May-18	0
Paterson	1 (Sandpiper Gate)	26-Jun-18	0	Paterson	3 (West, swam	4-Jun-18	0
Paterson	1 (Sandpiper Gate)	3-Jul-18	0	Paterson	3 (West, swam	12-Jun-18	0
Paterson	1 (Sandpiper Gate)	9-Jul-18	0	Paterson	3 (West, swam	19-Jun-18	0
Paterson	1 (Sandpiper Gate)	23-Jul-18	0	Paterson	3 (West, swam	26-Jun-18	0
Paterson	1 (Sandpiper Gate)	31-Jul-18	0.25	Paterson	3 (West, swam	3-Jul-18	0.25
Paterson	1 (Sandpiper Gate)	6-Aug-18	0.5	Paterson	3 (West, swam	9-Jul-18	0.25
Paterson	1 (Sandpiper Gate)	14-Aug-18	0	Paterson	3 (West, swam	23-Jul-18	0
Paterson	1 (Sandpiper Gate)	23-Aug-18	0	Paterson	3 (West, swam	31-Jul-18	3.25
Paterson	1 (Sandpiper Gate)	28-Aug-18	0	Paterson	3 (West, swam	6-Aug-18	3.25
Paterson	2 (East)	30-May-18	0.5	Paterson	3 (West, swam	14-Aug-18	10.5
Paterson	2 (East)	4-Jun-18	0	Paterson	3 (West, swam	23-Aug-18	5.25
Paterson	2 (East)	12-Jun-18	0	Paterson	3 (West, swam	28-Aug-18	0
Paterson	2 (East)	19-Jun-18	0				
Paterson	2 (East)	26-Jun-18	0				
Paterson	2 (East)	3-Jul-18	0				
Paterson	2 (East)	9-Jul-18	0				
Paterson	2 (East)	23-Jul-18	0				
Paterson	2 (East)	31-Jul-18	0.5				
Paterson	2 (East)	6-Aug-18	3.25				
Paterson	2 (East)	14-Aug-18	5.25				
Paterson	2 (East)	23-Aug-18	2				
Paterson	2 (East)	28-Aug-18	0				

Trap capture by sample date in 2019: Pheromone is the average of 4 traps per field:

Soil sample is the total number of MRB captured in eight 0.5 ft sq ft soil sample

Pheromone								
Location	**Field**	**Sample Date**	***MRB Average***	**Location**	**Field**	**Sample Date**	***MRB Average***	
Paterson	1 (Sandpiper Gate)	29-Jul-19	1	Paterson	3 (West, swamp)	29-Jul-19	0.5	
Paterson	1 (Sandpiper Gate)	8-Aug-19	3.75	Paterson	3 (West, swamp)	8-Aug-19	12.5	
Paterson	1 (Sandpiper Gate)	16-Aug-19	4.25	Paterson	3 (West, swamp)	16-Aug-19	4.5	
Paterson	1 (Sandpiper Gate)	23-Aug-19	0	Paterson	3 (West, swamp)	23-Aug-19	0.5	
Paterson	1 (Sandpiper Gate)	30-Aug-19	0	Paterson	3 (West, swamp)	30-Aug-19	0	
Paterson	1 (Sandpiper Gate)	4-Sep-19	0	Paterson	3 (West, swamp)	4-Sep-19	0	
Paterson	1 (Sandpiper Gate)	19-Sep-19	0	Paterson	3 (West, swamp)	19-Sep-19	0	
Paterson	1 (Sandpiper Gate)	25-Sep-19	0					
Paterson	2 (East)	29-Jul-19	4					
Paterson	2 (East)	8-Aug-19	8.25	**Soil**				
Paterson	2 (East)	16-Aug-19	5.75	**Location**	**Field**	**Sample Date**	***MRB***	
Paterson	2 (East)	23-Aug-19	0	Paterson	1 (Sandpiper Gate)	25-Sep-19	0	
Paterson	2 (East)	30-Aug-19	0.5	Paterson	2 (East)	25-Sep-19	0	
Paterson	2 (East)	4-Sep-19	0	Paterson	3 (West, swamp)	25-Sep-19	0	
Paterson	2 (East)	19-Sep-19	0					
Paterson	2 (East)	25-Sep-19	0					

Average number of male MRB captured per wk at 3 mint fields near Toppenish

Area	Site	Collection date	Average # moths /wk	Area	Site	Collection date	Average # moths /wk
Toppenish	1 (Main Farm)	1-Jun-18	0	Toppenish	3 (Baby)	1-Jun-18	0
Toppenish	1 (Main Farm)	6-Jun-18	0	Toppenish	3 (Baby)	6-Jun-18	0
Toppenish	1 (Main Farm)	15-Jun-18	0	Toppenish	3 (Baby)	15-Jun-18	0
Toppenish	1 (Main Farm)	22-Jun-18	0	Toppenish	3 (Baby)	22-Jun-18	0
Toppenish	1 (Main Farm)	29-Jun-18	0	Toppenish	3 (Baby)	29-Jun-18	0
Toppenish	1 (Main Farm)	6-Jul-18	0	Toppenish	3 (Baby)	6-Jul-18	0.5
Toppenish	1 (Main Farm)	12-Jul-18	0.75	Toppenish	3 (Baby)	12-Jul-18	0.75
Toppenish	1 (Main Farm)	26-Jul-18	0.5	Toppenish	3 (Baby)	26-Jul-18	4.5
Toppenish	1 (Main Farm)	3-Aug-18	0.25	Toppenish	3 (Baby)	3-Aug-18	5.5
Toppenish	1 (Main Farm)	10-Aug-18	0.5	Toppenish	3 (Baby)	10-Aug-18	2.5
Toppenish	1 (Main Farm)	17-Aug-18	0.5	Toppenish	3 (Baby)	17-Aug-18	0.5
Toppenish	2 (Larue Rd)	24-Aug-18	0.25	Toppenish	3 (Baby)	24-Aug-18	0
Toppenish	2 (Larue Rd)	1-Jun-18	0				
Toppenish	2 (Larue Rd)	6-Jun-18	0				
Toppenish	2 (Larue Rd)	15-Jun-18	0				
Toppenish	2 (Larue Rd)	22-Jun-18	0				
Toppenish	2 (Larue Rd)	29-Jun-18	0.25				
Toppenish	2 (Larue Rd)	6-Jul-18	0.75				
Toppenish	2 (Larue Rd)	12-Jul-18	1.5				
Toppenish	2 (Larue Rd)	26-Jul-18	6.75				
Toppenish	2 (Larue Rd)	3-Aug-18	3.25				
Toppenish	2 (Larue Rd)	10-Aug-18	0				
Toppenish	2 (Larue Rd)	17-Aug-18	0.75				
Toppenish	2 (Larue Rd)	24-Aug-18	0				

Trap capture by sample date: Pheromone is the average of 4 traps per field:

Soil sample is the total number of MRB captured in eight 0.5 ft sq ft soil sample

Pheromone								
Location	**Field**	**Sample Date**	***MRB Average***	**Location**	**Field**	**Sample Date**	***MRB Average***	
Toppenish	1 (Main Farm)	29-Jul-19	19.75	Toppenish	4 Main Farm house	29-Jul-19	37	
Toppenish	1 (Main Farm)	8-Aug-19	3.75	Toppenish	4 Main Farm house	8-Aug-19	2	
Toppenish	1 (Main Farm)	16-Aug-19	0	Toppenish	4 Main Farm house	16-Aug-19	0	
Toppenish	1 (Main Farm)	23-Aug-19	0	Toppenish	4 Main Farm house	23-Aug-19	0	
Toppenish	1 (Main Farm)	30-Aug-19	0	Toppenish	4 Main Farm house	30-Aug-19	0	
Toppenish	1 (Main Farm)	4-Sep-19	0	Toppenish	4 Main Farm house	4-Sep-19	0	
Toppenish	1 (Main Farm)	19-Sep-19	0	Toppenish	4 Main Farm house	19-Sep-19	0	
Toppenish	1 (Main Farm)	19-Sep-19	0	Toppenish	4 Main Farm house	19-Sep-19	0	
Toppenish	2 (Larue Rd)	29-Jul-19	59.75	**Soil**				
Toppenish	2 (Larue Rd)	8-Aug-19	22	**Location**	**Field**	**Sample Date**	***MRB***	
Toppenish	2 (Larue Rd)	16-Aug-19	2.25	Toppenish	1 (Larue Rd)	10-Sep-19	5	← 1 Sample had 5 MRB
Toppenish	2 (Larue Rd)	23-Aug-19	0.5	Toppenish	1 (Larue Rd)	19-Sep-19	3	
Toppenish	2 (Larue Rd)	30-Aug-19	0	Toppenish	1 (Larue Rd)	2-Oct-19	2	
Toppenish	2 (Larue Rd)	4-Sep-19	0	Toppenish	2 (Main Farm)	10-Sep-19	10	← 1 Sample had 8 MRB
Toppenish	2 (Larue Rd)	19-Sep-19	0	Toppenish	2 (Main Farm)	19-Sep-19	0	
Toppenish	2 (Larue Rd)	19-Sep-19	0	Toppenish	2 (Main Farm)	2-Oct-19	0	
				Toppenish	4 Main Farm house	10-Sep-19	0	
				Toppenish	4 Main Farm house	10-Sep-19	0	
				Toppenish	4 Main Farm house	19-Sep-19	0	
				Toppenish	4 Main Farm house	2-Oct-19	0	

Mint root borer larvae and tipulid larvae captured in soil samples in Berlese funnel samples 2018.

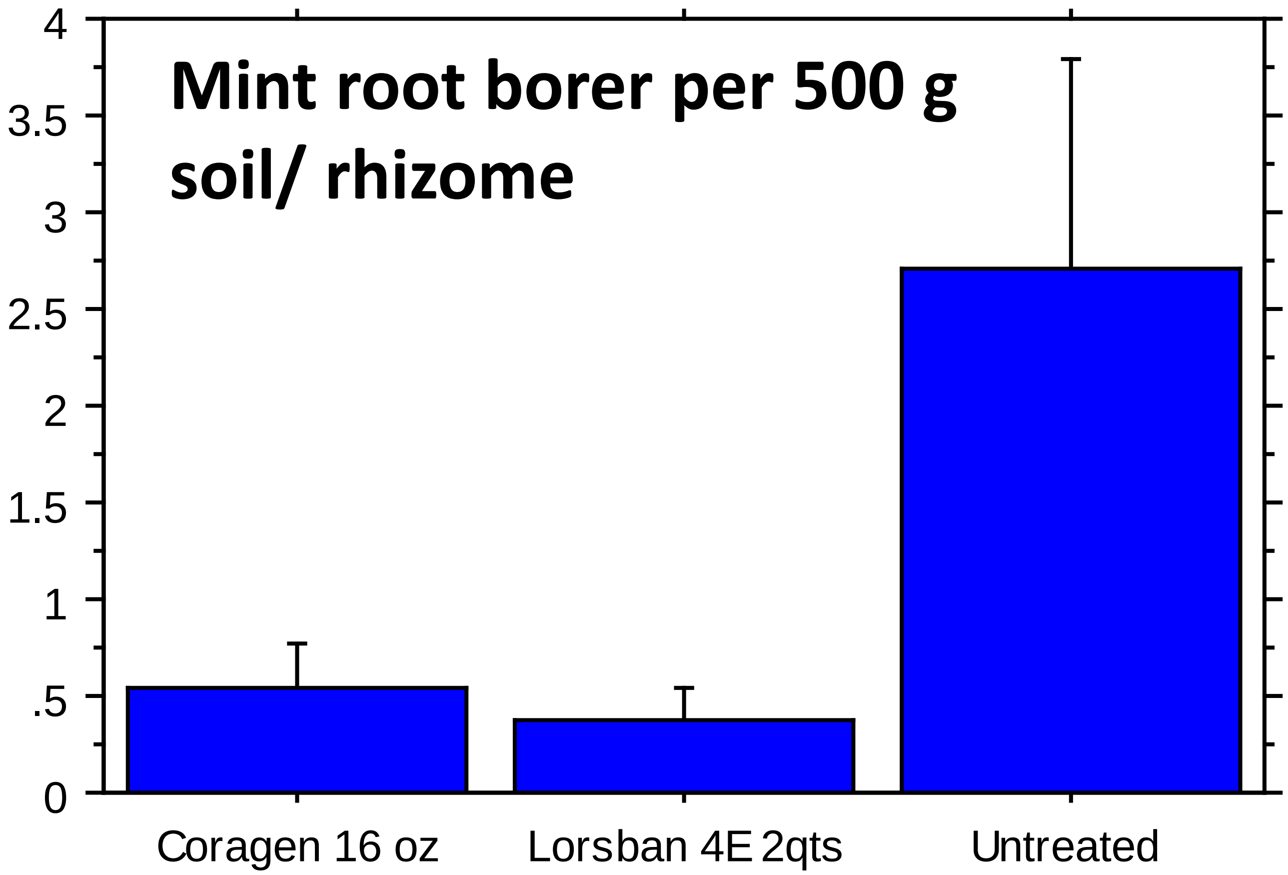
Location	**Field**	**Sample Date**	***MRB***	**Tipulids**
Othello	1 (East)	2-Oct-18	**0**	**0**
Othello	1 (East)	9-Oct-18	**0**	**0.125**
Othello	3 (North)	2-Oct-18	**0**	**0.75**
Othello	3 (North)	9-Oct-18	**0**	**0.625**
Paterson	1 (Sandpiper Gate)	2-Oct-18	**0**	**0**
Paterson	1 (Sandpiper Gate)	11-Oct-18	**1.125**	**0**
Paterson	2 (East)	24-Sep-18	0	2.25
Paterson	2 (East)	2-Oct-18	0	2.375
Paterson	2 (East)	11-Oct-18	0	2.25
Toppenish	1 (Main Farm)	20-Sep-18	0.375	0
Toppenish	1 (Main Farm)	27-Sep-18	0.125	0
Toppenish	2 (Larue Rd)	20-Sep-18	0	0
Toppenish	2 (Larue Rd)	27-Sep-18	0	0
Toppenish	3 (Baby)	20-Sep-18	0	0
Toppenish	3 (Baby)	27-Sep-18	0	0

Mint root borer Control.

- Traditional control has been achieved with a ground application of chlorpyrifos (Lorsban Advanced) in early fall followed by an irrigation event between ½ and ¼ of an inch to get the insecticide into contact with caterpillars feeding on the rhizomes.
- California Department of Pesticide Regulation has banned sale of chlorpyrifos after Feb. 6, 2020. Growers must use existing stocks by Dec 31, 2020
- Chlorantraniprole (Coragen) is also registered for control of mint root borer, but control is sporadic.

Mint Root Borer Control with chlorantraniprole in 2009

- Insecticides were applied to double-cut peppermint on the Roza in early October 2009.
- Coragen (chlorantraniprole) was applied at 5 oz ai/ acre
- Lorsban 4E (chlorpyrifos) at was applied at 2 qts per acre.
- ¼ inch irrigation was applied post treatment.
- Soil sample from these plots were collected in early March and placed them in a Berlese funnel for one week.

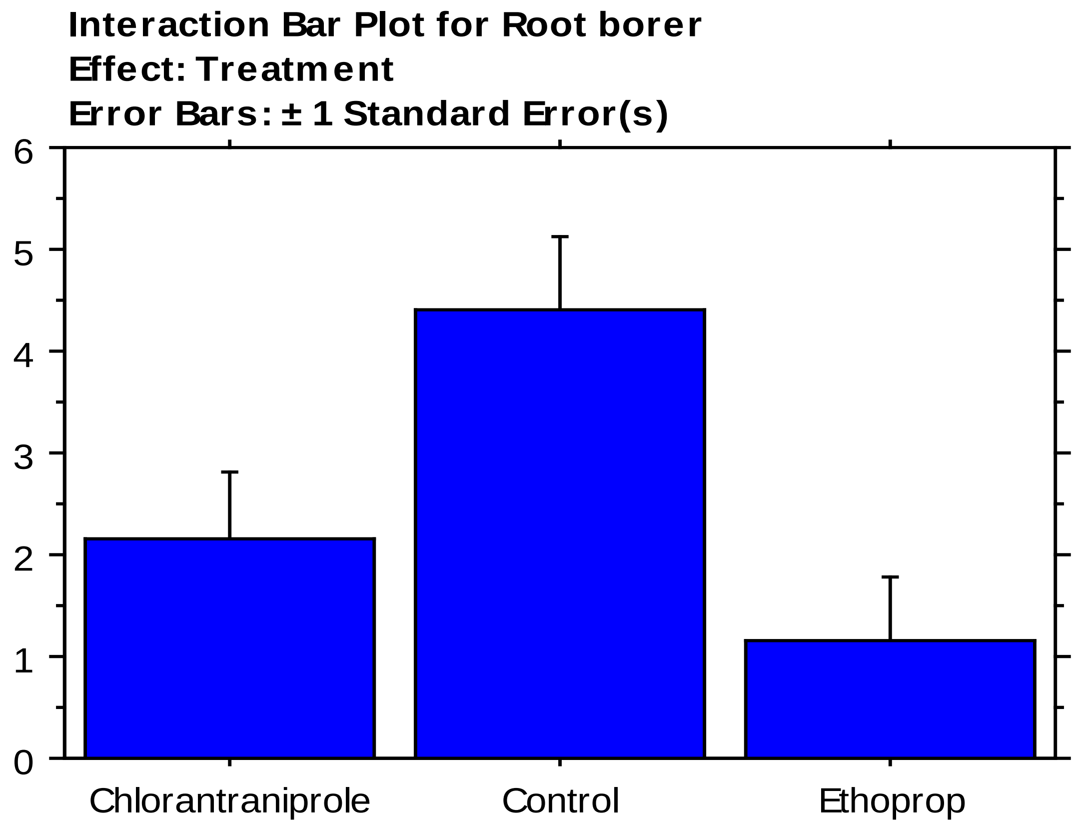


- Both Coragen and Lorsban provided significant (*p*<0.01) control of mint root borer compared to samples collected from the non-treated control plots.
- Coragen is much more environmentally benign then Lorsban.

We were also able to expand the label and develop a use pattern for chlorantraniprole for mint root borer control applied via chemigation.

- We applied chlorantraniprole (Altacor™,) through a center pivot on a peppermint field in Paterson, WA on 27 October, 2010.
- We compared this to chemigation with ethoprop (Mocap™) and a non treated control.

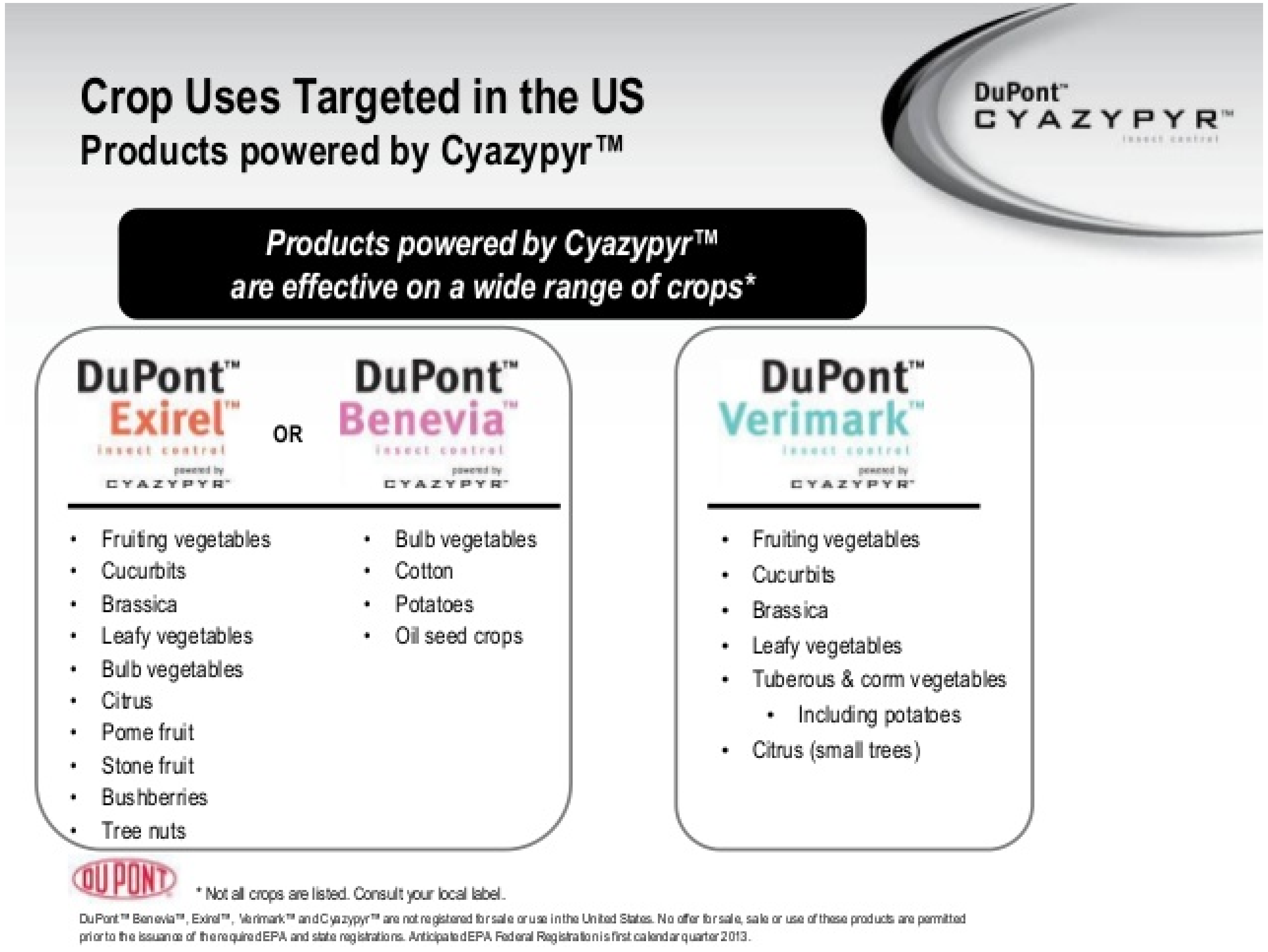
Mint Root Borer Pupa per core sample on 2/25/2009



6” cores down to approximately 4” in depth of soil. 28.26sq inches of surface then dried in a Berlese funnel

Mint root borer, *Fumibotys fumalis*, Control.

- Cyantraniliprole under the formulation Verimark™ is a reduced-risk insecticide marketed by FMC that has demonstrated good efficacy against other soil pests.
- We propose to test cyantraniprole for efficacy on mint root borer populations infesting Washington State mint fields.



IR-4 Residue Project for Cyantraniliprole

- Mint and Basil are now “representative crops” for EPA Crop Group 25-- spices
- If residue trials are run on mint and basil then other “spices” can get a tolerance.
- IR-4 HQ had my IR-4 Field Residue Program run residue trials in 2018 on mint for a request to control citrus psyllid on Indian curry leaves.
- The application was as a foliar spray.
- I requested to get the soil application use pattern added.
- Basically all I have to do is prove cyantraniliprole is effective against mint root borer and we could have a label in as short as 12 months.

We established 2 insecticide efficacy trials in peppermint fields near Patterson, WA in 2018

- We conducted an insecticide efficacy trial with candidate and registered insecticides for mint root borer control in fall 2018.

Treatment	Ingredient	Rate (product)/acre	a.i./acre
Lorsban Advanced	chlorpyrifos	4 pints	1.8775 lb
Coragen	chlorantraniprole	5 fl oz	0.065 lb
Verimark	cynatraniprole	13.5 fl oz	0.176 lb
Untreated			

- Each replicate plot was 6’ by 18’
- We tried evaluating efficacy via Berlese funnel
- We sampled 4 times and captured no MRB larva in any plots.

So, where do we go from here?

- I need to get some sort of product efficacy data on some pest with cyantraniliprole in 2020 to justify adding mint to the Verimark and Exirel labels.
- I'm giving up on mint root borer and will likely switch to spring cutworms in March and April 2020.

2012 National Survey of Pest Management Practices in Mint

Holly Ferguson, Sally O'Neal, and Douglas Walsh
Washington State University, IAREC, Prosser, WA 99350

Table 6: Disease and Arthropod Severity Ratings in Pacific Northwest Mint Growing Regions
(% variety acreage responding)

	Peppermint			Native Spearmint‡		Scotch Spearmint‡
DISEASE	ID*	OR†	WA	ID*	WA	WA
nematodes	3.5	3.1 (68)	**2.1 (89)**	3.0	4.1 (26)	2.4 (54)
powdery mildew	2.9	3.8 (79)	3.6 (96)	2.9	**3.5 (31)**	2.6 (100)
verticillium wilt	**2.8**	**2.5 (100)**	3.6 (89)	**2.3**	4.7 (56)	**1.4 (54)**
rust	4.9	3.3 (81)	4.6 (79)	3.0	3.9 (79)	5.0 (54)
leopard spot (anthracnose)	5.8	5.7 (28)	not rated	4.0	6.0 (13)	not rated
ARTHROPOD						
mint stem borer	3.7	3.7 (48)	**1.4 (79)**	5.2	5.0 (28)	not rated
mint flea beetle	not rated	4.5 (67)	1.5 (79)	not rated	4.9 (26)	**2.0 (46)**
spider mites	**2.6**	**2.1 (100)**	2.1 (100)	3.1	4.1 (38)	2.6 (100)
mint root borer	2.8	2.7 (100)	2.1 (93)	3.0	4.5 (29)	3.1 (54)
garden symphylan	5.9	4.9 (73)	2.4 (79)	6.0	3.6 (56)	not rated
mint bud mites	5.4	5.3 (49)	2.4 (79)	4.6	4.8 (16)	5.0 (46)
mint cutworm	3.4	2.9 (73)	3.0 (95)	3.4	3.2 (73)	3.0 (92)
alfalfa looper	4.3	5.0 (59)	3.0 (96)	3.2	**3.1 (55)**	4.1 (100)
spotted cutworm	4.1	4.7 (57)	3.2 (86)	3.8	4.6 (62)	3.0 (46)
bertha armyworm	3.8	4.8 (59)	3.2 (79)	4.2	4.5 (56)	not rated
aphids (mint aphids)	3.0	4.2 (59)	3.8 (96)	**2.7**	3.9 (53)	2.7 (100)
cabbage looper	4.1	4.5 (73)	4.0 (88)	4.0	4.4 (37)	not rated

Severity ratings were weighted based on amount of respondent acreage. The most severe pests in each state are marked in bold.
*For Idaho, percent responding acreage data for each severity rating were not available; it is assumed to be close to 100% for each rating.
†For Oregon, no spearmint acreage was reported by respondents.
‡For Idaho, response data were combined for native and Scotch spearmint severity ratings.

Table 14: 2012 Insecticide Usage on Mint in the Pacific Northwest Growing Regions

Active ingredient (formulation)	Variety	IDAHO Treated acres	IDAHO Base acres treated (% total response)	OREGON* Treated acres	OREGON* Base acres treated (% total response)	WASHINGTON Treated acres	WASHINGTON Base acres treated (% total response)	
chlorantraniliprole (Coragen®)	peppermint	7,966	6,331 (59)	721	721 (21)	485	275 (10)	Mint root borer
	spearmint	639	442 (83)	–	–	50	50 (2)	Caterpillars
acephate (Orthene®)	peppermint	5,498	5,348 (50)	1,763	1,406 (41)	1,650	1,630 (59)	
	spearmint	217	217 (41)	–	–	612	597 (20)	
chlorpyrifos (Lorsban®)	peppermint	3,833	3,796 (35)	218	218 (6)	125	125 (5)	Mint root borer
	spearmint	100	100 (19)	–	–	87	87 (3)	
hexythiazox (Onager®)	peppermint	3,138	2,788 (26)	873	873 (25)	–	–	Mites
	spearmint	20	20 (4)	–	–	371	371 (12)	
propargite (Comite®)	peppermint	2,688	2,688 (25)	1,552	1,433 (42)	1,230	1,230 (45)	Mites
	spearmint	165	165 (31)	–	–	555	555 (18)	
oxydemeton-methyl (MSR®)	peppermint	2,055	2,055 (19)	–	–	–	–	
	spearmint	52	52 (10)	–	–	–	–	
methoxyfenozide (Intrepid®)	peppermint	1,598	1,598 (15)	–	–	–	–	
	spearmint	–	–	–	–	–	–	
abamectin (AgriMek®)	peppermint	1,325	1,187 (11)	163	163 (5)	–	–	Mites
	spearmint	52	52 (10)	–	–	22	22 (<1)	
methomyl (Lannate®)	peppermint	803	803 (7)	–	–	–	–	
	spearmint	100	100 (19)	–	–	–	–	
malathion (sev. brands)	peppermint	303	303 (3)	–	–	–	–	
	spearmint	–	–	–	–	71	71 (2)	
tebufenozide (Confirm®)	peppermint	284	284 (3)	–	–	–	–	
	spearmint	–	–	–	–	–	–	
thiamethoxam (Actara®)	peppermint	160	160 (1)	–	–	–	–	Aphids
	spearmint	–	–	–	–	447	447 (15)	
dicofol (Dicofol)	peppermint	102	102 (<1)	–	–	–	–	
	spearmint	–	–	–	–	–	–	
TOTAL ACREAGE TREATED†		31,195	28,688	5,765	5,289	6,109	5,864	

*No spearmint acreage was reported by Oregon respondents.
†Reported uses of bifenazate, ethoprop, and etoxazole are included in totals.

Questions?

Nitrogen and Water Management on Spearmint

Principal Researchers:
Douglas B. Walsh, PhD, Professor of Entomology
Troy Peters, PhD. Professor of Bio-Science & Engineering
Ray Baker, Mint Technician, WSU IAREC.
Washington State University, Prosser-IAREC

Cooperator:
Ruijun (Ray) Qin, PhD, Assistant Professor & Agronomist
Hermiston Agricultural Research & Extension Center
Oregon State University

Statement of Research 2019:

- Water and nutrient quantities are factors that can and should be managed to optimize oil quantity and quality.
- A field plot was established of native spearmint at WSU IAREC on a linear line irrigation system.
- Onto this study we have imposed specific nitrogen fertilization amounts from above recommended rates to below recommended rates.
- This study of the interaction of irrigation quantity and nitrogen treatment will likely provide growers with a reference of specific optimal practices towards optimizing oil yields.
- Present recommendations for nitrogen management calls for 200 to 250 lb of nitrogen per acre to support optimal growth (Brown et al. 2003).

Methods:
Objective 1. Conduct a line-source by fertilizer quantity interaction study.

- Hagood (1969) determined that oil production in single cut peppermint was optimized with 31.2 inches of water spaced out over the growing season in 13 separate irrigation events.
- Okwany et al. (2012) concluded that deficit irrigation of double cut peppermint in the inland Pacific Northwest was not feasible.
- However, in their study the maximum irrigation level was calibrated to only replace moisture used in the plots the prior week.
- We believe that most spearmint growers in the Columbia Basin are over-irrigating because they fear “falling behind” in their irrigation program.

Methods:

- Field plots were established in 2019 and maintained using best management practices for mint.
- Terbacil (Sinbar) at 0.75 lb ai/a was applied on May 7, 2019 for weed maintenance after the spearmint was planted on May 3, 2019.
- Five fertilizer treatments using ½ rate amounts of ammonium sulfate from the determined 67%, 100%, 133%, 167% and 100% rate of urea were applied on May 7, and June 24, 2019.
- Fertilizer was watered in using 0.3 inches of water from the linear irrigation line shortly after applications.
- Baby mint harvest was completed on August 19, 2019.
- Hay and oil yields were determined on August 27, 2019 by weighing a 10 foot by 14 foot area from the center of each plot and taking three 7 pound fresh subsamples to dry and distill for oil yields.
- Chlorophyll readings were taken on September 30, 2019.
- Soil samples were taken on October 1, 2019 and sent in for analysis

Figure 1. Irrigation and Nitrogen Treatment Plot Map for Interaction Study.

Irrigation Levels		---Treatments---		Nitrogen Levels	Fertilizer
75%		1	67%	134 lb	AMS
100%		2	100%	200 lb	AMS
125%		3	133%	266 lb	AMS
		4	167%	334 lb	AMS
		5	100%	200 lb	Urea

125%	100%	75%	125%	75%	100%	
						Ammonium Sulfate 100%
						Ammonium Sulfate 167%
						Ammonium Sulfate 67%
						Ammonium Sulfate 133%
						Urea 100%
						Ammonium Sulfate 133%
						Urea 100%
						Ammonium Sulfate 100%
						Ammonium Sulfate 67%
						Ammonium Sulfate 167%
						Ammonium Sulfate 133%
						Urea 100%
						Ammonium Sulfate 100%
						Ammonium Sulfate 67%
						Ammonium Sulfate 167%

* Plot size 30' wide (6 sprinkler drops) by 20' long
Total Field Size = 200' wide (180' total plots with 10' boarders on each side) and 360' long. 1.65 acres.

In the 2019 establishment year we irrigated uniformly.

Starting in 2020 we will irrigate at 0.75. 1.0, and 1.25 times the calculated evapotranspiration from the plots. This is represented W1, W@, W3, & W4, respectively.

In spring 2020 we will have plots soil tested for the amount of residual N in the soil. After reading the results of these soil tests we will follow the recommendations provided by Mitchell (1998) for our 100% treatment of 80 units of N..

This setup will create a grid interaction of irrigation treatments above ETo, at ETo, and below ETo. ETo values will be taken by download from our nearby WSU AgWeathernet station.

Table 1. Hay and Oil Yields of Single Cutting (Baby Spearmint) Irrigation/Nitrogen Interaction Study in 2019.

		---8/19/2019---			
Treatment	Rate	Avg. Lbs. Hay	Avg. ml Oil	Ton Hay	Lbs. Oil
		10'x14' Plot	21 lbs. Hay	Acre	Acre
1	Ammonium Sulfate 67%	31.4 -	31.9 -	4.9 -	29.5 -
2	Ammonium Sulfate 100%	30.3 -	34.3 -	4.7 -	30.6 -
3	Ammonium Sulfate 133%	32.9 -	32.3 -	5.1 -	31.2 -
4	Ammonium Sulfate 167%	34.8 -	32 -	5.4 -	32.5 -
5	Urea 100%	32.3 -	32.8 -	5.0 -	31.3 -
	LSD P=0.05%	--4.986--	--5.335--	--0.751--	--9.324--

Single cut harvest on August 19, 2019.
Results averaged from three individual samples from each treatments replicated three times (nine total).
Means followed by the same letter are not significantly different at the LSD (P=0.05).

Methods continued

- Plant height was measured on 8/14/19.
- Chlorophyll readings were taken with our CCM-200 plus Chlorophyll Content Meter to quantify the in-season effects of the fertility treatments. (https://www.optisci.com/ccm-200.html).

Table 2. Height Measurements and Chlorophyll Leaf Readings from Nitrogen Treatments in 2019.

		8/14/2019	9/30/2019
Treatment	Rate	Avg. Height	Avg.Chlorophyll
		Inches	Leaf Reading
1	Ammonium Sulfate 67%	20.9 -	22.03 -
2	Ammonium Sulfate 100%	21.7 -	19.63 -
3	Ammonium Sulfate 133%	21.3 -	19.67 -
4	Ammonium Sulfate 167%	21.1 -	22.00 -
5	Urea 100%	20.8 -	22.43 -
	LSD P=0.05%	--0.750--	--2.772--

Average height measurements taken from seven measurements in each nitrogen treatment replicated three times (21 measurements total).
Average chlorophyll leaf readings were taken from ten leaf readings in each nitrogen treatment replicated three times (30 leaf readings total).
Means followed by the same letter are not significantly different at the LSD (P=0.05).

Table 3. Total Nitrogen, P, K, SO4-N and pH Levels from Samples Collected October 9, 2019.

Treatment	Rate	Total Nitrogen	Total P	Total K	Total SO4-N	Total pH
1	Ammonium Sulfate 67%	35.3 -	14.7 b	275.3 -	37.3 a	7.67 -
2	Ammonium Sulfate 100%	68.3 -	17.7 a	253.3 -	58 a	7.53 -
3	Ammonium Sulfate 133%	69.7 -	12.0 b	233 -	67.7 a	7.57 -
4	Ammonium Sulfate 167%	85 -	12.7 b	236.3 -	60.7 a	7.3 -
5	Urea 100%	93 -	14.0 b	245.3 -	9.3 b	7.87 -
	LSD P=0.05%	-74.18-	-2.06-	-38.97-	-27.74-	-0.454-

Samples were analyzed from an independent laboratory source KTL (KUO Testing Labs) in Umatilla, Oregon.

Means followed by the same letter are not significantly different at the LSD (P=0.05).

Conclusion:

- There were no significant height measurement differences between treatments at time of harvest.
- There were no significant leaf chlorophyll reading differences between treatments.
- Fresh hay and oil yields from the 67% treatments were slightly lower than all other treatments but also was of no significant difference.
- The available nitrogen levels from the 67% nitrogen treated soil analysis were the lowest of all treatments but again was of no significant difference.
- Nitrogen levels within the soils within each plot were ascending accordingly as the nitrogen rates increased but no significant differences were quantified.

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